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# SCHOLARLY ELECTRONIC COMMUNICATION AMONGST THE AEROSPACE ENGINEERING COMMUNITY AND THE IMPACT OF ELECTRONIC JOURNALS: A REVIEW STUDY

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This review paper highlights the very special 'niche segment' to which the aerospace scientists and engineers belonging to different countries right across the globe occupy. Highlighting aviation as one of the most significant technological marvels of our times, the paper discusses in detail the various significant aspects related to what aerospace engineering is all about and how the electronic media has come in a big way to support scholarly communication within this 'niche' aerospace engineering community. The paper also reviews the impact of Internet, the availability of high-speed networks which has enabled these scientists and engineers have access to electronic journals right at their desktops and also keep track of the global R&D happenings in their respective field of specialization. Various studies conducted (as indicated in this paper) illustrate how 'electronic journals' are highly important to the aerospace scientists and engineers. Important studies in this connection have also proved that scientists are willing to pay a high price in their time to spend many hours reading electronic scientific literature. Many relevant studies also have revealed that the information that a scientist or engineer gets from refereed journals has greatly resulted in their improved performance. The review paper also touches upon key aspects like: (a) Distinguishing engineers from scientists, (b) Their differences in knowledge diffusion, (c) Their communication behaviours, (d) Their information seeking behaviour, (e) The aerospace engineering community in particular and the (g) the importance of scientific communication for advances in aerospace engineering and the need for electronic information resources.

**KEYWORDS/DESCRIPTORS**: Information Processing in Science and Technology, Communication Behaviour of Scientists and Engineers, Engineers Information Seeking Behaviour, Scholarly Electronic Communication, The Aerospace Engineering Community, Impact of Electronic Journals



## 1 INTRODUCTION

Aviation is one of the most significant technological marvels of our time and empowers the nation with strength. It is a major tool for economic development and has a significant role in national security and international relations. India has been fortunate to have started aeronautics related activities as early as 1940, with the establishment of Hindustan Aeronautics Limited (HAL) in Bangalore. The Company was conceived by the visionary and far-sighted industrialist Sir Walchand Hirachand in Dec 1940 in association with the then Government of Mysore.

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Aerospace engineering is the application of advanced science and technology for the design and development of flight vehicles. These include aircraft, spacecraft, missiles and rockets. An aerospace engineer develops new technologies for control, navigation and propulsion that will lead to future milestones in the history of flight. Originally called aeronautical engineering dealing solely with aircraft, the broader term "aerospace engineering" has replaced the former in most usage, as flight technology advanced to include craft operating outside the earth's atmosphere. In analogy with "aeronautical engineering", the branch is sometimes referred to as astronautical engineering, although this term usually only concerns craft which operate in outer space.

Aerospace engineering deals with the design, development and performance of flight vehicles such as transport and military aircraft, helicopters, missiles, and launch vehicles (rockets) and spacecraft such as the space shuttle. To understand the principles of flight, it requires a strong background in mathematics and physics. Aerospace engineering comprises several disciplines: aerodynamics, flight mechanics and control, avionics, navigation, propulsion, structures, materials, and manufacturing, etc. The knowledge of aerodynamics is needed to understand why and how an aircraft lifts itself and flies. The knowledge of aircraft structures and materials is required to build the wings, fuselage, tails, and other components of the aircraft and put them together. The knowledge of the science of propulsion is needed to build aircraft engines to propel them into the atmosphere. The understanding of aircraft dynamics and stability is needed for the design of control systems to guide it along a desired flight path. Aerospace engineers apply their knowledge and skills to the design and manufacture of aircraft components (e.g. wings and fuselage), systems (e.g. control systems), and spacecraft components and systems.

In this information explosion age, it is practically impossible for an aerospace scientist or engineer to carry out his research work without embracing the network and Internet technologies. They greatly depend upon these electronic innovation tools for accessing electronic information resources in the form of e-journals related to aerospace engineering right at their desktops. In fact, many of the scientists in today's R&D organizations have the unique privilege of downloading full-text e-journals right at their desktops through their organization's e-conglomerate.

It is absolutely clear that the use of electronic media to support scientific communication has undoubtedly been one of the paradigm shifts in the practice of science in this era. For a research scientist today, with access to the Internet, working across continents and in different time zones and keeping in touch with his peers has indeed become a reality due to the exponential growth of the telecommunication infrastructure that the world has witnessed. Most surprisingly, all this happens with very marginal costs of communication.

With the coming of e-journals, there has been a significant transformation by which scholarly information is disseminated throughout the world. In fact, the arrival of e-journals has greatly affected the way a scientist or an engineer seeks this information, acquires it and then uses it effectively.

With this radical shift in scholarly research, it is not surprising that the role of the librarian as an 'information provider' has dramatically changed. With constant advances in technology, the library and the librarian need to adjust by 'embracing the electronic technology' to meet the constant fluctuation and demands in the user's information seeking behavior and needs.

Today, scientists and engineers have adopted electronic journals because of quick, easy access, and convenience. Also, very little effort is required to retrieve information from these e-journals.

Scholarly communication is very rapidly evolving. The usage trend is leaning more and more towards electronic formats. In many of the scientific areas, it is also observed that the electronic version of scientific publications is being read almost as often as the printed journals. If this trend continues, many authors feel that in the years to come the print versions of scientific publications will more or less disappear. It is very clear that the World Wide Web has very largely facilitated and propelled the emergence of these electronic journals. In fact, with the arrival of the electronic platform, some of the research studies show that the range of scientific journals read by scientists has also increased rapidly. It has also been observed in some major studies that a large number of scientists make use of electronic journals at least part of their time. During a research interview by Tenopir and King (2001), many of the scientists have revealed that 'electronic journals' are highly important to their work, more than any other information resources. Today, scientists are even willing to pay a high price for their time to spend many hours reading electronic scientific literature. Their study also revealed that the quality of information that a scientist gets from refereed journals has greatly resulted in their improved performance.

It is important to note that the scientists and engineers in aerospace organizations are currently working on projects, which are of strategic importance to this country. These scientists largely depend on rapid collection of information from various 'electronic information resources'

On a thorough review of extensive literature, the investigator has found that work has not been done before on the 'Use Patterns of Electronic Information Resources by Aerospace Scientists and Engineers in Bangalore'.

It is learnt that even though there are quite a number of studies on information seeking behaviour or electronic information use pattern by different kinds of clients belonging to different disciplines, it is however, seen that, there is no single Indian study on the "Use Patterns of Electronic Information Resources by Aerospace Scientists and Engineers in Bangalore" or any other state in particular. Hence, this study would not only be unique but something that has not been done before.

## 2 KEY AEROSPACE ESTABLISHMENTS IN BANGALORE AND NATIONAL AEROSPACE LABORATORIES IN PARTICULAR

The city of Bangalore, Karnataka is considered the 'Aerospace Hub' of the country with many key aerospace organizations which have already been established several years ago like (a) The National Aerospace Laboratories (NAL), (b) The Hindustan Aeronautics Limited (HAL), (c)The Aeronautical Development Establishment (ADE), (d) The Indian Space Research Organization (ISRO), (e) The Aeronautical Development Agency (ADA). It also comprises many key Indian Air Force establishments like (a) Air Force Systems and Testing Establishment

(ASTE), (b) Air Force Technical College (AFTC), and the (c) Institute of Aviation Medicine (IAM). In a nutshell, many of these organizations come under the broad umbrella of (i) Council of Scientific and Industrial Research (CSIR), (ii) Defense Research and Development Organizations (DRDO), (iii) The Indian Air Force (IAF), (iv) Educational Institutions like IISc (The Aerospace Engineering Department) and (v) Major public sector undertakings. All of them in their own way have significantly contributed to a large number of Indian aerospace programmes.

The National Aerospace Laboratories is India's premier civil aviation R&D aerospace research organization in the country. Its main mandate is the 'Development of aerospace technologies with a strong science content and with a view to their practical application to the design and construction of flight vehicles'. NAL is also required 'to use its aerospace technology base for general industrial applications'. NAL, today is in its 50$^{th}$ year of existence and over these years has made remarkable contributions to a variety of Indian aerospace programmes. It also has well-established aerospace related collaborative projects with reputed international agencies. NAL is the harbinger of civil aviation design and development activities in India. In the years to come, 'Technology' would be its core engine-driver for the future. NAL is also best known for its main sophisticated aerospace R&D testing facilities which are not only unique for this country but also comparable to similar facilities elsewhere in the world.

With a powerful campus-wide network with high-speed Internet band-width and being part of the NAL-NISCAIR-CSIR e-Conglomerate, NAL scientists are at a 'unique privilege' to get access to online electronic scholarly information right at their desktops. Access has been provided to almost 6,000 e-journals by tying up with 23 international publishers. This facility enables any CSIR scientist to access, browse, and search and download 'full-text' journal articles from any computer system connected to the campus wide network. This enables the scientist to quickly adapt to the modern day Internet technologies of electronic publishing and downloading of scientific content and carry out hard-core research right from his desktop.

## 3 SCIENCE AND TECHNOLOGY

According to Pinelli (2001), the relationship between science and technology is often expressed as a continuous process or normal progression from basic research (science) through applied research (technology) to development (utilization). This relationship assumes that technology grows out or is dependent upon science for its development. This assumption that all technology has its ultimate roots in science perpetuates a service and dissemination system that assumes all technology will have a science base.

However, the belief that technological change is somehow based on scientific adances has been challenged in recent years. Technological change has been increasingly seen as the adaptation of existing technological concepts in response to demand (Langrish, 1972). Moreover, several years of study attempted to trace the flow of information from science to technology have produced little empirical evidence to support the relationship Illinois Institute of Technology (1968); U.S. Department of Defense (1969). Price (1965), for example, claimed that most technological advances are derived immediately from the technology that preceded them, not from science. According to him, science and technology progress independently of one another. Technology builds upon its own prior developments and advances in a manner independent of any link with the current scientific frontier and often without any necessity for an understanding of the basic science underlying it. Shapley and Roy (1985), contend that a normal progression from science and technology does not exist, nor is there direct communication between science and technology. Rather, both are directly and indirectly supported by each other.

Science is an introverted activity. It studies problems that are usually generated internally by logical discrepancies or inconsistencies or by anomalous observations that cannot be accounted for within the present intellectual framework. Indeed, scientists are said to do their best work when investitating problems of their own selection and in a manner of their own choosing, Bush (1945), Amabile (1983), Amabile and Gryskiewicz (1987). The output of science is knowledge that is regarded by scientists essentially as a free good. The expectation within the scientific community is that knowledge will be made universally available through presentations at conferences and society meetings and publication in scholarly and professional journals.



Technology, on the other hand, is an extroverted activity; it involves a search for workable solutions to problems. When technology finds solutions that are workable and effective, it does not pursue the *why*, Salomon (1984). Moreover, the output of technology is frequently a process, product, system, or service. Technological knowledge is not easily or completely codified, nor is it freely communicated. Unlike science, the output of technology is not made universally available. Technology successfully functions only within a larger social environment that provides an effective combination of incentives and complementary inputs into the innovation process. Technology is a process dominated by engineers rather than scientists, Landau and Rosenberg (1986).

Generally speaking, the scientific community tends to view knowledge as a public consumption good, while engineers (or, more precisely the firm that employ them) regard it as a private capital good (Dasgupta, 1987). Thus, the rules of the two communities concerning the communication and ownership of knowledge are fundamentally different. Scientists are obligated to disclose their findings and to submit them for critical inspection to other members (i.e., peers) of the scientific community. Hence, the ability of scientists to communicate freely and openly is critical.

Moreover, knowledge production takes place in the context of two very different reward systems. In science, rewards are based on priority of discovery or the rule of priority. This rule acts as an incentive for scientific discovery, and serves to promote public disclosure of that discovery. Thus, scientists are compelled to take privately created knowledge and to make that knowledge accessible to the scientific community and the general public. The rule of priority also precludes a second or third place winner because from a societal point of view, there is no value added when a discovery is made a second or third time.

Technological knowledge is considered proprietary, is afforded patent protection, can be a "trade" secret, and is often the subject of industrial espionage. Its use can be licensed to those willing to pay an agreed upon price. What is interesting about knowledge in the technology community is that, although patent protection is used to make private knowledge public, it does not attempt to place a monetary or societal value on the knowledge.

Many researchers have questioned the basic distinctions between science and technology and between scientists and engineers in the past five years. According to Law and Callon (1988), engineers are social activists who design societies and societal institutions to fit technologies. In summarizing the differences between science and technology, Price (1965), made the following 12 points:

**Table 1: Differences between Science and Technology**

| | Differences Between Science and Technology |
|---|---|
| 1. | Science has a cumulating, close-knit structure; that is, new knowledge seems to flow from highly related and rather recent pieces of old knowledge, as displayed in the literatre |
| 2. | This property is what distinguishes science from technology and from humanistic scholarship |
| 3. | This property accounts for many known social phenomena in science and also for its surefootedness and high rate of exponential growth |
| 4. | Technology shares with science the same high growth rate, but it shows quite a complementary social phenomena, particularly in its attitude to the literature |
| 5. | Technology therefore may have a similar, cumulating, close-knit structure to that of science, but the structure is of the state-of-the-art rather than of the literature |
| 6. | Science and technology therefore have their own separate culminating structures |
| 7. | A direct flow from the research front of science and technology, or vice versa, occurs only in special and traumatic cases since the structures are separate |
| 8. | It is probable that research-front technology is strongly related only to that part of scientific knowledge that has been packed down as part of ambient learning and education, not to research-front science. |
| 9. | Research-front science is similarly related only to the ambient technological knowledge of the previous generation of students, not to the research front of the technological state of the art and its innovation. |
| 10. | This reciprocal relationship between science and technology, involving the research front of one and the accrued archive of the other, is nevertheless sufficient to keep the two in phase in their separate growths within each one's otherwise independent accumulation. |
| 11. | It is naive to regard technology as applied science. |
| 12. | Because of this, one should be aware of any claims that a particular scientific research is needed for particular technological breakthroughs, and vice versa. Both accumulations are only supported of their own separate ends (Price, 1965). |

*Source: Distinguishing Engineers from Scientists-The Case of for an Engineering Community*
*Thomas E. Pinelli et al., Science and Technology Libraries, V21(3/4), 2001.*

Allen (1977), finds an inherent compatibility between the input and outputs of the information-processing system of science. Because both are verbal formats, the output of one stage is in the format required for the next stage. The problem of supplying information to the scientist is a matter of collecting and organizing these outputs and making them accessible. Since science operates for the most part on the premise of free and open access to information, the problem of collecting outputs is made easier.

In technology, however, there is an inherent incompatibility between inputs and outputs. Since outputs differ typically in form from inputs, they usually cannot serve as inputs for the next stage. Further, the outputs are usually in two parts, one physically encoded and the other verbally encoded. The verbally encoded part does not serve as input for the next stage because it is a by-product of the process and is itself incomplete. Those unacquainted with the development of the hardware or physical product therefore require some human intervention to supplement and interpret the information contained in the documentation. Since technology operates to a large extent on the premise of restricted access to information, the problem of collecting the documentation and obtaining the necessary human intervention becomes difficult.

(Allen 1977), and others used a somewhat restricted definition of technology in that they assume that it is always a physical product. Engineers in Aerospace and in other industries often create systems and products that are verbally encoded, such as management systems and software. These differences do not alter the basic premise that substantial differences exist between the goals of engineers and scientists as they produce different types of outputs in their daily activities. The connection between science and technology, in aerospace and elsewhere, is tenuous, vague, and sporadic. The processes used in science and technology to produce their respective outputs create parallel and weakly connected systems. A clear recognition of these differences is needed to establish a context for and to understand aerospace knowledge diffusion (i.e., production, transfer and use).

## 4 INFORMATION PROCESSING IN SCIENCE AND TECHNOLOGY

Information processing in Science and Technology is shown in the Figure below in the form of an input-output model. Scientists use information to produce information. From a system standpoint, the input and output, which are both verbal, and compatible. The output from one stage is in a form required for the next stage. Engineers use information to produce some physical change in the world. Engineers consume information, transform it, and produce a product that is information bearing; however, the information is no longer in verbal form. Whereas scientists consume and produce information in the form of human language, engineers transform information from a verbal (or often visual or tacit) format to a physically encoded form. Verbal information is produced by a byproduct to document the hardware and other physical products produced.

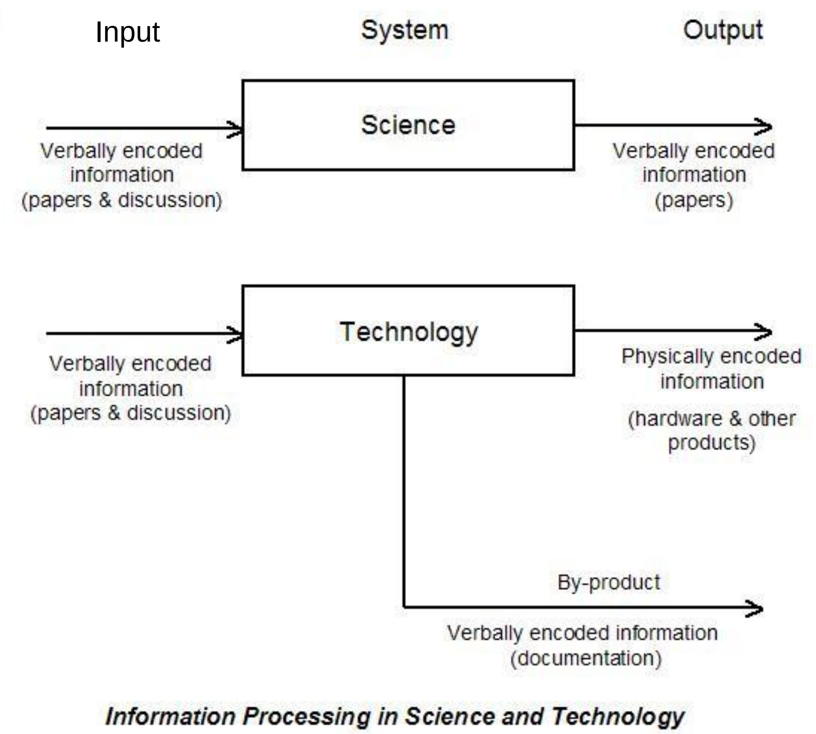


**Fig. 1: Information Processing in Science and Technology**

*Source: Information Seeking Behaviour of Scientists and Engineers, Thomas E. Pinelli et al. NASA/DOD Aerospace Diffusion Project, Paper 31, 1993.*

## 5 DISTINGUISHING ENGINEERS FROM SCIENTISTS

Allen (1977) has stated that the independent nature of science and technology and different functions performed by engineers and scientists directly influence the flow of information in science and technology. Science and technology are ardent consumers of information. Both engineers and scientists require large quantities of information to perform their work. At this level, there is a strong similarity between the information needs of engineers and scientists. However, the difference between scientists and engineers in terms of information processing becomes apparent upon examination of their outputs. Scientists use information to produce information. From a system standpoint, the input and output, both of which are verbal, are compatible. The output from one stage is in a form requiring for the next stage. Engineers use information to produce some physical change in the world. Engineers consume information, transform it, and produce a product that is information-bearing; however, the information is no longer in verbal form. Whereas scientists consume and produce information in the form of human language, engineers transform information from a verbal (or often, visual or tacit) format to a physically encoded form. Verbal information is produced only as a by-product to document the hardware and other physical products produced.

For our purposes, we define the essential difference between engineers and scientists based on the primary goal of the output of their work-scientists produce knowledge (facts) and engineers produce designs, products, and processes (artifacts). Engineers and scientists exhibit many other differences in education, technical discipline, and type of work activities. These differences point to differences in their information-seeking behaviours and information needs.

Differences between engineers and scientists are difficult to determine from either self-classification or the analysis of their tasks. Citro and Kalton (1989), describe differences based on analyses of tasks, job descriptions, education, and self-identification. Their analysis indicated that even using multiple indicators did not reduce the error in classifications into engineering and science. Pinelli (2001), suspects that the increasing burueaucratization of these professions makes it more difficult to accurately differentiate them. Latour (1987), used the term "technoscience" to describe the rerlationship between engineering and science. Using a network actor perspective, he described the daily activities of both scientists and engineers. He found that personal success in technoscience did not depend primarily on how well engineers and scientists performed their jobs, but on how well they were able to recruit others into believing in the value of what they did. For those in technoscience, recruiting others included writing proposals, looking for funding for projects, doing research, and other activities that would not be considered either science or engineering. That is, success in engineering and science does not depend so much on what is made (engineers) or on the development of new knowledge (scientists) but rather on how well the engineers and scientists are able to recruit others into the process of technoscience.



When one examines engineers and scientists over the course of their careers, it becomes increasingly difficult to distinguish them. When each does those activities that we traditionally consider the activities of engineers and scientists (making new products and new knowledge, respectively), each group appears to behave quite differently. Yet many of their activities, such as management, are the same. Contradictions based on the various differences between the groups contribute to the misunderstanding that engineers are the same as scientists.

**5.1** Differences

Despite the changes in engineering and science over the past 20 years, many differences noted by Ritti (1971), still distinguish the two groups. In his study of engineers in industry, Ritti found marked contrast between the goals of engineers and scientists.

- The goals of engineers in industry are very much in line with meeting schedules, developing products that will be successful in the marketplace, and helping the company expand its activities;

- Although both engineers and scientists desire career advancement or development, advancement for the engineer is tied to activities within the organization, whereas advancement for the scientist is dependent upon the reputation established outside the organization; and
- Whereas publication of results and professional autonomy are clearly valued goals of the Ph.D. scientist, they are clearly the least valued goals of the Baccalaureate engineer (Allen 1977).

Blade (1963), states that engineers and scientists differ in training, values, and methods of thought. In particular, in their individual creative processes and in their creative products:

- Scientists are concerned with discovering and explaining nature; engineers use and exploit nature
- Scientists search for theories and principles; engineers seek to develop and make things
- Scientists seek a result for its own end; engineers are engaged in solving a problem for the practical operating results
- Scientists create new unities of thought; engineers invent things and solve problems.

Danielson (1960), found that engineers and scientists are fundamentally different in terms of how they approach their jobs, the type and amount of supervision they require, the type of recognition they desire, and their personality traits.

Allen (1977), stated that the type of person who is attracted to a career in engineering is fundamentally different from the type of person who pursues a career as a scientist. He wrote that:

> *Perhaps the single most difference between the two is the level of education. Engineers are generally educated to the baccalaureate level; some have master's degree, while some have no college degree. The research scientist is usually assumed to have a doctorate. The long, process of academic socialization involved in obtaining the Ph.D. is bound to result in persons who differ considerably in their life views.*

Much of the research on the differences between engineers and scientists is dated and does not reflect the impact of changes in post-World War II engineering curricula. During World War II and throughout the era of Sputnik, government and industry leaders recognized that engineering training in the U.S. was not adequate to meet military and industrial challenges, Grayson (1993). The Ginter Report, prepared by a committee of the American Society for Engineering Education (ASEE), urged the inclusion of more science and liberal arts into engineering education. This 1955 report transformed engineering education over the subsequent two decades from "hands-on" training to a more theoretical perspective resembling other types of academic disciplines, particularly the sciences. In his history of engineering education in the U.S., Grayson (1993), terms the period from World War II through 1970 the "scientific" period. Engineering education since the 1960s has tended to blur the distinction between the training of engineers and scientists. In addition, the types of work that they do in the large bureaucratic organizations that employ them makes it increasingly difficult to differentiate them by title alone.

From a research perspective, it is difficult to observe a clear difference between engineers and scientists in many settings.

Engineers and scientists exhibit important differences other than the evident differences in education (degree), technical discipline, and type of work/activity. They share common psychological needs as survival, security, self-esteem, self-expression, belonging, opportunity for growth, and self-determination. The strength of these needs varies from person to person and fluctuates over time. In a collective sense, engineers and scientists share the following attitudes that are conducive to high productivity:

- effective communication;
- optimum salary-band benefits;
- freedom authority; and
- optimum authority.

There are also differences that tend to create sharp distinctions between the two groups. At the risk of inviting a charge of "overgeneralization", Peake (1969), offers the following list of differernces:

**Table 2: Differences between Scientists and Engineers**

| Most Engineers | Most Scientists |
|---|---|
| Do development, design or applications work | Do research, basic or applied |
| Apply scientific knowledge | Seek new knowledge |
| Have engineering degree | Have science degree |
| Recognize managerial authority | Respect "colleague" authority |
| Want assignments to good, challenging projects | Want freedom to select their own projects |
| Like a company with a good record of engineering accomplishment | Like a company with a reputation for scientific advancement |
| Are hardware oriented | Are software oriented |
| Dislike preparing talks and publications | Insist on freedom to publish their work |
| Are company oriented (i.e. committed to a variety of work areas, tasks, positions) | Are career oriented (i.e. committed to limited kinds of work areas, tasks, positions) |
| Dislike ambiguous, uncertain situations | Can work effectively with ambiguity, uncertainty |
| Are interested in processes, results, realizations | Are interested in concepts, meanings, abstractions |
| Believe in equalitarian group practices | Believe in authoritarian group practices |
| Expect to be faced with work schedules, deadlines, constrained resources | Abhor schedules, believe schedules should be self-determined, desirer autonomy |

*Source: Information Seeking Behaviour of Scientists and Engineers, Thomas E. Pinelli et al. NASA/DOD Aerospace Diffusion Project, Paper 31, 1993.*

Engineering is defined as the creation or improvement of technology. As such, it clearly encompasses both intellectual and physical tasks (i.e. both knowing and doing). Engineering work is fundamentally both a social and technical activity. It is a social activity in that it often involves teamwork, as individuals are required to coordinate and integrate their work. It is also a social activity in that the production of the final product depends on the ability to maintain successful social relationships (e.g., negotiate with vendors, maintain smooth personal relations among members of a work group). Membership in a community is important for the effective functioning of current engineering and engineers. Engineers do their work in an embedded set of contextual relationships. Science, on the other hand, allows scientists to conduct their daily activities with only a vague reference to others doing similar work.

**5.2** Similarities

A number of writers note that engineers behave very similarly to scientists. At times, they adopt the methods used by scientists to generate knowledge. For example, Riti (1971), says engineering work consists of scientific experimentation, mathematical analysis, design and drafting, building and testing of prototypes, technical writing, marketing, and project management. Kemper (1990), too, noted that the typical engineer is likely to define problems, come up with new ideas, produce designs, solve problems, manage the work of others, produce reports, perform calculations, and conduct experiments. Ziman (1984), wrote that:

*Technological development itself has become "scientific". It is no longer satisfactory, in the design of a new automobile, say, to rely on rule of thumb, cut and fit, or simple trial and error. Data are collected, phenomena are observed, hypotheses are proposed, and theories are tested in the true spirit of the hypothetico-deductive method.*

Constant (1980), also described the similarities between engineering and science in his detailed history of the origin of the modern jet engine. He defined a "variation-retention" model to describe how engineers and scientist create technological change. Change, in technology, results from random variation and selective retention. Technological conjecture, which can occur as a result of knowledge gained from scientific theory or engineering practice, yields potential variations to existing technologies. For example, in the case of the turbojet revolution, technological conjecture was based on engineer's knowledge of scientific theories. In contrast, in their writings, scientists usually describe their methods as following the hypothetico-deductive method. However, in many of their daily research activities, they use methods similar to those used by engineers-particularly the variation-retention method.

**5.3** Convergence

During this century, and especially since World War II, engineers and scientists have been increasingly employed in such large organizations (Florman1987; Layton 1974; Meiksins and Smith 1993), as the major corporations and the federal government. The integration of engineers and scientists into these organizations has significantly reduced their autonomy. Both groups have increased attempts to maintain their autonomy by defining and controlling separate spheres of knowledge. Yet, in most organizations, the opportunity for upward mobility is limited to management. But engineers and scientists tend to move into management during their careers. If we look at both groups over their careers, we see that they tend to converge in their daily activities. Although they may consider themselves engineers or scientists based on education or professional orientation, in reality they become managers and behave alike in their respective organizations.

## 6 DIFFERENCES BETWEEN ENGINEERS AND SCIENTISTS IN KNOWLEDGE DIFFUSION

Engineers and scientists are similar in that knowledge production and use are critical to the performance of their jobs, but there are major differences in how and when they use it.

Scientists use knowledge as part of the process of generating new knowledge. Latour (1987), described how scientists "recruit" their intellectual and research predecessors to demonstrate the importance of their current research. They use knowledge to show how their research differs from or improves upon previous research in the field. The intellectual context of the research must be established if the priority and importance of a finding or fact are to be established. In most instances, scientists gather most of their knowledge before beginning research or at least before writing their research results.

Engineers, on the other hand, use knowledge to help make decisions. They care more about the ability of the research to provide guidance on their particular problem than about its intellectual history. They use knowledge throughout the research, design, development, and manufacturing process. When engineers produce new knowledge, they often do so solely to provide guidance to others in their organization who might face a similar issue in the development of another product. In these instances, the intellectual history of previous research is not as important as documenting the procedures and results.

Scientists tend to use hypothesis testing (at least as they describe their research) in gaining new knowledge. Engineers are more likely to use iterative parameter variation and selective retention (Vincenti, 1990), to generate new knowledge. Each technique produces different types of documentation. Journal articles are appropriate for scientists to describe the development and testing of one idea. In contrast, technical reports are more appropriate for engineers to document engineering processes, products etc.

When preparing to do research, scientists will search for knowledge that may not be directly related to the research but can be used to place the research in context. The information needs of engineers are more immediate, at least in critical phases of design. They select information because it directly relates to solving a problem. For eg. According to Allen (1977),

*Engineers read less than scientists, they use literature and libraries less, and they seldom use information services which are directly oriented to them. They are more likely to use* *specific forms of literature such as handbooks, standards, specifications, and technical reports.*

What an engineer usually wants, according to Cairns and Compton (1970), is "a specific answer, in terms and format, that is intelligible to him-not a collection of documents that he must sift, evaluate, and translate before he can apply them". Young and Harriott (1979), report that,

*The engineer's search for information seems to be based more on a need for specific problem solving than around a search for general opportunity. When engineers use the library, it is more in a personal-search mode, generally not involving the professional (but nontechnical) librarian.*

Young and Harriiott conclude by saying:

*When engineers need technical information, they usually use the most accessible sources rather than searching for the highest quality sources. These accessible sources are respected colleagues, vendors, a familiar but possibly outdated text, and internal company (technical) reports. The engineer prefers informal network to be the more formal search of publicly available and catalogued information. We are not convinced that there is a neat dichotomy between engineers and scientists in their production, transfer, and use of knowledge. Rather, there is a continuum of activities and behaviours that each group uses in different amounts in their daily activities. Included among these are knowledge production, transfer, and use activities that appear to be similar to those of the other profession. Because of the variety of tasks that engineers and scientists perform, it is difficult to assume that any model of knowledge diffusion can be simple and meet the needs of all engineers and scientists.*



## 7 COMMUNICATION BEHAVIOUR OF ENGINEERS AND SCIENTISTS

Communication in engineering and science are fundamentally different. Communication patterns differ because of the fundamental differences between engineering and science and because of the social systems associated with the two disciplines. Holmfeld (1970), offers the following examples of how the social systems affect the communication behavior of engineers and scientists:

**Table 3: Communication behaviour of Engineers and Scientists**

| Engineers | Scientists |
|---|---|
| Contribution is (technical) knowledge used to produce end items or products | Contribution is new and original knowledge |
| New and original knowledge is not a requirement | Reward is social approval in the form of professional (collegial) recognition |
| Reward is monetary or materialistic and serves as an inducement to continue to make further contributions to technical knowledge | Recognition is established through publication and claim of discovery |

| Engineers | Scientists |
|---|---|
| Seeking rewards that are not part of the social system of technology is quite proper and also encouraged | A well-developed communication system based on unrestricted access is imperative to recognition and claim of discovery |
| The value of technical knowledge lies in its value as a commodity of indirect exchange | Since recognition and priority of discovery are critical, strong norms against any restriction to free and open communication exist in the social system of science |
| Exchange networks found in the social system of technology are based on end-item products, not knowledge | Seeking rewards that are not part of the social system of science in return for scientific contribution is not considered proper within the social system of science |
| Strong norms against free exchange or open access to knowledge with others outside of the organization exist in the social system of technology | Exchange networks commonly referred to as "invisible colleges" exist in the social system of science; in these networks the commodities are knowledge and recognition |
| Restriction, security classification, and proprietary claims to knowledge characterize the social system of technology | |

*Source: Information Seeking Behaviour of Scientists and Engineers, Thomas E. Pinelli et al. NASA/DOD Aerospace Diffusion Project, Paper 31, 1993.*



Taylor (1986) *interalia* quotes Brinberg (1980), who offers the following characteristic for engineers and scientists: "Unlike scientists, the goal of the engineer is to produce or design a product, process, or system; not to publish and make original contributions to the literature. Engineers, unlike scientists, work within time constraints; they are not interested in theory, source data, and guides to the literature nearly so much as they are in reliable answers to specific questions".

Anthony et al. (1969), suggest that engineers may have psychological traits that predispose them to solve problems alone or with the help of colleagues rather than finding answers in the literature. They further state that "engineers like to solve their own problems. They draw on past experiences, use the trial and error method, and ask colleagues known to be efficient and reliable instead of searching or having someone search the literature for them. They are highly independent and self-reliant without being positively anti-social".

## 8 ENGINEERS AS INFORMATION PROCESSORS

The ultimate goal of engineering is to produce a design, product, or process. It is informative to view engineering as an information-processing system that uses knowledge to reduce work-related uncertainty. That is, engineers are heavy information processors. Throughout the engineering process, data, information and knowledge are acquired, produced, transferred and used. The fact that these data, information, and knowledge may be physically or hardware encoded should not detract from the observation that the process of engineering is fundamentally an information-processing activity.

Uncertainty, defined as the difference between the information possessed and the information required to complete a task, is central to the concept of engineering as an information-processing activity. Rogers (1982), stated that coping with uncertainty is the central concept in information use behavior. The process of engineering is one of grappling with the unknown. These unknowns or uncertainties may be technical, economic, or merely the manifestations of personal and social variables. When faced with uncertainty, engineers typically seek data, information, and knowledge. In other words, data, information and knowledge are used by engineers to moderate technical uncertainty. Because engineering generally entails coping with the relatively high degree of uncertainty, engineering can certainly be viewed as an informational process. Consequently, information-seeking behavior and patterns of technical communication cannot be ignored when studying engineers.

In Orr's (1970), conceptual framework, the engineer is an information processor. This framework focuses on information-seeking behavior and assumes that an internal, consistent logic governs the information-seeking behavior of engineers, individual differences notwithstanding.

If a decision is made to search the existing information, engineers must choose between two information channels. They can choose to gather the information through informal methods such as interpersonal (oral) communications with peers, coworkers, colleagues, gatekeepers, vendors, consultants, "key" personnel, and supervisors, or the use of their personal collections of information. They might also choose to use the formal information system, which includes libraries, technical information centres, librarians and technical information specialists, information products and services, and information storage and retrieval systems. It is assumed that the decision to choose a particular information channel is influenced by personal and institutional characteristics.

More recent work highlights the value of exploring contextual and situational factors related to information seeking and use. Taylor's analysis recognizes that information-seeking behavior and use are determined by the nature of the particular project, task, or problem at hand.

The data, information, and knowledge that result from an engineer's search are evaluated subjectively. The engineer as an information processor faces three possible courses of action: first, if the created or available data, information, and knowledge used to complete the project or task or solve the problem are sufficient, the process is terminated; second, if the created or available data, information, and knowledge are useful but only partially sufficient to complete the project or task or to solve the problem, a decision is made either to continue the process by reevaluating the information source selected or to terminate the process; and third, if the created or available data, information, and knowledge are not applicable to or do not complete the project or task or solve the problem, a decision is made either to continue the process by redefining the project, task, or problem or to terminate the process. Throughout the process, the engineer evaluates both process and outcomes in light of what others in the engineering community would do and also in light of the anticipated acceptance by others within the engineering community and the employing organization. The complexitities of the decision process used by engineers to evaluate knowledge require an understanding of the personal, situational, contextual, and community characteristics in which the engineers work.

## 9 EMPIRICAL STUDIES OF ENGINEERING INFORMATION SEEKING BEHAVIOUR

Studies concerned with the information seeking behavior of engineers were reviewed by Pinelli (1991), to further develop the conceptual framework. The table below lists those major research studies as shown by him.

**Table 4: Overview of Engineering Information Behaviour Studies**

| Year | Principal Investigator | Research Method | Population | Sample Frame | Sample Design | Sampl e Size | % Response Rate (No. Responding | Des-cription |
|---|---|---|---|---|---|---|---|---|
| 1954 | Herner | Structured Interview | All scientific and technical personnel at Johns Hopkins | Unknown | Unknown | 600 | 100 | Survey to deter-mine the infor-mation-gathering methods of scientific and technical personnel at Johns Hopkins |
| 1970 | Rosenbloom and Wolek | Selfadminis-tered questionnaire | Members of 5 industrial R&D organiza-tions Members of 4 IEEE interest groups | 2,430 | | Un-known | Census | |
| Probability | 2,430 | | Unknown | 71 (1,735) | Unknown (1,034) | | Survey to determine how engineers and scientists in industrial research and development organizations acquire STI | 1977 |

| Year | Principal Investigator | Research Method | Population | Sample Frame | Sample Design | Sampl e Size | % Response Rate (No. Responding | Des-cription |
|---|---|---|---|---|---|---|---|---|
| Allen | Record analysis self-administered questionnaire | Unknown | Unknown | Unknown | Unknown | Un-known (1,153) | Survey to determine technology transfer and the dis-semination of tech-nological information in research and development organizations | 1980 |
| Kremer | Selfadminis-tered questionnaire | All design engineers at one engineering design firm | 73 | Census | 73 | 82 (60) | Survey to identify and evaluate the information channels used by engineers in a design company | 1981 |
| Shuchman | Structured interview Selfadminis-tered question-naire | Engineers in 89 R&D and non-R&D organiza-tions | 14,797 | Probability | 3,371 | 39 (1,315) | Survey to determine information used and production in engineering | 1983 |
| Kaufman | Self-adminis-tered questionnaire | Engineers in six technology based organiza-tions | 147 | Census | 147 | 100 (147) | Survey to determine the use of technical information in technical problem solving | |

*Source: Information Seeking Behaviour of Scientists and Engineers, Thomas E. Pinelli et al. NASA/DOD Aerospace Diffusion Project, Paper 31, 1993.*

## 10 AEROSPACE SCIENTISTS AND ENGINEERS

Aerospace Scientists and Engineers: There is no sharp distinction between science and engineering, although engineers typically have practical goals in mind while scientists investigate fundamental phenomena. Both proceed from problems toward solutions.

**Aerospace**: generally, means the earth's atmosphere and outer space. Often aerospace refers to the technology of aviation in this area.

**Aerospace Scientist:** Generally is a person who studies the earth's atmosphere or outer space, or who studies the technology of aviation in this area.

**Aerospace Engineer:** Aerospace Engineers are involved in all aspects of aereonautics (working with aircraft) and astronautics (working with spacecraft). They conduct research, design and develop vehicles and systems for atmospheric and space environments. These engineers often specialize in one of many areas such as aerodynamics, propulsion, flight mechanics, orbital mechanics, fluids, structures, guidance and control, and computation.

Aerospace engineers research, design and develop aerospace vehicles, aerospace systems and their components, and perform duties related to their testing, evaluation, installation, operation and maintenance. They are employed by aircraft and spacecraft manufacturers, air transport carriers, and in government and educational and research institutions.

### 10.1 Types of Aerospace Engineers

- aerodynamics engineer
- aeronautical engineer
- aerospace engineer
- aerospace engineer – design and development
- aerospace engineer – flight operations
- aerospace engineer – flight support
- aerospace engineer – flight test
- aerospace engineer – mass properties
- aerospace engineer – material stress
- aerospace engineer – materials and processes
- aerospace engineer – military
- aerospace engineer – propulsion systems
- aerospace engineer – systems
- aerospace engineer – systems analysis
- aerospace engineer – weight and balance
- aerospace engineer, structures
- aerospace reliability specialist
- aerospace structural engineer
- aerospace systems engineer
- aerospace test engineer
- aircraft design engineer
- design engineer, aircraft
- projects engineer, aeronautical
- propulsion engineer – aerospace vehicles
- space reliability specialist
- stress engineer – aerospace
- structural engineer, aerospace

- structures aerospace engineer
- systems engineer, aerospace
- test engineer, aerospace
- weight analyst, aircraft design – engineer
- weight and balance engineer – aerospace

## 11 THE AEROSPACE ENGINEERING COMMUNITY

Aerospace employs a wide range of engineers and scientists who represent many engineering specialities and scientific disciplines. Most of the scientists in aerospace are employed in the national labs and in Universities, but some are employed in major aerospace firms. In contrast, engineers are employed in private companies that range from major firms like Boeing Airplane Company to small engineering firms with a few employees. Aerospace is further unique in that most of the engineers in one discipline – aerospace engineering – are employed in large bureaucracies As such, aerospace engineers have unique work environments that affect their production, transfer and use of knowledge.



The notion of an aerospace engineering community was addressed by Vincentti (1990). He described informal communities of practitioners as the most important source of knowledge generation and means of knowledge transfer in aerospace. Vincentti defined a community as those involved in work on a particular aerospace development or problem (e.g., fasteners, airfoils, or propellers), and he attributed several functions to these engineering communities. Competition among members supplies motivation, while cooperation provides mutual support. The exchange of knowledge and experience generates further knowledge, which is disseminated by word of mouth, publication, and teaching, and is also incorporated into the tradition of practice. The community also plays a significant role in providing recognition and reward.

Vincentti (1990), described the particular roles of important types of aerospace engineering institutons, such as government research organizations, university departments, aircraft manufacturers, military services, airlines, professional socities, government regulatory agencies, and equipment and component suppliers.

Constant (1980), described aerospace engineering communities as the central locus of technological cognition. He noted that the aeronautical community is, in fact, composed of a multilevel, over-lapping hierarchy of sub-communities; he argued that technological change is better at the community level than at the individual, organizational, national, or industry level. Constant described the community as the embodiment of traditions of practice.

Aerospace engineering might be thought of as a series of communities. Despite being a relatively new engineering discipline, aerospace engineering has diversified as it has grown. The aerospace engineering communities include a range of activities from basic science through very applied production engineering. The communities are held together because of a common use of aerospace-related knowledge. Data demonstrate that aerospace engineers and scientists have varied duties and responsibilities and, consequently, differing information-seeking behaviours and information needs. These various behaviours and needs must be taken into account in the development of an effective system for diffusing aerospace knowledge.

*In aerospace in particular, there are likely to be fewer distinctions between scientists and engineers because most of the industry is focused on the development and exploitation of material artifacts to improve flight.*

To give an example of differences between science and engineering, we could assume that aerospace includes the following components: aerodynamics, structures, and propulsion. Scientists working in aerospace would base their work on the factual and theoretical foundations of one ore more of the components. In contrast, engineers would examine one or more components but would also include one or more of the following-economics, sociology, psychology, market analysis, system analysis, cultural analysis, and management issues-in their work.

Because of the nature of the aerospace industry, many aerospace engineers and scientists could generate science as well as engineering in their everyday activities. Pinelli (2001), contends that non-science part of the engineer's work (the social part) distinguishes them from the aerospace scientists. It is the inclusion of the social part of their work that demonstrates engineering. The ability of engineers to understand the social part of their work is a distinguishing feature of the engineering community.

Advances in aerospace knowledge cannot happen without effective knowledge production, transfer, and use.

Pinelli (1993) and his colleagues in their analysis of existing research in the use of information by engineers coupled with research results from the NASA/DoD Aerospace Knowledge Diffusion Research Project, allowed them to use aerospace engineers and scientists as a means of developing similarities and differences between engineers and scientists in terms of their information-seeking behavior. Collectively, these results confirm that libraries and librarians, as information intermediaries, serve a vital role in completing the producer-to-user transfer of knowledge and in providing the vital information to the users. Considering that libraries are service organizations, it might be instructive for librarians to examine existing policies and practices as they pertain to the provision of information services to engineers. Finally, in providing information services to engineers and scientists, the librarians should finally realize that *"knowing your customer is fundamental and essential to servicing the information needs of your customer".*

## 12 THE GROWTH OF SCIENTIFIC COMMUNICATION

Over 300 years ago scientists Garvey (1997), found that keeping up with one another's current work had become too great a burden to handle by word of mouth and correspondence. As a result, the scientific paper was formalized and distributed by means of scientific journals, the first of these having been established in 1665. Since that time, the number of scientists, the number of scientific papers, and the number of scientific journals have increased steadily and exponentially.

The quantity of scientific output over the years can be estimated by counting the number of scientific journals published.

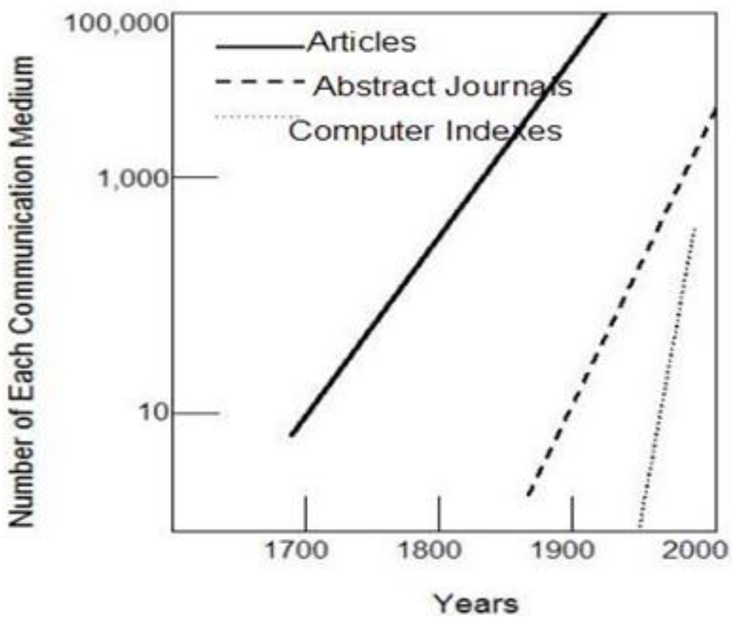


**Fig. 2: Growth of three types of Scientific Communication Media**

*Source: Menhard, H.W., Science, Growth and Changes, Cambridge, Mass: Harvard University Press, 1971*

The figure above shows the growth of three types of scientific communication media: journal articles, abstracting articles, and computer index. Journal articles have increased at a rate of 10 every 50 years since 1750; abstracting journals, at a rate of 10 every 30 years since 1860; and computer indexes, at a rate of 10 every 10 years since 1949.

During the past quarter of a century, we have witnessed the following changes in science which are a result of scientist's collective efforts to adjust to the rapidly decreasing possibility of individual mastery of any one area of science, and which could not help but result in overlapping and redundant abstracting and indexing services.

- Increased specialization in smaller and smaller subject-matter areas;
- Increased team research – not only multidisciplinary teams but inderdisciplinary teams;

- Increased number of specialists developing out of boundaries between disciplines – biophysics, psycholinguistics, biochemistry, etc.; and
- Increased repetition of research – in some disciplines it is occasionally easier to repeat an experiment than it is to determine that the experiment has already been done.

The current situation is further complicated by the fact that while science in general is doubling in manpower and information every 15 years or so, within science some fields are growing much slower and others considerably faster.

**13 SCIENTIFIC COMMUNICATION**

According to Tenopir and King (2001), science is undergoing some fundamental changes. Much of science is experiencing greater specialization, while, on the other hand, some parts of big science is getting even bigger. Also, a great deal of research is becoming more multidisciplinary. This has led to collaboration among universities, government, industry all of which extend across national borders. Science education is becoming not only multidisciplinary, but also collaboratory, as more and more faculties teach across disciplines, departments and universities.

Garvey (1979), is of the opinion that learning is fundamental to science and communication is the heart of learning. A psychologist at the Johns Hopkins University, summed up nearly two decades of scientific communication research by saying that "communication is the essence of science". 14 independent studies conducted from 1958 to 1998 observed that scientists spend a large, and perhaps increasing, proportion of their time communicating. Recent studies place this proportion in the range of 50 to 60 percent of scientist's time is spent in communicating (on average).

Traditional scientific patterns have evolved into a multitude of channels, including data and image transmissions, informal discussions, e-mails/messages, laboratory notes and technical reports, conference presentations and proceedings, journal articles, patents and books, to name a few. Each channel providing several distribution means and can involve a variety of media. All these channels of distribution result in a complex pattern of information flow.

Many studies conducted by the American Psychological Association (APA) for the National Science Foundation (NSF), during 1963-1968 and later in the 70's led many to believe that electronic technologies could minimize redundancies and produce more efficient communication capabilities.

Sharma and Pant (2004), say that a scientist needs information at every step of his research work, from the time that the germ of an idea sprouts in his mind to the time of its taking shape.

Garvey (1979), has listed the following reasons as to why a scientist needs information: (a) To aid in perception or definition of the problem, (b) To formulate a scientific or technical solution, (c) To place work in proper context with similar work already completed, (d) To relate work to ongoing work in the area of specialization, (e) To select a design or strategy for data collection, (f) To design equipment or apparatus, (g) To choose a data analysis technique, (h) To enable full interpretation of the collected data and (i) To integrate his findings into the current state of knowledge in his area.

According to Tenopir and Donald W King (2000), the past few decades have witnessed profound changes in science, scientific communication, and scientific journals. Scientific research is also becoming more multidisciplinary, often involving many in-depth specialties coupled with more collaboration among universities, government and industry, and extending across national borders. Learning is fundamental to science, whether directly through research and discovery or through education and other forms of lifelong learning, and communication is at the heart of learning. We can learn by acquiring information and developing appropriate understandings. But learning can also result from the creativity associated with the thought processes needed to organize and explain our ideas through writing or personal discourse. Many have agreed with Garvey (1979) that “Communication is the essence of science”. Also, information is one, if not the most important, resource used for performing research, teaching, and other scientific pursuits, and it is also the principal output of scientists’ work that is communicated to others. In their studies, they have mentioned that scientists spend a large proportion of their time communicating, and some evidence suggests that the proportion has increased from approximately 43% in the early 1960s to over 50% in recent years.



Tenopir and King (2000), are of the opinion that scientists typically communicate by receiving information through such modes as observing, reading and listening and by sending information through talking, writing and creating images. This is achieved through a number of communication channels including conferences and their proceedings, journal articles, and books. Each such channel can involve a number of distribution means (personal subscriptions, local and remote library access, preprints, reprints and photocopies provided by authors and colleagues) and several media (journals found in paper, CD-ROM, online and microform). The combination of channel distribution means and media form an extensive and complex pattern of information flow. The authors say that it is abundantly clear that individual scientists communicate using a variety of modes and channels, but the extent to which they are used varies among scientists, depending on their individual learning styles and abilities, the field of science, the type of work (e.g. basic or applied research, teaching) and other factors.

## 14 A BRIEF HISTORY OF SCHOLARLY ELECTRONIC COMMUNICATION

According to Tenopir and King (2000), until the late seventeenth century, communication between scholars depended heavily on personal contact and by attending meetings arranged by the early learned societies (e.g. the Royal Society). As the membership to these societies increased gradually, more and more people could not attend these meetings and so the proceedings, usually a record of the last meeting became a place to publish papers that had not been at all presented at the meetings, these eventually evolved into scholarly journals. To briefly get into its history, the first peer reviewed journals were the Philosophical Transactions of the Royal Society and Journal de Scavans both first published in 1665. These and a few more published later on were mainly published by societies and non-profit making organizations. In the 19th century there was an explosion in the number of journals produced, caused by the increased specialization and diversification of academic research and also the means of producing mass publishing (using cheap wood pulp based paper). The massive increase in output meant that societies found it more and more difficult to keep up with the demand for publishing. Elsevier Scientific Publishing was publishing engineering journals as far back as 1884. The credit goes to Robert Maxwell who pioneered the move towards mass commercial publication after WW.II when he set up the Peragmon Press. By 1960, commercial publishers occupied a major part of the market. Although, the first prototype e-journal was in 1976, the booming time for electronic journals was during the period 1990-95, mainly dominated by non-profit making groups who exploited the technology for their own sake. Commercial publishers joined in around 1996 and are now a dominant force, mainly providing direct electronic copies of their print journals. If Gutenberg's invention of the movable printing press in the 15th century was a great leap forward towards information dissemination and communication, the invention of the Web is equally a great leap. Willis (1995), interalia quotes Steven Harnad (1991), who says that 'the arrival of electronic communication is the fourth revolution in the means of production of knowledge' after spoken language, written language and the printing press.

## 15 RAPID EVOLUTION OF SCHOLARLY COMMUNICATION AND ROLE OF ELECTRONIC MEDIA

Kling and McKim (2000), say that the shift towards the use of electronic media in scholarly communication appears to be an inescapable path. He says that, the use of electronic media to support scientific communication is one of the major shifts in the practice of science in this era. According to them, electronic communication media can often expedite special kinds of communications between scientists who work across continents and 10-15 time zones while reducing the marginal costs of communication. Today, the Internet is the primary medium of this communication. According to him, different scientific fields have developed and use distinctly different communicative forums, both in the paper and electronic areas, and these forums play different communicative roles within the field. On thing is clear that we are in the early stages of electronic communication revolution, and it is only a matter of time before other fields converge on a stable set of electronic forums – "sooner or later everyone will catch on" and learn to use the e-media structures in all fields.

According to Andrew Odlyzko (2002), traditional journals, even those available electronically, are changing slowly. However, there is rapid evolution in scholarly communication. Usage is moving to electronic formats. In some areas, it appears that electronic versions of papers are being read about as often as the printed journal versions. He mentions that although there are serious difficulties in comparing figures from different media, the growth rates in usage of electronic scholarly information are sufficiently high that if they continue for a few years, there will be no doubt that print versions will be more or less eclipsed. Further, he adds, that much of the electronic information that is accessed is outside the formal scholarly publication process. There is also vigorous growth in the forms of electronic communication that take advantage of the unique capabilities of the web, which simply do not fit into the traditional journal-publishing format. The Internet is growing rapidly. Typical growth rates, whether of bytes of traffic on backbones, or of hosts, are of the order of 100% per year. When one looks at usage of scholarly information online, typical growth rates are in the 50 to 100% range.

It is hard to measure online activity accurately. The earliest and still widely used measures are that of 'hits', or 'requests' for a file. However, with the growth of complicated pages, the measure becomes even harder to evaluate. Wherever, possible, the author has mentioned that he prefers to look at full article downloads. Web log analysis of studying use patterns of electronic journals is one of the methodologies adopted for this research work.

## 16 THE ELECTRONIC JOURNALS AND THE CHANGING PATTERNS OF USE

According the Alison Wells (1988-1999), the coming of age of the Electronic Journals (more popularly called e-journals), has altered the way scholarly information is disseminated throughout the world. E-journals have not only affected the way information is spread, but the way information is acquired and how scientific researchers seek that needed information. There is no doubt that this particular innovation has changed the information usage of scientists (Brown (1999)), but the important questions that still remain are: How has the innovation affected this usage and how have these changes affected the role of the library as an information provider. Though librarians and information specialists do possess some knowledge about these issues, there still is so much to learn in this area. Due to the frequent changes in technology, it is that important to keep up with the constant fluctuation in user information needs.

In an interesting study by Borrée Po-Yee Kwok (1992), essentially before the birth of the medical/scientific electronic journal, sampled a group of "scientists" who were queried on their use of materials such as CD-ROM databases, online databases, journals, monographs, etc. to do research. Based on the respondent's resulting ranked the list of the five most useful resources, namely: (a) Journals (obviously print), (b) personal contacts, (c) conference/meetings, (d) online databases and (e) Research reports. When a similar survey was conducted by Amy C Gleeson (2001), 10 years later on the five most useful resources that a scientist needed for his research, there was a concern about asking the scientists to recall their resource usage from ten years ago, because of the possible lack of accuracy. However, she found that when responses were received and compared to the earlier work done by Kwok (1992), it was observed that most of the preferred resources remained the same. For example, print journals, personal contacts, and conferences, all listed in the five most useful resources (Kowk (1992), can be found in the top five of the Table given below:

**Table 5: Ranking of Information Resources**

| Sl. No. | Today | Five Years Ago | Ten Years Ago |
|---|---|---|---|
| 1. | Electronic Journals | Print Journals | Print Journals |
| 2. | Print Journals | Conferences / Meetings | Reprints |

| Sl. No. | Today | Five Years Ago | Ten Years Ago |
|---|---|---|---|
| 3. | Online Databases | Colleagues / Personal Contacts | Conferences / Meetings |
| 4. | Colleagues / Personal Contacts | Reprints | Books |
| 5. | Conferences / Meetings | Books | |

*Source: Information Seeking Behaviour of Scientists and their Adaption to Electronic Journals*
*Amy C. Gleeson, MLIS Thesis, Univ. North Carolina, 2001*

In their study, looking across the ten-year period, they observed that the combination of conferences, reprints, colleagues, print journals and books (the most used resources) made up 83% of the total resource usage in the early 1990's, whereas today they make up only a little over (51%) of the total. Despite this, print journals have remained the most used resource by scientists only to be replaced by their electronic form in today's research world. Their findings revealed that there has been an increase in usage by all electronic resources during the ten-year period of 1991-2001. The most astounding of these increases is in electronic journals, which have more than tripled in usage during the past 5 years and are now considered to be the most heavily used information source.

Today, scientists have adopted electronic journals because of quick, convenient access from their desktops and the little effort required to retrieve information from them. It's quite obvious that electronic journals are a resource of convenience and therefore will be quickly adopted by most of the scholarly groups.



## 17 TRENDS IN INFORMATION SEEKING AND READING PATTERNS OF SCIENTISTS

According to Tenopir and King (2001), use of electronic journals saw a big jump in the last half of the 1990s and is continuing to escalate. On an average, one-half to nearly 100% of scientists in a field use electronic journals at least part of the time. In their study which spanned almost over three decades, it was found that information in journals serve many purposes (research, teaching, current awareness, background reading, etc) for scientists in both university and non-university settings. Many more scientists read than write, although University scientists tend to both read and write more journal articles than do scientists outside the university setting. The convenience of desktop access to journal articles allows all scientists to read more, from a wider variety of sources, although there is an upper limit on the time they can devote to reading. This limit is reached whether the articles carry a fee or are freely available. Finally, the information that scientists get from refereed journals results in improved performance, as evidenced by the awards and accomplishments of scientists who read more.

Evidence suggests that amount of reading and time spent on reading by Scientists have been relatively stable over the past 20 years, there have been some changes in the ways in which scientists identify the articles they read and there are appreciable differences in the sources of these articles. Surveys (Tenopir and King, (2001), from 1993 to 1998 show that scientists identify articles they read by browsing through journal issues or bound volumes. 62% of readings are identified in this way, by automated searches accounts for 12 %, by having other person tell them about the articles amounts to 11%, by using citations found in other articles, books etc. adds up to 9%, or by other means such as current awareness services, printed indexes, and so on fills the remaining 6%. The same study indicates that during the period 1993 to 1998, the scientists surveyed averaged about 120 readings of scholarly articles per year. In general, reading has shifted from personal subscriptions to library-provided journals, due in large part to a decline in the number of personal subscriptions and to better library services.

There are a number of factors that influence information-seeking and reading patterns (Tenopir and King, (2001). Variation among Scientists' communication patterns is partially attributable to personal characteristics such as one's discipline, level of education and experience, and general communication capabilities. There are also situational factors as well, such as size of the organization, level of research funding, amount of funds available for information services, and availability and access to library services.

The authors in an interesting study opine that, scientists read at least one article from an average of 18 scholarly journals. However, they tend to read only a few of these journals extensively and most of them sparsely. For example, across all journals read by scientists only five percent of them are read more than 25 times by a scientist (on average) and about 80 percent are read less than 10 times. The amount of reading of a journal has a major bearing on whether it should be purchased, depending, of course, on the price compared with the cost of using alternative sources of the article. In the past, libraries have been the principal alternative to purchasing journals.

So, what do the various trends reflect? Since their birth in the 17th century, scientific scholarly journals have become the most type of publication and, for most fields of science, 'the most inevitable, and the single most important channel of communication' (Tenopir and King, (2001). Over the last 40 years, numerous studies indicate that journals are extensively read; the information they contain is extremely useful for research, teaching and lifelong learning; and the information is valuable in terms of the favourable outcomes from its use.

## 18 CONCLUSION

In this context, it is important to note that the scientists and engineers working in the Indian aerospace organizations are currently working on projects which are of strategic importance to the country. These scientists largely depend on rapid collection of information from various 'electronic information resources'

Amongst the aerospace organizations in the country, the National Aerospace Laboratories (NAL) is India's pre-eminent civil R&D establishment in aeronautics and allied disciplines. Today, every NAL scientist has access to online electronic scholarly information right at his desktop. Through the NISCAIR-CSIR e-Conglomerate, NAL scientists have the unique privilege of accessing almost 6,000 e-journals from about 23 international publishers. This enables the scientist to quickly adapt to the modern day internet technologies of electronic publishing and downloading of scientific content and carry out hard-core research right at his desktop.

## 19 ACKNOWLEDGEMENTS

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