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Paper Twenty One

Technological Innovation and Technical Communications: Their Place in Aerospace Engineering Curricula. A Survey of European, Japanese, and U.S. Aerospace Engineers and Scientists

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Technological Innovation and Technical Communications: Their Place in Aerospace Engineering Curricula. A Survey of European, Japanese and US Aerospace Engineers and Scientists

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SUMMARY *Aerospace engineers and scientists from Western Europe, Japan and the USA were surveyed as part of the NASA/DoD Aerospace Knowledge Diffusion Research Project. Questionnaires were used to solicit their opinions regarding (1) the importance of technical communications to their profession, (2) the use and production of technical communications, and (3) their views about the appropriate content of an undergraduate course in technical communications. The ability to communicate technical information effectively was very important to the aerospace engineers and scientists who participated in the study. A considerable portion of their working week is devoted to using and producing technical information. The types of technical communications used and produced varied within and among the three groups. The type of technical communications product used and produced appears to be related to respondents' professional duties. Respondents from the three groups made similar recommendations regarding the principles, mechanics, and on-the-job communications to be included in an undergraduate technical communications course for aerospace majors.*

1. Introduction

Technological innovation, in terms of the application and communication of knowledge, has been described as the critical factor in the long-term economic growth of modern industrial nations [1]. In a general sense, technological innovation involves some or all of the components of the process of moving ideas for a product or process from research to the marketplace [2]. With the emergence of global markets, technological innovation and its key infrastructures have become topics of growing concern in academic government and industry. In academic circles and among engineering educators the question is how best to educate engineers to work in an international economy where technological innovation plays an increasingly important role.

Although engineers dominate technological innovation, they characteristically know little and understand even less about this process [3]. In particular, studies have shown that the communication of technical information is critical to the success of technological innovation [4, 5]. As early as 1963, a national study undertaken in the USA [6] concluded that, "the transfer of information is an inseparable part of the research and development (R&D) process. The effectiveness of technological innovation depends on the efficiency of information transfer". Therefore, the ability of engineers to identify, acquire and utilize technical information is of paramount importance to the efficiency of the R&D process.

Testimony to the central role of technical information in the R&D process is found in numerous studies. Engineers devote more time, on the average, to the communication of technical information than to any other scientific or technical activity [7]. Strong relationships exist between the communication of technical information and technical performance at both the individual [8, 9] and group levels [10, 11]. We concur with Fischer's conclusion that the "communication of technical information is thus central to the success of the innovation process, in general, and the management of R&D activities, in particular" [12]. Moreover, we believe that engineering education should include a strong technical communications component in addition to the traditional technical knowledge preparation.

The field of aerospace engineering may be symptomatic of both the importance of technical communications to the technological innovation process and the problems inherent in current engineering curricula *vis-à-vis* technical communications. With its contribution to trade, its coupling with national security, and its symbolism of technological strength, aerospace engineering holds a unique position in the industrial and economic structures of Western Europe, Japan and the USA. Increasing cooperation and collaboration among these structures will create a more international manufacturing environment, altering the current structure of the aerospace industry and resulting in an even more rapid diffusion of technology. Aerospace producers will feel increasing pressure to push forward with new technological developments and to maximize the inclusion of recent technological developments into the R&D process. Aerospace educators, therefore, must take steps not only to develop and maintain the technical competency of aerospace engineers, but also to enhance their communications skills.

A recent manpower study of the US aerospace industry found employers generally satisfied with the technical-knowledge preparation of entry-level aerospace engineers. However, industry officials are worried about the writing and presentation skills of entry-level hires: "If there is a significant problem with entry hires, it lies in their lack of training and skill in communications" [13]. This same study goes on to quote a General Dynamics official who said, "General Dynamics and other aerospace firms are concerned that a growing number of entry-level engineers cannot write technical reports, fail to make effective presentations of their ideas or concepts, and find it difficult to communicate with peers" [13]. Such perceived weaknesses do not bode well for the effective utilization and communication of technical information.

2. Background

Rapidly changing patterns of international cooperation and collaboration and revolutionary technological and managerial changes are combining to influence and transform the communication of technical information in the workplace. Consequently, if academic programs are to prepare aerospace engineers to communicate effectively, these programs must reflect workplace culture, organization and communications at the national and international levels. To contribute to this understanding, this article provides insight into the international workplace by presenting the views of aerospace engineers and scientists from Western Europe, Japan and the USA. The data reported in this article were collected through a series of initial studies undertaken in several

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countries as part of *Phase 4* of the NASA/DoD Aerospace Knowledge Diffusion Research Project. These studies included the following objectives:

(1) to solicit the opinions of aerospace engineers and scientists regarding the importance of technical communications to their profession;
(2) to determine the use and production of technical communications by aerospace engineers and scientists;
(3) to seek their views about the appropriate content of an undergraduate course in technical communications.

(Discussion of the studies' fourth and fifth objectives—to determine their use of libraries, technical information centers, and on-line data bases and to determine the use and importance of computer and information technology to them—is beyond the scope of this article.)

This research project is a joint effort of the Indiana University Center for Survey Research and the NASA Langley Research Center. It is sponsored by the NASA, Director of the Scientific and Technical Information Division (Code NTT) and the DoD, Office of the Assistant Secretary of the Air Force, Deputy for Scientific and Technical Information, and the Defense Technical Information Center (DTIC). The results of this research will provide useful information to R&D managers, engineering educators, information managers and others concerned with improving access to and the utilization of the results of aerospace R&D [14].

2.1 Survey Methodology

Approximately 125 Western European and 50 US aerospace engineers and scientists working in the fields of cryogenics, magnetic suspension and adaptive walls served as the sample frames for the studies. Each member of the sample was asked to complete one questionnaire and to give one questionnaire to a colleague. We received 101 responses from Western Europe and 63 from the USA. In Japan, 13 aerospace engineers and scientists distributed questionnaires to other aerospace engineers and scientists within their organizations. We received 96 responses from Japan. This article highlights selected results of the initial studies, with the Western European aerospace engineers and scientists' responses presented first, followed by the Japanese and the US participants' responses.

2.2 Demographic Information About the Survey Respondents

Survey respondents identified their professional duties, type of organization, years of professional work experience, education, current duties, whether English was their first (native) language and their gender. These demographic findings are shown in Table I (numbers given in percentages).

A comparison of the three groups reveals that they are similar in education, educational preparation and gender. The three groups differ in professional duties, organizational affiliation, years of professional work experience and current duties. We speculate that the differences in organizational affiliation and professional duties may account for variations across countries. We further assume that national culture and customs might also be responsible for differences resulting from a comparison of the data.

TABLE I. Demographic distributions

	Western Europe (%)	Japan (%)	USA (%)
Professional duties			
Design/Development	24	27	14
Administration/management	7	2	27
Research	45	40	35
Other	24	31	24
Organizational affiliation			
Industry	25	37	24
Government	20	26	41
Academic	31	36	24
Not for profit	18	1	0
Other	6	0	11
Professional work experience			
0–9 years	14	26	8
10–19 years	31	35	14
20–29 years	38	24	34
30 or more years	17	15	44
Education			
Bachelor's degree or less	16	22	18
Postgraduate	84	78	82
Educational preparation			
Engineer	81	91	86
Scientist	19	9	14
Current duties			
Engineer	66	91	68
Scientist	31	6	10
Other	3	3	22
English first (native) language	33	0	89
Gender			
Male	96	99	98
Female	4	1	2

3. Survey Findings

3.1 Importance of Technical Communication

Using a five-point scale to measure importance, survey participants were asked to indicate the relative importance of their ability to communicate technical information effectively. About 94% of the European, 97% of the Japanese and 95% of the US respondents indicate that the ability to communicate technical information effectively is very important. (Values of '1' and '2' on a five-point scale were combined.)

Table II shows the time that the respondents spend in technical communication. As professional work experience increases, so does the time the respondents spend on technical communication. Table III shows how the amount of time spent by respondents communicating technical information has changed in the past 5 years.

In the past 5 years the time they spend on technical communication has changed. Table IV shows the changes in the past 5 years in the amount of time spent working with technical communications received from others as professional advancement has occurred.

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TABLE II. Median number of hours spent each week by Western European, Japanese and US aerospace engineers and scientists in communicating technical information

	Western Europe	Japan	USA
Communications with others	8.0	5.0	10.0
Working with communications from others	8.0	10.0	10.0
Per cent of working week devoted to technical communications[a]	40%	37.5%	50%

[a]Based on a 40-hour working week.

TABLE III. Changes in the past 5 years in the amount of time spent communicating technical information by Western European, Japanese and US aerospace engineers and scientists

	Western Europe (%)	Japan (%)	USA (%)
Increased	60	38	42
Stayed the same	31	47	45
Decreased	9	15	13

These data demonstrate that the ability to communicate technical information effectively is important to European, Japanese and US aerospace engineers and scientists. Each group devotes considerable time (about 40%, 38% and 50%, respectively, of a 40-hour working week) and effort to technical communication and considers it a significant component of professional duties. Over the past 5 years, the amount of time spent working with technical communications has increased dramatically among the European respondents and to a lesser extent among their Japanese and US counterparts.

TABLE IV. Changes in the amount of time spent communicating technical information as part of professional advancement by Western European, Japanese and US aerospace engineers and scientists

	Western Europe (%)	Japan (%)	USA (%)
Increased	70	48	56
Stayed the same	19	34	25
Decreased	11	18	19

3.2 The Use and Production of Technical Communications

European, Japanese and US aerospace engineers and scientists use and produce a variety of technical information products. Table V shows the types and amounts used by the respondents.

TABLE V. Median number of technical information products used in the past 6 months by Western European, Japanese and US aerospace engineers and scientists

	Western Europe	Japan	USA
Letters	20	5	10
Memos	20	1	10
Journal articles	20	10	6
In-house technical reports	10	6	10
Abstracts	10	10	7
Conference/meeting papers	10	10	7
Drawings/specifications	10	5	4
Trade/promotional literature	5	2	4
Technical proposals	5	2	3
AGARD technical reports	5	3	2
Computer program documentation	5	5	2
Technical manuals	5	5	2
Audiovisual materials	3	3	5
US government technical reports	2	2	5
Technical talks/presentations	—	5	8

The European aerospace engineers and scientists in this study use more technical information products than do their Japanese and US counterparts. The overall use figures suggest to us that much of the technical information used by the European and US groups is communicated in simple, basic formats. The Japanese respondents report considerably less use of the formats favored by their European and US counterparts. As Cutler [15] and Hass & Funk [16] noted, Japanese researchers apparently prefer to exchange information in face-to-face dialog.

Table VI shows the types and amounts of technical information products produced by the respondents. From this it can be seen that the aerospace engineers and scientists in this study use significantly more information than they produce. Again, the overall figures suggest that such information is produced in simple, basic formats. The Japanese respondents make slightly greater use of oral and visual communications than do their European counterparts, but the US respondents make even greater use of them than do the Japanese.

3.3 Content for an Undergraduate Course in Technical Communications

The ability to communicate technical information effectively is important to workplace performance and professional advancement. Responses of the European, Japanese and US survey participants point to a positive relationship between classroom study and on-the-job communications proficiency. Survey participants were first asked to indicate whether they had taken a course(s) in technical communications/writing. Table VII shows the responses to this question.

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TABLE VI. Median number of technical information products produced in the past 6 months by Western European, Japanese and US aerospace engineers and scientists

	Western Europe	Japan	USA
Letters	10	5	10
Memos	4	1	6
Abstracts	2	2	1
Audiovisual materials	2	0	4
Conference/meeting papers	2	1	1
Drawings/specifications	2	0	0
In-house technical reports	2	3	1
Technical proposals	2	1	1
AGARD technical reports	0	0	0
Computer program documentation	0	0	0
Journal articles	0	1	0
Technical manuals	0	0	0
Technical talks/presentations	—	2	3
Trade/promotional literature	0	0	0
US government technical reports	0	0	0

TABLE VII. Education in technical communications

	Western Europe (%)	Japan (%)	USA (%)
Studied technical communications/ writing	20	14	60
As undergraduates	4	1	26
After graduation	10	11	26
Both as undergraduates and after graduation	6	2	8
Courses were helpful	100	100	94

TABLE VIII. Opinions favoring an undergraduate course in technical communications for aerospace majors[a]

	Western Europe	Japan	USA
Should be taken	75% (39)	12% (9)	87% (41)
Taken for credit	34% (14)	53% (40)	84% (42)
Taken as non-credit	38% (15)	46% (32)	17% (8)
Taken as a required course	71% (41)	23% (17)	90% (45)
Taken as an elective course	37% (19)	80% (67)	22% (10)
Taken as part of an engineering course	81% (50)	48% (34)	60% (31)
Taken as a separate course	35% (17)	43% (31)	57% (25)
Taken as part of another course	18% (8)	10% (7)	13% (6)

[a]Percentages do not total 100 because respondents could answer yes to more than one.

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Survey participants were also asked their opinion regarding aerospace majors' need for an undergraduate course in technical communications. Table VIII presents their responses to this question (number of respondents in parentheses).

The European and US respondents indicate that aerospace engineering and science majors should take an undergraduate course in technical communications. An overwhelming majority of the Japanese respondents do not favor such a course. Of those respondents who indicate the desirability of such a course, the majority of the Japanese and US respondents feel it should be taken for credit. The European and US respondents favor it as a required course rather than an elective; the Japanese favor it as an elective course rather than a requirement. The European and, to a lesser extent, the US respondents believe that technical communications should be incorporated as part of an engineering course. The Japanese respondents appear divided on its appropriate placement in the curriculum.

European and US respondents were asked to identify the appropriate communications principles to be taught in an undergraduate technical communications course for aerospace majors. Their responses appear in Fig. 1. Despite reported demographic differences, European, Japanese and US participants made similar recommendations. They stressed

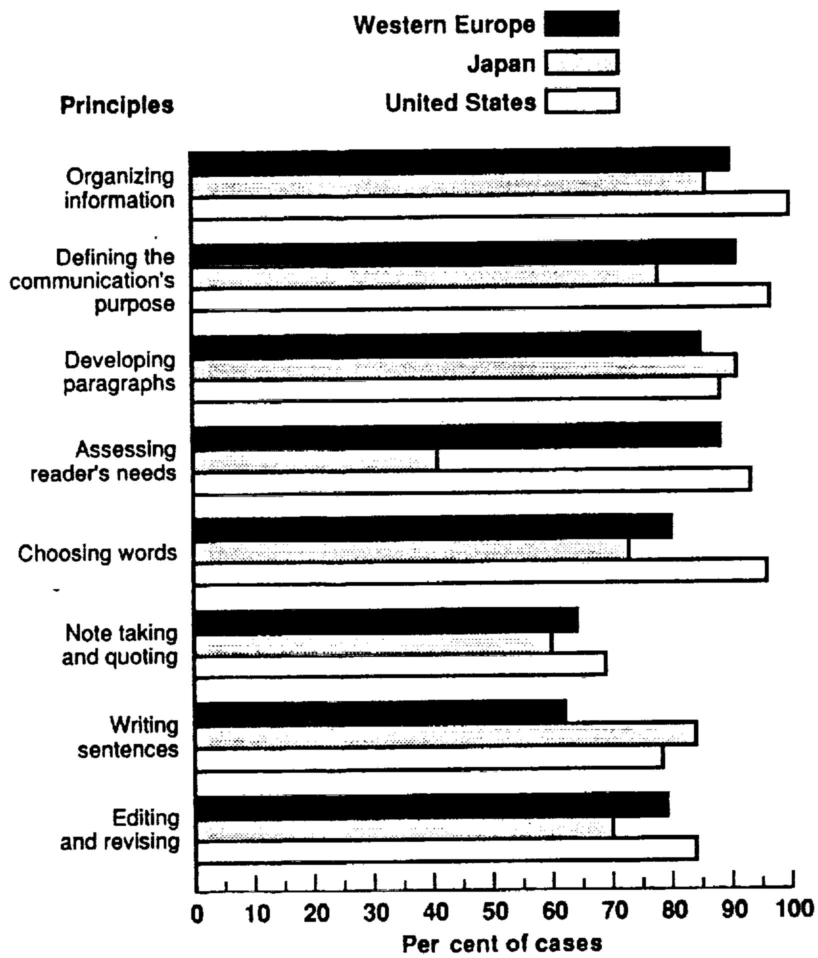

FIG. 1. Recommended principles for an undergraduate technical communications course for aerospace majors.

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organizing information, defining the communication's purpose, developing paragraphs and choosing words. The European and US respondents also recommended assessing readers' needs; however, the Japanese did not. This finding is consistent with the traditional Japanese view that the reader assumes responsibility for interpreting meaning. A list of the top five principles selected by each group is shown in Table IX in descending order of frequency.

The European, Japanese and US respondents also chose from a list of eight topics the appropriate mechanics to be covered in an undergraduate technical communications course for aerospace majors. Their recommendations for inclusion appear in Fig. 2. European Japanese and US respondents demonstrate agreement in matters of interpretation and correctness. Approximately 70% of all three groups want the course to include references, symbols and punctuation. About 50% of all three groups want abbreviations included. A list of the top five mechanics selected by each group is shown in Table X in decreasing order of frequency.

TABLE IX. Top five principles in descending order

Western Europe	Japan	USA
Organizing information	Developing paragraphs	Organizing information
Defining the communication's purpose	Organizing information	Defining the communication's purpose
Assessing reader's needs	Writing sentences	Choosing words
Developing paragraphs	Defining the communication's purpose	Assessing reader's needs
Choosing words	Choosing words	Developing paragraphs

Given a list of 13 topics, European, Japanese and US respondents were asked to identify appropriate on-the-job communications to be included in an undergraduate technical communication course for aerospace major. Their recommendations appear in Fig. 3. The three groups of respondents displayed a lack of agreement regarding which on-the-job communications should be included. There was general agreement on abstracts, technical reports, technical instructions and journal articles (within 5 percentage points for all three groups). A list of the top five on-the-job recommendations for each group is shown in Table XI in descending order of frequency.

In an attempt to validate these findings, the top five recommended on-the-job communications were compared with the top five (on the average) technical communications products 'used' and 'produced' by European, Japanese and US aerospace engineers and scientists (Table XII). Overall, the respondents' recommendations seem consistent with the types of communications they use and produce.

TABLE X. Top five mechanics in descending order

Western Europe	Japan	USA
References	References	References
Symbols	Symbols	Punctuation
Punctuation	Punctuation	Symbols
Abbreviations	Abbreviations	Abbreviations
Spelling	Numbers	Spelling

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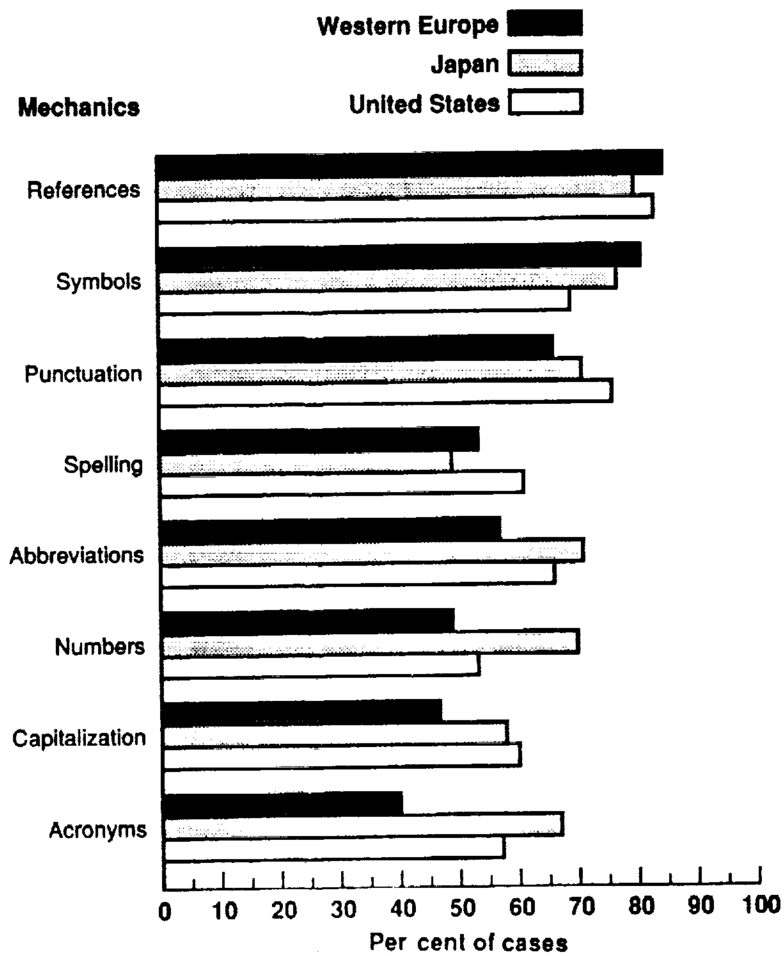

FIG. 2. Recommended mechanics for an undergraduate technical communication course for aerospace majors.

4. Discussion of the Findings

Given the limited purposes of the initial studies, the overall response rates and the use of convenient samples, no attempt is made to generalize the findings to all aerospace engineers and scientists in Western Europe, Japan and the USA. For the purpose of

TABLE XI. Top five on-the-job communications in descending order

Western Europe	Japan	USA
Oral presentations	Abstracts	Oral presentations
Abstracts	Technical reports	Use of information sources
Use of information sources	Oral presentations	Abstracts
Conference/meeting papers	Technical manuals	Technical reports
Technical reports	Journal articles	Literature reviews

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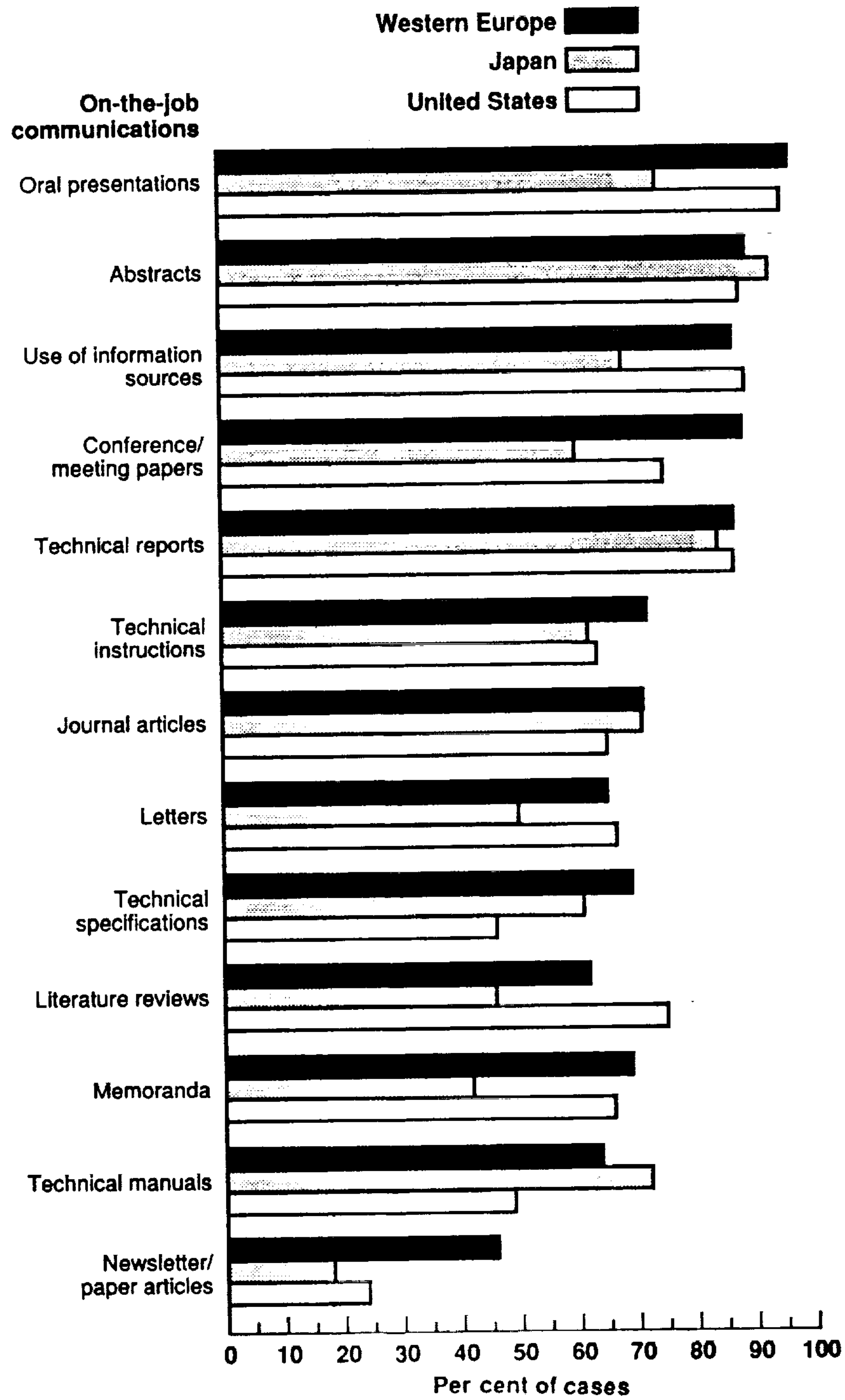

FIG. 3. Recommended on-the-job communications to be taught in an undergraduate technical communication course for aerospace majors.

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discussion, the findings are presented here within the context of related and relevant findings from other studies. The findings from the initial and other studies are included under the corresponding objective.

4.1. The Importance of Technical Communication

There is no consensus definition for technical communications. Most textbooks on the subject use the term to include the practices of writing and oral communications. For purposes of our initial studies, 'technical communications' was broadly defined and encompasses the skills needed and the processes and institutions used by aerospace engineers and scientists to acquire, produce, transfer and utilize scientific and technical information.

The ability to communicate technical information effectively is very important to the aerospace engineers and scientists who participated in our initial studies. These individuals devote a considerable portion of their working week to using and producing technical information. The use and importance of technical information to them does not diminish as a function of 'years of professional work experience' and appears to be related to professional advancement.

In a study to determine the importance of technical communications to successful engineers, Davis [17] found that 96% of the respondents indicated the ability to write was both an important aspect of their work and an important consideration when a

TABLE XII. Comparison of the top five 'produced, used' and 'recommended' communication products

Western Europe	Japan	USA
Used		
Journal articles	Journal articles	In-house technical reports
In-house technical reports	Abstracts	Technical talks/presentations
Abstracts	Conference/meeting papers	Abstracts
Conference/meeting papers	In-house technical reports	Conference/meeting papers
Drawings/specifications	*Drawings/specifications	Journal articles
	*Computer programs and documentation	
	*Technical manuals	
	*Technical talks/presentations	
Produced		
Abstracts	In-house technical reports	A/V materials
A/V materials	Abstracts	Technical talks/presentations
Conference/meeting papers	Technical talks/presentations	Abstracts
Drawing specifications	Conference/meeting papers	Conference/meeting papers
*In-house technical reports	*Technical proposals	*In-house technical reports
*Technical proposals	*Journal articles	*Technical proposals
Recommended		
Oral presentations	Abstracts	Oral presentations
Abstracts	Technical reports	Use of information sources
Use of information sources	Oral presentations	Abstracts
Conference/meeting papers	Technical manuals	Technical reports
Technical reports	Journal articles	Literature reviews

*Tied results.

subordinate is considered for advancement. Participants in the Davis study reported spending about 55% of their working week using and producing technical information, and 63% indicated that, as their professional responsibilities increased, so too did the time they spent using and producing technical communications. Spretnak [18] conducted a comparable study and reported similar findings. Respondents to her study indicated that their ability to communicate had aided their professional advancement, and the amount of time devoted to the communication of technical information had increased as they advanced in their careers. In addition, they would weigh the 'ability to communicate effectively' when making hiring and promotions decisions.

4.2 The Use and Production of Technical Communications

The types of technical communications used and produced by the European, Japanese and US aerospace engineers and scientists in these initial studies vary within and among the three groups. The type of product used and produced appears to be related to respondents' professional duties. The use, production and recommended inclusion of technical reports in an undergraduate course for aerospace majors are corroborated by the work of Allen [19] and Shuchman [20]. Both researchers reported a high use and importance rate for technical reports among aerospace engineers.

4.3 Content for an Undergraduate Course in Technical Communications

Although a majority of the US participants had studied technical communications, most of the European and Japanese respondents had not. What is not known is the extent to which technical communications are available/offered in Western Europe and Japan. US respondents, and to a lesser extent their European and Japanese counterparts, favored an undergraduate course in technical communications for aerospace majors. Of those favoring inclusion, respondents favored credit over non-credit courses. European and US respondents recommended a required course over an elective course. Respondents from the three groups preferred that the course be part of an engineering course rather than a separate course for aerospace majors.

Respondents from the three groups made similar recommendations regarding the *principles*, *mechanics* and *on-the-job communications* to be included in an undergraduate technical communications course for aerospace majors. The on-the-job communications recommended by the study participants compared quite favourably with the types of technical information products they produced. Respondents to the Davis and Spretnak [17, 18] studies indicated that engineering students should be required or encouraged to take a course in technical communications as part of their undergraduate engineering education.

The question of 'course content' has been a topic of considerable discussion. Kellner [21] states that, "there is no consensus or even close agreement about what constitutes a course in technical communications'. Respondents to Davis's [17] study stated that clarity (directness, simplicity, unambiguousness and comprehensibility), brevity (conciseness, compactness and succinctness) and logical order (organization of ideas and continuity of thought) were 'essential' elements of a course in technical communications. Spretnak [18] asked the participants in her study to identify the 'problems' common to the effective communication of technical information. A strong similarity exists between the problems identified by her respondents and the principles and mechanics recommended by the participants in our initial studies.

5. Concluding Remarks

A number of studies have shown that efficient information transfer plays a major role in the effectiveness of technological innovation. Although the technological innovation process itself may not be well understood, its importance to economic growth and prosperity cannot be denied. As increasing collaboration and cooperation create a more international manufacturing environment and speed the diffusion of technology, engineers will have to be educated to work in a global economy. In particular, engineering curricula must acknowledge the need for effective communication skills to facilitate the technological innovation process.

For years land, labor and capital were perceived to be the forces propelling the economic growth of industrialized nations. With the advent of a global economy, information has been added to the traditional sources of wealth. In international industries such as aerospace, the successful firms will be those that produce, transfer and utilize information for marketplace and strategic advantages. "Comparative advantages of organizations are to be found more in knowing **how and when** to use information rather than in simply having it" [22]. Given that the 'how' of information use is "inadequately developed and poorly applied in very nearly all private and public organizations" [23], we believe that including the 'how' of information use as a larger part of the engineering curriculum will contribute to developing and maximizing the competence of engineers. The successful production and use of information—specifically, technical communications products and services—are crucial to engineers' effective participation in the technological innovation process. In addition, technological innovation is crucial to successful participation in the global economy.

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