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ABSTRACT

This paper describes the preliminary analysis of a survey of the American Institute of Aeronautics and Astronautics (AIAA) student members. In the paper, we examine (1) the demographic characteristics of the students, (2) factors that affected their career decisions, (3) their career goals and aspirations, and (4) their training in technical communication and techniques for finding and using aerospace scientific and technical information (STI).

We determine that aerospace engineering students receive training in technical communication skills and the use of STI. While those in the aerospace industry think that more training is needed, we believe the students receive the appropriate amount of training. We think that the differences between the amount of training students receive and the perception of training needs is related partially to the characteristics of the students and partially to the structure of the aerospace STI dissemination system. Overall, we conclude that the students' technical communication training and knowledge of STI, while limited by external forces, makes it difficult for students to achieve their career goals.

INTRODUCTION

This paper provides the first analysis of the data from a series of surveys of aerospace and other engineering and science students that we conducted as part of the NASA/DoD Aerospace Knowledge Diffusion Research Project. The NASA/DoD Aerospace Knowledge Diffusion Research Project attempts to understand the uses and flows 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. To understand the process and the system more fully, we surveyed aerospace engineering students and other science and engineering students. Our goal in this part of the Project is to determine how the recruitment and training of new personnel in the aerospace professions affects STI use and dissemination.

The Project has four phases. Phase One examines the production and use of aerospace information by US aerospace engineers and scientists. Phase Two examines how information intermediaries (principally librarians and technical information specialists) in the aerospace industry evaluate and disseminate technical information. Phase Three looks at aerospace engineering in academic settings. This paper reports on a Phase Three activity. The surveys reported here are similar to others we conducted of students, faculty, and librarians in universities and colleges with aerospace programs. Phase Four looks at the international dimensions of aerospace STI. A variety of surveys of aerospace engineers in western Europe and in Asia were conducted in this Phase.

The data we report in this paper were collected from the student members of AIAA during spring 1993. We also collected data from engineering and science students attending the University of Illinois, and Texas A&M University, and technology students at Bowling Green State University. Additional data from students in India, Turkey, Holland, Japan, and Russia will be available in the next few months. We used a similar questionnaire in all surveys, and we plan to analyze the data from the remaining groups during 1994.

As an earlier Phase Three activity, we conducted a survey of 640 students who were enrolled in an undergraduate design capstone course in 39 universities (Pinelli et al, 1991a). That survey was designed to measure the information-seeking behavior and technical communication skills of undergraduates. Many questions were repeated in the student surveys conducted last spring, which will allow us to track the stability and changes over time in these two components of undergraduate aerospace engineering education. The survey we report in this paper extends the Project's focus to look also at the students' motivation for choosing engineering as a career and their goals and plans for their careers.

This paper has three parts. In part one, we report on demographic characteristics of the student members of the AIAA. The second part presents an analysis of the professional and personal goals of current aerospace students. In the final part, we evaluate the training in technical communication skills the students received. We only recently completed tabulating these data, so the results reported in this paper must be considered preliminary results only.

METHODS AND DATA

Self-administered questionnaires were sent to a sample of 4300 student members provided by the AIAA. The questionnaires and a cover letter on NASA stationery were mailed from NASA Langley in spring 1993. Altogether, 1673 AIAA student members returned the questionnaires by the termination date of September 1, 1993. Due to the summer break, only one mailing was possible. After reducing the sample size for incorrect addresses and other mailing problems, the response rate for the survey was 42 percent. This rate is very acceptable for a student survey with one mailing.

Demographics

The AIAA has both undergraduate and graduate student members. Most respondents to this survey were undergraduates (950 or 57 percent). There were 723 graduate students who responded.[2] Males outnumbered females approximately five to one (Table 1). The proportion of females is greater among undergraduates. The gender distribution is very similar (within two percentage points) to the distribution in our earlier survey of senior aerospace students (Pinelli et al, 1991b; Peterson et al, 1991).

The students were asked to evaluate their families' incomes relative to those of other families when they were growing up. Most students perceive that their families' incomes were about equal to or greater than those of other families. Only about one-sixth of the sample reported that their families' incomes were lower than those of others. Graduate students are a little more likely than are undergraduates to come from higher income families.

Table 1: Selected Characteristics of AIAA Student Members. (N=950 undergraduate and 723 graduate students; percentages)

Characteristics	Undergraduate	Graduate
Gender		
Males	81.8	87.0
Females	18.2	13.0
Relative Family Income		
Higher than other families	29.3	33.7
Same as other families	52.1	47.9
Less than other families	16.2	16.4
Don't know	2.2	2.1
Native Country		
United States	84.3	73.3
Other	15.7	26.7
Native Language		
English	87.3	76.9
Other	12.7	23.1

There are substantial differences between the graduate and undergraduate samples in the percentages of students whose native language is not English and who are not native US citizens. Each difference is about ten percentage points. Over one-fourth of the graduate students are not native US citizens, and almost one-fourth do not consider English their native language. In a later section of this paper, we look at the need for technical communication skills. When a substantial proportion of students do not use English as their native language, teaching these skills becomes more difficult.

We do not assume that these numbers reflect the demographic composition of all aerospace students in the US, because there are probably differences between the students who join the AIAA and those who do not. In particular, non-US native students are probably less likely to join a US aerospace organization than are native US citizens. There may be smaller or larger gender and family income differences among all aerospace students, but the degree of difference, if any, cannot be determined. In later analyses, we intend to examine the differences in the responses to questions by characteristics of the students, including gender and citizenship.

Career Choice

This section focuses on the career decision-making process and students' career plans. Most students made their decisions about their career choices while in high school (Table 2). Almost one-third of the graduate students made their decisions when or after they started college. Only about one-sixth of the undergraduates made their decision after they began college. This difference may indicate that graduate students think pursuing a graduate degree is their career choice. Decisions about graduate school are often made after students start college, and they may consider this decision a different choice from choosing aerospace engineering as a career.

Table 2: Timing of the Decision on Area of Study. (N=950 undergraduate and 723 graduate students; percentages)

Timing	Undergraduate	Graduate
Elementary school	15.9	10.5
High school	64.4	54.8
When starting college	9.0	14.8
After starting college	7.4	15.8
Other	3.3	4.6

We interpret the data in Table 3 to indicate that undergraduate and graduate students consider the opportunity for a career with rewarding activities the most important factor in their career choices (84 percent and 77 percent, respectively). No other factors were cited as often.

Table 3: Factors That Influenced Career Choices. (N=950 undergraduate and 723 graduate students; percentages)*

Career Choice Factor	Undergraduate	Graduate
Parents	12.6	16.5
Other family	8.0	6.4
Teachers	14.6	16.4
Leads to financial security	30.9	21.9
Career with rewarding activities	84.3	77.3
Information on career opportunities	28.4	20.3

* The students used a 7-point scale, where 7 indicated the highest rating, to evaluate the importance of each factor. The percentages listed in Table 3 are the students who rated the factor as either a 6 or 7.

About 31 percent of undergraduates and 22 percent of graduates chose opportunities for financial security and the availability of information on aerospace engineering as factors in their career choices. The impact of family and teachers was minimal. Parents influenced only about 13 percent of undergraduates and 17 percent of graduates. Teachers influenced career choices at about the same levels.

Many AIAA student members are not as happy about their career choices now as when they made them (Table 4). These percentages may reflect some pessimism about the near-term prospects for employment in the aerospace industry.[3] Over 30 percent of the graduate students are less happy with their career choices now than when they made them.

Table 4 also contains a comparison of data collected at the same time at the University of Illinois. Approximately 1150 students in all disciplines in the College of Engineering comprised the Illinois sample. Aerospace engineering students comprised less than ten percent of the Illinois sample. Overall, the Illinois students are happier about their career choices than are the AIAA students. This difference offers support for the premise that aerospace engineering students are concerned about the current employment conditions in the aerospace industry.

We looked at two additional factors that might explain changes over time in the students' happiness about their career choices[4] - undergraduate class (freshman, sophomore, etc.) and when the students decided on their career (elementary school, high school, etc.). As expected, seniors are much less happy about their career choices than other undergraduates are. Also, it appears that graduate students who made their career choices after starting college are the least happy respondents. These data offer additional support for the premise that happiness with career choices is influenced by job opportunities. Among undergraduates, those who reported they made their career choices either in elementary school or after they were in college are most pleased with their career choices. This finding indicates that the engineers who "always thought they would be engi-

Table 4: Current relative happiness with career choices compared with relative happiness at the time the choices were made. (AIAA=950 undergraduate and 723 graduate students; Illinois=623 undergraduate and 511 graduate students; percentages)

	AIAA		Illinois	
Relative Happiness	Undergraduate	Graduate	Undergraduate	Graduate
More happy now	26.6	27.6	38.8	37.8
Equally happy	47.2	41.7	44.8	42.9
Less happy now	24.2	30.6	16.4	19.4

neers" (i.e., made their choices in elementary school) as well as those who made their decisions after starting college (students who might have the best knowledge about careers) are the happiest with their choices.

Career Aspirations

Table 5 presents the distribution of responses to a series of questions about the factors that the AIAA student members feel are important for their careers.[5] The factors in Table 5 are grouped roughly into (1) advanced technical applications (a-e), (2) professional reputation (f-i), and (3) management (j-o).

Table 5: Importance of Career Goals and Aspirations. (N=950 undergraduate and 723 graduate students; percentages)*

	Goals and Aspirations	Undergraduate	Graduate
(a)	Explore new technology or systems	84.3	84.6
(b)	Work on complex technical problems	62.3	72.1
(c)	Learning new technical knowledge	68.3	71.3
(d)	Utilize the latest theoretical results	58.9	55.2
(e)	Receive patents	28.8	20.1
(f)	Be evaluated on technical contributions	49.6	58.5
(g)	Establish reputation outside organization	49.8	53.7
(h)	Publish articles in technical journals	27.9	50.7
(i)	Present papers at professional meetings	26.7	49.5
(j)	Technical leader of less experienced professionals	49.7	43.6
(k)	Attain a high-level staff technical position	49.2	51.8
(l)	Plan and coordinate the work of others	42.7	36.2
(m)	Become a manager or director	45.1	35.3
(n)	Plan projects affecting the organization	51.9	46.1
(o)	Advance to a policy-making position	35.7	34.1

* The students used a 7-point scale, where 7 indicated the highest rating, to evaluate the importance of each factor. The percentages listed in Table 5 are the students who rated the factor as either a 6 or 7.

We expected some differences in the undergraduates and graduates on these factors, but overall there appear to be relatively few differences except for two factors that reflect a research/academic career orientation that is more typical of graduate students -- publishing articles and presenting papers.

Those factors related to the technical aspects of their careers (a-c) are most important to the students. Over 80 percent rated the opportunity to explore new ideas about technology or systems very important for a successful career. Two other technical factors (working on complex technical problems and working on projects that require learning new technical knowledge) were rated very important by about two-thirds of the students. Over one-half of the students felt that working on projects that utilize the latest theoretical results was very important.

The students think that developing a strong reputation is not as important a factor for a successful career as the types of projects they work on. It appears that enhancing a professional reputation is more important to graduate students than to undergraduates. Graduate students (as expected) are much more interested in publishing papers and presenting at professional conferences. Also, more graduate students than undergraduates think that it is important to develop a reputation for technical contributions, both inside and outside the organization.

The students in the sample do not think that management achievements are as important to a successful career as technical achievements are. For example, only about one-third of both graduate and undergraduate students feel that it is very important to advance to a policy-making position in management (o). The leadership positions valued most are technical leadership positions (j) and project planning (n). Overall, these students are more oriented towards being engineers than managing engineers.

Technical Communication

Both employers of engineers and engineers themselves place a high value on technical communication skills. In another survey from this Project (Murphy, 1994), we asked members of the AIAA to rate the importance of oral and written communication for performing their professional duties. Over 90 percent of the respondents rated oral communication very important and 80 percent rated written communications very important.[6] In a pilot study of a small sample of engineers that we conducted as part of the Phase 4 activities of the Project, 87 percent recommended that undergraduates take a course in technical communication (Pinelli et al, 1991b).

There are many articles in the engineering education literature about the need for technical communication skills. (See Katz, 1993; Kimmel and Monses, 1979; Goubil-Gambrel, 1992; Barnum, 1982; Garry, 1986; Sylvester, 1980; Devon, 1985.) A recent article (Evans et al, 1993) contained the results from a survey of industry employers and engineering school alumni. Both the employers and the alumni respondents said that technical communication skills were the second most important skills (behind problem recognition and solving skills) for engineers to have. Given a list of eight skills, both groups indicated that engineers were least well-trained in technical communication skills. Among the alumni, technical communication skills were considered almost as important as engineering core courses. The authors summarize the alumni survey (in part) by stating "that insufficient development of communications skills remains a chronic problem that must be addressed" (Evans et al, 1993, pg 210).

Engineering is essentially a social process that makes observations of the physical world and changes them into products that can be used by others. To do so, engineers must effectively communicate their ideas and interpretations of their data to others. Engineers build the solutions to problems partially on their interpretations of the work of others who preceded them. The ability to find and use technical communication products effectively and the skills needed to interpret and present the findings of their own and others' research are crucial to the success of engineers.

Table 6 contains the tabulations from three questions that we asked about training in technical communication skills and the use of STI. We interpret the data in Table 6 to indicate that the aerospace engineering students understand the importance of technical communication skills to their careers. Over 80 percent of both graduates and undergraduates rated these skills very important. Almost three-fourths of the students received training in technical writing, and about 60 percent received training in oral presentations. We think these figures indicate clearly that engineering educators and students take seriously the message from industry and alumni about the importance of technical communication skills.

Table 6: Importance of Selected Skills and Training. (N=950 undergraduate and 723 graduate students; percentages)*

Skills and Training	Undergraduate	Graduate
Technical writing		
Importance to career	81.6	87.2
Received training	73.4	71.1
Helpfulness of training †	56.2	49.2
Oral presentations		
Importance to career	83.3	83.3
Received training	64.8	58.0
Helpfulness of training †	54.1	50.3
Using STI materials		
Importance to career	82.9	76.9
Received training	68.7	55.8
Helpfulness of training †	45.8	40.5

* The students used a 7-point scale, where 7 indicated the highest rating, to evaluate the importance of each skill . The percentages listed in Table 6 are the students who rated the factor as either a 6 or 7.

† The "helpfulness" percentages are based only on those who reported that they received the training.

Most students receive training in technical communication skills.[7] In a pilot study that was part of the Phase One activities, about 70 percent of the engineers and scientists surveyed (AIAA members) reported they took a course in technical communication.[8] A smaller proportion of the student AIAA members reported receiving training in technical communication, but some of this difference can be attributed to the 24 percent of the AIAA member sample who reported receiving training after completing their degrees. The evidence is quite clear that students recognize the importance of the technical communication training and are taking steps to obtain the necessary skills.

Even if engineering educators provide access to the training and a substantial portion of students take the training, the students may not perceive the training was helpful. Only about one-half of the students who received training in these skills rated them helpful. A smaller percentage of graduate students than undergraduates think the training was helpful. The percentages who rated the training are based only on those who received training, so only about 35 percent of the students received training that they thought was helpful. The contrast between the availability and the helpfulness of the training will be discussed in the summary.

Use of STI Materials

Engineers are information collectors. They need information to perform their everyday tasks and duties. Yet the evidence we have from our other studies is that information gathering is not facilitated by the information-seeking behaviors of engineers or the current aerospace STI distribution methods. The types of information that engineers seek out might be thought to comprise a continuum from established literature with important information that does not change (such as the information in the NACA reports) to the most up-to-date technical information. From our research, we think that it is relatively easy for engineers to gain access to and to use older standard materials. Our research also indicates that the passive system of STI distribution does not facilitate the effective dissemination of recent aerospace research.

The US aerospace industry and the federal agencies involved in aerospace (NASA, DoD, FAA) invest heavily in aerospace research. The distribution of federally-funded STI uses a passive system that requires considerable effort by end-users (engineers) to gather the recently-released STI. In addition, classified and limited distribution federal aerospace research and proprietary research conducted in industry are minimally distributed to the aerospace engineering community. To compete effectively in the world aerospace economy, aerospace producers need access to the most current research.

To further understand the process of STI dissemination and use, in earlier studies we looked at the behavior of engineers when they need information. We know that practicing engineers (AIAA members) use their personal collections, colleagues, supervisors, and the library, in that order, when they need technical information (Pinelli, 1991). This pattern will not necessarily provide the most up-to-date or the most useful information. The STI-gathering activities of the students we surveyed is very similar to those of the practicing engineers (Table 7). The patterns may be learned (or taught) as part of undergraduate education. Teaching improved STI-gathering skills to undergraduates would be an effective means of improving the use of STI, improvements that may prove critical to the competitive position of the US aerospace industry.

We do not interpret these data to indicate that students are not trained effectively in gathering and using STI. For example, graduate students are more likely to look for information in a library than to seek it from other students or faculty. As a point of comparison, approximately two-thirds of the AIAA sample (Pinelli, 1991) had advanced degrees. These data from the two surveys indicate that, sometime after they leave school, the students start to rely less on the library. Many reasons might explain this change, but they are beyond the scope of this paper.

The STI products that students use to meet their engineering information needs indicate a

Table 7: Use and Importance of Selected STI Sources and Products. (N=950 undergraduate and 723 graduate students; percentages)

	Undergraduate		Graduate	
Source	Use*	Importance†	Use	Importance
Personal collection	71.4	65.9	72.7	75.2
Other students	49.1	38.4	38.6	29.2
Faculty members	37.8	46.2	44.7	47.8
Library	32.4	34.7	49.2	46.6
Product				
Textbooks	88.7	80.4	78.3	72.1
Handbooks	31.5	35.2	27.9	29.9
Journal articles	25.5	26.5	63.2	60.3
Technical reports	18.1	21.0	36.2	38.0
Conference papers	10.5	13.1	39.6	46.9

* The "use" percentages are based on the students who reported using the source or product frequently.

† The students used a 7-point scale, where 7 indicated the highest rating, to evaluate the importance of each source or product. The percentages listed in Table 7 are the students who rated the factor as either a 6 or 7.

pattern of choosing what is most accessible, at least for the undergraduate students. Many undergraduates can use textbooks for most of their information needs. Graduate students are more likely than undergraduates to use journal articles, but since the sample is comprised of members of the AIAA, we assume these students have easy access to journals. This difference between graduate and undergraduate students may also be related to the differing amounts of library use they reported. Aerospace faculty and graduate students demonstrate similar use of information sources and products (Holland et al, 1991; Pinelli et al, 1991a).

For most engineers, the patterns of use and the ratings of the importance of STI sources and products carry over from school into the workplace.[9] In general, engineers use a pattern of relying on what is available nearby, what is easily available, and what can be obtained without much trouble. This pattern starts in undergraduate training and continues through the engineers' careers. In the last section of the paper, we look at the implications of these patterns and technical communication training for the students' careers.

SUMMARY AND DISCUSSION

The US aerospace industry depends on US universities and colleges to provide a technically-skilled workforce. Some in the aerospace industry may feel that new engineers do not receive enough training in technical communication skills, but for the most part, it is likely that engineering training in the US is as complete as possible. Engineering education in other countries averages about five years (Doratto 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.

We think these preliminary data and our analysis start to answer some important questions about the success of engineers and the continuing success of the US aerospace industry. Training in technical communication skills appears to be an important factor in the successes of engineers, both from the employers' perspective and from the perspective of engineering students' personal goals and aspirations. In our analysis of Table 5, we summarized the students' aspirations as oriented more towards technical achievements than either an enhanced reputation or management positions. Success in technological achievements requires that engineers communicate the value and importance of their achievements; therefore, engineering students may find that their inability to effectively communicate STI is an obstacle to personal success.

Employers consider the technical communication skills of new engineers to be very important. The papers we cited earlier in this paper provide substantial evidence that both aerospace industry managers and aerospace engineers want newly-recruited engineers to have more and better technical communication skills. Obviously, if new engineers are well-trained in technical communication, they are more likely to succeed in the aerospace industry.

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. The four factors rated as most important to career success by the students we surveyed all require that they obtain and use the most current STI, although old STI is still valuable for much research.[10] Tools and skills that will allow engineers to access easily and quickly the most important recent research are very important for their careers. Their current training does not provide enough of these skills, at least as evidenced by their responses to the questions presented in this paper.

In addition, the continuing competitive success of the US aerospace industry requires that its engineers and scientists have access to the best and most current STI. Journals and conference papers are heavily used by research engineers (typically members of the AIAA). They also use in-house technical reports heavily. They are not heavy users of NASA or DoD technical reports, but they give highly favorable evaluations of government technical reports (Pinelli et al, 1991e). The research conducted at the NASA labs is generally cutting-edge and aimed at solving significant aerospace problems, yet our earlier studies indicate that this research does not diffuse easily to the engineering research world and even less fully to design and development engineers (Pinelli et al, 1993). There are many reasons for this problem, but the student data indicate that some are the result of engineering training.

Inadequate technical communication skills training and the difficulties in obtaining STI should not be considered an engineering education problem alone. It is unreasonable to expect that colleges and universities should solve problems that result from the shortcomings of the existing aerospace STI distribution system. Sociologists often use the term "blaming the victim" when problems are seen as the fault of the people who suffer from the design of a system. We tend not to look at a complete system to see how much of a problem is based in the system itself. It is not fair to blame engineering educators for the perceived shortcomings of recent engineering graduates. In reality, the larger system of aerospace information production and transfer must be examined to determine the real causes of the problems.

The NASA/DoD Aerospace Knowledge Diffusion Research Project focuses on all aspects of STI dissemination because we recognize this large system must be examined in a broad context. The problems with aerospace research dissemination can be traced partially to the research producers, the distribution system, the users, and engineering training. Only by looking comprehensively at the entire system can we propose workable solutions.

Our research requires that we examine all parts of the system, from the motivations of new recruits to the industry, through the industrial settings and research labs, to the policies of the Office of Aeronautics and Space Technology. In this paper, we reported on a portion of the system - the recruitment, goals, aspirations, and some small part of the training of aerospace engineers. The results we report here are obviously preliminary and tentative, but they point to some incongruities between the expectations of new engineers and the need for training that will help them meet their expectations. We hope to provide more detailed analyses and suggestions for improvements in forthcoming papers.

ENDNOTES

1. Data entry for this project was funded by a grant from the Council for Library Resources to Indiana University. Data collection and analysis were conducted as part of the NASA/DoD Aerospace Knowledge Diffusion Research Project. Barbara Lawrence from the American Institute of Aeronautics and Astronautics (AIAA) provided the sample of AIAA student members.
2. We received 70 additional questionnaires in which the respondents did not indicate a class status.
3. The students are legitimately concerned about employment in aerospace. A recent article in the *AIA Newsletter* (November, 1993) cited a Bureau of Labor Statistics study that showed the aerospace industry will be more likely to cut employment in the future because of the lessened demand for military aircraft (p. 6). The article also noted that reductions in engineering costs will improve the productivity of the industry.
4. The data are not reported here, but they will be available in a subsequent report and from the authors.
5. This series of questions was adapted from earlier studies of engineering students conducted by Danielson (1960) and Krulee and Nadler (1960).
6. In this survey, a five-point importance scale was used where 5 indicated the "most important" rating. The percentages reported here are those who responded 4 or 5 on the scale.
7. We expect to analyze these data further to determine if seniors are more likely to report receiving training and if the lower proportion who received training among graduate students might be related to undergraduate training in another country. We hope to analyze other factors such as male/female differences and fluency in English at a later time.
8. These engineers and scientists were in all phases of their careers.
9. One exception is the increased reliance on in-house technical reports in industrial settings (Pinelli, 1991). In the aerospace industry, in-house technical reports are very accessible (Pinelli et al, 1991c).
10. For example, both users and librarians report regular use of NACA reports. (Pinelli et al, 1991d). Conversations with technical information specialists during recent visits to aerospace organizations by Pinelli corroborate the survey evidence.

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