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Examining The Technical Communications Practices of
Early Career-Stage U.S. Aerospace Engineers and Scientists

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FROM STUDENT TO ENTRY-LEVEL PROFESSIONAL: EXAMINING THE TECHNICAL COMMUNICATIONS PRACTICES OF EARLY CAREER-STAGE U.S. AEROSPACE ENGINEERS AND SCIENTISTS

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Abstract

Studies indicate that communications and information-related activities take up a substantial portion of an engineer's work week; therefore, effective communications and information-use skills are one of the key engineering competencies that early career-stage aerospace engineers and scientists must possess to be successful. Feedback from industry rates communications and information-use skills **high** in terms of their importance to engineering practice; however, this same feedback rates the communications and information-use skills of early career-stage engineers **low**. To gather adequate and generalizable data about the communications and information-related activities of entry-level aerospace engineers and scientists, we surveyed 264 members of the AIAA who have no more than 1-5 years of aerospace engineering work experience. To learn more about the concomitant communications norms, we compared the results of this study with data (1,673 responses) we collected from student members of the AIAA and with data (341 responses) we collected from a study of aerospace engineering professionals. In this paper, we report selected results from these studies that focused on the communications practices and information-related activities of early career-stage U.S. aerospace engineers and scientists in the workplace.

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Introduction

Engineers in the world of work report that communications and information-related activities take up as much as 80% of their time, that the communication of information is an essential element of successful engineering practice, and that the ability to communicate and use information effectively is critical to professional success and advancement (Mailloux, 1989). Feedback from professional engineers and from engineers' supervisors concerning engineering competencies ranks communications and information use skills—the ability to write effectively, to make oral presentations, and to search out and acquire information—**high** in terms of importance to engineering practice. This same feedback, however, ranks the communications skills of entry-level engineers **low** (Bakos, 1986; Chisman, 1987; Katz, 1993; Kimmel and Monsees, 1979). Although government and industry officials are generally satisfied with the technical knowledge preparation of new hires, they worry about the ability of entry-level engineers to communicate. Kandebo (1988) notes, "if there is a significant problem with entry-level hires, it lies in their lack of training and skill in communication... a growing number of entry-level engineers cannot write technical reports, fail to make effective presentations of their ideas of concepts, and find it difficult to communicate with peers." Because effective communication and information use is fundamental to engineering and to the professional (career) success of engineers, important questions arise about the communications and information-use skills of early career-stage U.S. aerospace engineers and scientists. In this paper, we report selected results from a survey of 264 early career-stage U.S. aerospace engineers and scientists for the following topics: importance of and time spent communicating information; collaborative writing; importance of, receipt of, and helpfulness of communications and information-use skills instruction; an undergraduate course in technical communications, use of libraries, and the use and importance of electronic (computer) networks.

Background

Four elements are missing from current discussions of communications and information-related activities and competencies for U.S. aerospace engineers and scientists.

1. 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/information-use 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.
4. A higher-level theoretical framework, a comprehensive understanding of the nature of knowledge and learning, within which the interpretation of such data can take on consistent and fuller meaning.

If these four elements were present, we could construct a mechanism that solicits feedback from the workplace and a system that uses that feedback to answer the questions of what and how much should be taught and when and to determine the effectiveness of instruction.

To contribute to the third element and to collect descriptive data concerning the use, frequency of use, and importance of technical communications to engineers in the workplace, as part of the National Aeronautics and Space Administration (NASA)/ Department of Defense (DoD) Aerospace Knowledge Diffusion Research Project, we surveyed 264 early career-stage U.S. aerospace engineers and scientists who have no more than 1-5 years of aerospace engineering work experience (Pinelli, Barclay, and Kennedy, 1995a). To contribute to the second element we surveyed 1,673 aerospace engineering students (Pinelli, Hecht, Barclay, and Kennedy, 1994). To contribute to the first element we surveyed 341 U.S. aerospace engineers and scientists with an average 21.9 years of aerospace work experience (Pinelli, Barclay, and Kennedy, 1995b).

Related Literature

Our review of the literature centered on engineering as a profession, engineering knowledge and technical work, engineers and their use of information, and engineering communications and the composing and writing practices of workplace engineers. For the purposes of this paper, we have limited our review to literature that focuses on engineering communications and the composing and writing practices of engineers. The composing and writing practices of individual engineers were studied by Selzer (1983) and Winsor (1990, 1992). Davis (1977) and Spretnak (1982) surveyed engineering professionals to determine the impact and importance of effective communications skills on career success and advancement and the value of technical communications training. Middendorf (1980) examined the academic subjects most needed for success in the workplace and proposed a competency inventory for engineering students that prioritized information retrieval and dissemination skills. David (1982) surveyed recent engineering and science graduates to determine the importance of writing proficiency to job performance. In an exploration of specific writing skills and applications, Goubil-Gambrell (1992) studied recent electrical and computer engineering graduates to determine the types of communications they produce in entry-level positions; Strother (1992) surveyed electrical, mechanical, and civil engineering seniors to determine their expectations of the importance and types of writing they anticipate doing in the workplace.

Paradis, Dobrin, and Miller (1985) note that college training itself does not prepare engineering graduates to communicate successfully in the work environment because core engineering and science curricula seldom include writing and editing; when the core curricula do, instructors of engineering or science writing usually know little about the actual environments in which students will work. Paradis, Dobrin, and Miller suggest that the writing skills of engineering students be improved by modifying the curricula in schools of engineering on the basis of the results of studies of communication in the workplace. Tebeaux (1985) concluded from a review of the literature that many academic writing courses that purportedly focus on pragmatic writing (i.e., writing for business and industry) teach writing that bears little resemblance to on-to-job communications. Schreiber (1993) analyzed the differing discourse communities of academic writing and technical communication. The literature suggests, based on feedback from professional engineers about the communications abilities of new engineering graduates, that (1) a disconnect may exist between the academic preparation of engineers and the world of work that they enter on graduation, and (2) many academicians agree that college training may not prepare engineering graduates to communicate successfully in the workplace. They suggest that the curricula in schools of engineering could benefit from modifications based on studies of communication in the workplace.

Methods and Sample Demographics

Self-administered (self-reported) questionnaires were sent to a sample of 700 and consisted of U.S. aerospace engineers and scientists who had changed their AIAA membership from student to professional in the past five years. The study was undertaken as a Phase 1 activity of the NASA/DoD Aerospace Knowledge Diffusion Research Project (Pinelli, Kennedy, and Barclay, 1991). The survey was conducted in April-July 1995. By July 27, 1995, 264 usable questionnaires had been received; we heard from 163 AIAA members who did/could not participate. The adjusted completion rate for the survey was 49%.

Of the respondents, 52% (136 respondents) worked in industry, 32% (83 respondents) worked in government, 9% (24 respondents) worked in academia, and 8% (20 respondents) had some other affiliation. The following "composite" participant profile was developed for the respondents: works in industry (51.7%), has a bachelor's degree (51.9%), has an average of 2.4 years of work experience in aerospace, was educated as and works as an engineer (98.1%, 85.2%), works in design/development (49.4%), and is a male (89%).

Presentation of the Data

To learn more about the concomitant communication norms among the three groups, we compared selected results from the student and professional engineering studies with the results obtained from the survey of early career-stage U.S. aerospace engineers and scientists. Data are presented for the following topics: importance of and time spent communicating information; collaborative writing; importance of, receipt of, and helpfulness of communications and information-use skills instruction; an undergraduate course in technical communications; use of libraries, and use and importance of electronic (computer) networks.

Importance of and Time Spent Communicating

The early career-stage (i.e., new) respondents and professional (i.e., established) engineers agree that the ability to communicate technical information effectively is important (Table 1). The time spent each week communicating technical information in writing and orally was greater for the established than for the new engineers. The amount of time spent working with technical information received from others was appropriately equal for both groups. The time spent communicating technical information, compared to five years ago, was greatest for new engineers; the amount of time spent working with technical information received from others, as a function of professional advancement, was slightly more for the new engineers.

Table 1. Technical Communicaton Practices of New and Established U.S. Aerospace Engineers and Scientists

	New Engineers		Established Engineers	
Communication Factors	n	Mean	n	Mean
Importance of communicating technical information effectively	264	4.6	337	4.7*
Hours spent each week communicating technical information in writing	257	9.7	328	11.5**
Hours spent each week communicating technical information orally	252	10.5	320	11.0
Hours spent each week working with written technical information received from others	253	9.9	332	9.8
Hours spent each week working with technical information received orally from others	249	8.0	322	8.3
Changes Over Time	n	%	n	%
Compared to 5 years ago, time spent communicating technical information has				
Increased	181	71.5	196	58.3
Stayed the same	57	22.8	97	28.9
Decreased	15	5.9	3	12.8
As you have advanced professionally, the amount of time spent working with technical information received from others has				
Increased	167	65.5	202	60.5
Stayed the same	74	29.0	86	25.7
Decreased	14	5.5	46	13.8

*$p \le 0.05$. **$p \le 0.01$.

Collaborative Writing

The process of collaborative writing was examined. Survey participants were asked whether they write alone or as part of a group (Table 2). About 31% of the new engineers and about 29% of the established engineers write alone. Although a higher percentage of the established engineers than the new engineers write with a group of 2-5 people and a group of more than 5 people, writing appears to be a collaborative process for both groups.

New and established engineers were asked to assess the influence of group participation on writing productivity (Table 3). About 39% of the new engineers and about 29% of the established engineers indicated that group writing is more productive than writing alone. About equal percentage of both groups reported (20%) that writing with a group was as productive as writing alone. Conversely, almost 22% of the established engineers, compared to 12% of the new engineers, reported that writing as part of a group was less productive than writing alone.

Table 2. Collaborative Writing Practices of New and Established U.S. Aerospace Engineers and Scientists

Collaborative Practices	New Engineers			Established Engineers		
	$\overline{X}$ %	%*	n	$\overline{X}$ %	%*	n
I write alone	71.2	30.7	251	72.8	29.4	323
I write with one other person	14.2	57.9	151	12.5	54.7	179
I write with a group of two to five people	11.3	44.4	116	10.3	48.3	157
I write with a group of more than five people	3.3	13.0	34	4.2	21.4	70

*Percentages do not total 100.

Table 3. Influence of Group Participation on Writing Productivity of New and Established U.S. Aerospace Engineers and Scientists

Productivity	New Engineers		Established Engineers	
	n	%	n	%
A group is more productive than writing alone	99	38.5	96	29.4
A group is about as productive as writing alone	49	19.1	64	19.6
A group is less productive than writing alone	30	11.7	71	21.7
I only write alone	79	30.7	96	29.4

Importance of Selected Communications/Information-Use Skills

New engineers and student survey participants were given a list of six communications/information-use skills and asked to indicate the importance of each of these skills to their professional success (Table 4). The effective use of computer, communication, and information technology was considered to be most important by the new engineers and engineering students. The effective communication of technical information in writing or orally was rated next in importance by both groups for professional success. Statistically, the engineering students rated the importance of having a knowledge and understanding of engineering/science information resources and materials, the ability to search electronic (bibliographic) databases, and the ability to use a library containing engineering/science information resources and materials higher than did the new engineers.

Table 4. Importance of Selected Communications/ Information-Use Skills to U.S. Aerospace Engineering Students and New U.S. Aerospace Engineers and Scientists

Importance of	Engineering Students		New Engineers	
	n	Mean[a]	n	Mean[a]
Effectively communicating technical information in writing	1728	6.3	262	6.2
Effectively communicating technical information orally	1728	6.3	263	6.2
Having a knowledge and understanding of engineering/science information resources and materials	1722	6.2	263	5.7**
Ability to search electronic (bibliographic) databases	1699	5.5	259	4.3**
Ability to use a library that contains engineering/ science information resources and materials	1723	5.8	262	4.6**
Effectively using computer, communication and information technology	1729	6.5	262	6.3**

[a]Participants used a 7-point scale to rate the importance of each skill, where 7 indicates the highest rating.
*$p \leq 0.05$. **$p \leq 0.01$.

Table 5. Communications/Information-Use Skills Instruction Received by U.S. Aerospace Engineering Students and New U.S. Aerospace Engineers and Scientists

	Engineering Students		New Engineers	
Instruction	n	%	n	%
Technical writing/ communication	1250	72.2	224	84.4
Speech/oral communication	1076	62.2	199	75.4
Using a library that contains engineering/ science information resources and materials	1037	59.9	198	75.3
Using engineering/science information resources and materials	1100	63.6	212	80.6
Searching electronic (bibliographic) databases	869	50.2	160	60.8
Using computer, communication, and information technology	1433	82.9	222	84.4

Table 6. Helpfulness of Communications/Information-Use Skills Instruction Received by U.S. Aerospace Engineering Students and New U.S. Aerospace Engineers and Scientists

	Engineering Students		New Engineers	
Instruction	n	Mean[a]	n	Mean[a]
Technical writing/ communication	1248	5.5	224	5.5
Speech/oral communication	1092	5.5	201	5.6
Using a library that contains engineering/ science information resources and materials	1042	5.1	201	4.8**
Using engineering/science information resources and materials	1104	5.3	212	5.1
Searching electronic (bibliographic) databases	900	5.0	167	4.6**
Using computer, communication, and information technology	1416	5.9	225	6.1**

[a]Participants used a 7-point scale to rate the helpfulness of each competency, where 7 indicates the highest rating.

*$p \leq 0.05$. **$p \leq 0.01$.

Next, we asked the engineering students and the new engineers to indicate if they had received instruction/training in the six communication/ information-use skills and asked to indicate if they had received instruction/training in each of the six skills (Table 5) and to rate the perceived helpfulness (usefulness) of that instruction (Table 6). One-half or more of the respondents in both groups had received some form of instruction/training in the six skills. About 83% of the respondents in both groups reported having received some form of training/instruction in using computer, communication, and information technology. A higher percentage of the new engineers (84%/75%) than the students (72%/62%) reported having received some form of instruction/training in technical writing and oral communications. A higher percentage of new engineers also reported having received some form of instructions/training in using a library containing engineering/science information resource and materials, using engineering/science information resources and materials, and searching electronic (bibliographic) databases.

Perceptions of the respondents in both groups regarding the helpfulness (usefulness) of the instruction/training varied (Table 6). Of those who had received instruction/training in using computer, communication, and information technology, the new engineers found it to be more helpful than did the engineering students. The mean responses for both groups concerning the helpfulness of the instruction/training they received in technical writing and oral communication were about equal. Otherwise, the mean responses of the new engineers concerning the instruction/training they received in the three remaining skills were less than the mean responses of the engineering students.

Undergraduate Course Content for Technical Communications

We asked the new and established engineers what principles, mechanics, and on-the-job skills should be included in an undergraduate technical communications course for aerospace engineering and science students (Table 7). The top five principles identified for inclusion by the new engineers were: preparing/presenting information, defining the purpose of the communication, assessing the needs of the reader, developing paragraphs, and notetaking and quoting. In somewhat different order, the established engineers selected 4 of the 5 same principles selected by the new engineers. The exception was writing grammatically correct sentences. The new engineers recommended

Table 7. Principles, Mechanics, and On-the-Job Skills Recommended for Inclusion in an Undergraduate Technical Communications Course by New and Established U.S. Aerospace Engineers and Scientists

	New Engineers		Established Engineers	
Principles	n	%	n	%
Defining the purpose of the communication	237	92.6	547	90.7
Assessing the needs of the reader	236	92.2	490	81.7
Preparing/presenting information in an organized manner	251	97.7	582	96.5
Developing paragraphs (introductions, transi - tions, conclusions)	167	65.2	520	86.2
Writing grammatically correct sentences	125	49.0	483	80.0
Notetaking and quoting	138	54.8	299	50.0
Editing and revising	221	26.3	469	77.8
Mechanics	n	%	n	%
Abbreviations	149	59.1	304	51.4
Acronyms	164	65.1	295	49.7
Capitalization	122	48.8	361	61.0
Numbers	148	59.4	286	48.7
Punctuation	166	65.6	450	75.9
References	234	92.9	455	76.7
Spelling	119	47.4	386	65.1
Symbols	194	79.5	339	57.3
On-the-Job Skills	n	%	n	%
Abstracts	202	80.2	406	69.0
Letters	168	65.9	412	69.4
Memoranda	186	72.7	463	77.8
Technical instructions	213	84.2	340	57.6
Journal articles	121	47.8	275	46.4
Conference/meeting papers	143	56.7	243	43.8
Literature reviews	105	42.0	220	37.3
Technical manuals	194	77.0	287	48.3
Newsletter/newspaper articles	60	24.4	143	24.3
Oral (technical) presentations	249	96.9	567	95.3
Technical specifications	205	81.3	330	55.7
Technical reports	242	94.5	398	58.1
Use of information sources	216	86.7	468	79.1

the following mechanics: references, symbols, punctuation, acronyms, and numbers. The established engineers recommended the following mechanics: references, punctuation, spelling, capitalization, and symbols. The new engineers recommended the following on-the-job skills: oral (technical) presentations, technical reports, use of information sources, technical instructions, and technical specifications. The established engineers recommended the following on-the-job skills: oral (technical) presentations, use of information sources, memoranda, letters, and abstracts.

Use of Libraries

Almost all of the respondents indicated that their organization has a library. Both the new and established engineers were asked to indicate the number of times they had used their organization's library in the past 6 months (Table 8). About 28% of the new engineers and about 25% of the established engineers reported that they had not used their organization's library in the past 6 months. Overall library use for both groups of respondents is approximately equal. Those respondents who had not used their organization's library in the past 6 months were asked to indicate why they had not. The two top reasons were the same for both new and established engineers: "my information needs were met some other way" (86.8%/89.49%) and "I had no information needs" (50.7%/47.5%).

Table 8. Use of a Library in the Past 6 Months by New and Established U.S. Aerospace Engineers and Scientists

	New Engineers		Established Engineers	
Number of Visits	n	%	n	%
0	73	28.4	76	25.1
1-5	105	40.9	125	41.3
6-10	38	14.8	50	16.5
11-25	26	10.1	33	10.9
26-50	10	3.9	13	4.3
51 or more	3	1.9	6	2.0
Mean	7.3		7.6	
Median	3.0		3.0	

$^{*}p \leq 0.05$.

Use and Importance of Electronic (Computer) Networks

Nearly all respondents in both groups have access to electronic (computer) networks. About 90% of the new engineers and about 86% of the established engineers use electronic (computer) networks in their work. Nearly all respondents reported that electronic (computer) networks are important in performing their present professional duties. About 95% and 94% of the new engineers used electronic (computer) networks for electronic mail and for electronic file transfer (Table 9). About 92% and 74% of the established engineers used electronic (computer) networks for electronic mail and to connect to geographically distant sites. Finally, new and established engineers were asked to report with whom they exchange messages or files (Table 10). About 86% and 84% of the new engineers exchange files with members of their own work group and with people outside their work group. Established engineers reported the greatest exchange of messages and files with members of their own work group (89.6%) and with people in their organization at the same geographic who are not in their own work group (84.5%).

Discussion

The findings permit the formulation of the following general statements regarding the technical communications practices of the early career-stage (i.e., new engineers) U.S. aerospace engineers and scientists we surveyed.

1. Statistical differences were noted between new engineers and established engineers and their responses concerning the importance of communicating technical information effectively and the number of hours spent each week communicating technical information to others in writing.
2. The number of hours spent each week by new engineers and established engineers working with technical information received from others in writing and orally was approximately equal.
3. The new engineers reported a greater increase in the amount of time they spend communicating technical information, over the past five years, than did the established engineers.
4. A higher percentage of the new engineers reported that writing as a member of a group is more productive than writing alone. Conversely, a higher percentage of established engineers reported that writing alone is more productive than writing as a member of a group.

Table 9. Uses of Electronic (Computer) Networks by New and Established U.S. Aerospace Engineers and Scientists

	New Engineers		Established Engineers	
Purpose of Use	n	%	n	%
Connect to geographically distant sites	180	78.6	206	74.4
Electronic mail	219	94.8	267	92.4
Electronic bulletin boards or conferences	128	55.7	110	41.2
Electronic file transfer	218	94.4	—	—
Log into computers for computational analysis or to use design tools	155	67.4	150	56.8
Control equipment such as laboratory instruments or machine tools	44	19.1	12	4.7
Access/search the library's catalog	143	61.9	117	43.3
Order documents from the library	57	24.8	50	19.0
Search electronic (bibliographic) databases	—	—	91	34.4
Information search and data retrieval	161	69.7	153	56.0
Prepare scientific and technical papers with colleagues at geographically distant sites	61	26.6	77	28.9

Table 10. Use of Electronic (Computer) Networks by New and Established U.S. Aerospace Engineers and Scientists to Exchange Messages or Files

	New Engineers		Established Engineers	
Exchange With—	n	%	n	%
Members of your work group	199	85.8	259	89.6
Other people in your organization at the **same** geographic site who are not in your work group	190	82.3	240	84.5
Other people in your organization at a **different** geographic site who are not in your work group	158	68.7	195	69.1
People outside of your work group	193	83.5	226	80.1

5. Overall, higher mean importance ratings (i.e., scores) for the six communications/information-use skills were reported by the engineering students than by the new engineers.
6. Overall, a higher percentage of the new engineers than the engineering students reported having received training/instruction in the six communications/information-use skills.
7. Engineering students and new engineers reported about equal mean scores for the helpfulness of the instruction/training they received in technical writing and oral communications.
8. Statistically different mean scores were reported by the engineering students and the new engineers for the helpfulness of the instruction/training they received in three of the six communications/information-use skills.
9. The principles, mechanics, and on-the-job skills recommended by new engineers and established engineers for inclusive in an undergraduate course in technical communication for aerospace engineering and science students were very similar.
10. Library use (i.e., use of the organization's library in the past six months) for new and established engineers was about equal for both groups of respondents.
11. Both groups of respondents reported having access to and using electronic (computer) networks in performing their present professional duties. Both groups of respondents reported that electronic (computer) networks were important in performing their present professional duties.

Concluding Remarks

The literature we reviewed suggests that, in general, entry-level engineers lack the communications and information-use skills to write effectively, make oral presentations, and search out and acquire information—the very skills and competencies that the literature indicates are needed for a successful engineering career. In the absence of an explanation from the professional engineering community about what constitutes acceptable and desirable communications norms, and given the lack of adequate and generalizable data that would demonstrate the communications and information-use skills of entry-level engineers, we will assume that the early career-stage U.S. aerospace engineers and scientists we surveyed recognize the importance of and the relationship that exists between effective communications and professional career success. Most of the new engineers we surveyed reported receiving instruction/training in each of the six communications/information-use skills and they reported that the instruction/training they received was helpful.

Given the limited purposes of this exploratory study, the overall response rate, and the research design, no claims are made regarding the extent to which the attributes of the new engineers in this study reflect the attributes of all early career-stage aerospace engineers and scientists in the U.S. A different research design, larger sample size and methodology would be needed before such claims could be made.

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