Scientific Communication Pathways: An Overview and Introduction to a Symposium†

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This overview of scientific communication pathways examines communication patterns from ancient to modern times through oral, written, mechanically printed, and electronic media. Communication channels, such as personal contacts and correspondence, books, journals, treatises, and interactive online mechanisms, are reviewed.

INTRODUCTION

The history of scientific communication may be traced back several thousand years. This paper provides a brief chronology of the many different methods of exchanging scientific information from ancient to modern times, focusing primarily on the following: oral, written (including pictures and pictographs as well as alphabets), mechanically printed, and electronic communication. The corresponding media for these methods are diverse: air waves, stone, clay tablets, papyri, silk, paper, wires, and electromagnetic waves. Scientific communication channels, or the way messages are "packaged", include oral exchanges, such as meetings and conferences as well as telephone conversations, messages, such as letters and telegrams, mechanically printed books and journals, and the more recent electronic mail systems and electronic journals.

EARLY COMMUNICATION

There are no records for the "earliest" form of transmitting information; oral communication was passed on from one generation to another. Gradually, recorded forms were developed, tools, carvings, and drawings, and from these grew picture writing. Here there are some records; the earliest of what might be called scientific records dates back some 6000 years to the Persian Gulf region of Sumer. It was here that pictorial representations evolved into cuneiform, a kind of syllabic writing used to communicate technology as well as commerce.

The Sumerians, and the Babylonians after them, developed and refined writing for communicating technology. However, they were primarily interested in the practical applications of technology, not the underlying scientific principles from which technology was developed. Nevertheless, the Sumerians greatly influenced later civilizations.

The situation in Egypt was somewhat similar. The hieroglyphics system was well advanced around 3000 B.C. One of the earliest documents to survive is the so-called "Edwin Smith Surgical Papyrus", a copy made around 1700 B.C. of a "medical" book dating back to approximately 2500 B.C. It described the diagnosis and treatment of head and chest injuries, but most of the information was empirical.

The scientific contributions of both China and India also affected later cultures. The Chinese civilization was isolated from the western world, yet the developments in ceramics and metal working became well-known. India's culture dates back 4000–5000 years, where a decimal system evolved that eventually wound its way through Arabia to us where it erroneously became known as the Arabic numbering system.

The Greeks made significant advances on the foundations laid by the Babylonians and Egyptians. Mathematics can be used as a gauge to illustrate the difference between developments in scientific communication in Babylonia and Egypt and those in Greece. While the Babylonians and Egyptians were very adept at calculations and manipulation of numbers, the Greeks were fascinated by the abstract properties of numbers, some aspects of number theory, and abstract concepts of geometry.

The rate of scientific advances and their communication slowed as Rome came to rule the western world. The Romans were skillful administrators and military tacticians but had comparatively low interest in science. With the fall of the Roman Empire in 476 A.D. and the beginning of the Middle Ages, much less progress was made on any scientific front. During this time there were, however, some important advances that had significant impact on scientific communication. Of enormous significance was the invention of movable type, often attributed to Gutenberg in 1455. Prior to that time, printing was carried out by using fixed blocks of wood or metal.

BEGINNING OF MODERN SCIENCE

By the 17th century there were two main channels for scientific communication: books and letters. To these was added the scientific society (the Royal Society of London being the first European one), which provided a forum for both written and oral discussion of scientific discoveries and principles.

Letters or personal correspondence were used more frequently than books as a means of communicating ideas. A scientist would write a letter to another scientist who, in turn, would share it with others. In some cases, the scientist writing the letter would make copies to send to several others.

Prior to the 17th century when the scholarly journal was introduced, the communication of ideas was also fostered by "centers of information". These "centers" were men who would correspond with a large number of scientists within a given expertise, passing along ideas from one scientist to another.

Books were another important means of communication before the introduction of the scholarly journal but were used less often than letters. A book was generally not published until enough material was accumulated by a scientist to warrant publication.

The 17th century saw the achievements of Bacon and Galileo with their emphasis on observation and experimentation, the founding of the Accademia del Cimento (Academy of Experiment) in Florence, and, shortly thereafter, the beginning of the scientific journal as we know it today. There were several kinds of publications that influenced the development of the journal; the two most dominant ones are the newspaper and the learned, or erudite, letter. The first newspaper dates back to the early 17th century and appears to have started in several European cities at about the same

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Table I. Journal Growth

year	no. of scientific and technical periodicals
1670	4
1700	8
1800	90
1900	10000
1985	70000

time. From the very earliest times, newspapers carried scientific news.

There is a direct link between the early scientific journal format and the learned letter. Many of the early papers are in the form of letters that were sent directly to the editor of a journal or were forwarded to the editor from the person who received the communication. Journal form slowly evolved into a style that demanded clearly defined sections in a scientific paper: background, experimental procedures and methods, results, discussion, and conclusions of the reported research.

MODERN COMMUNICATION

The 19th and 20th centuries produced new and improved ways of communicating information, but for the most part, these did not significantly affect scientific communication. Science is to some extent communicated by telephone, radio, television, and film. These media, however, are used primarily for communicating other kinds of information. Electronic methods, such as online search services, are only now beginning to make an impact on scientific communication. The four primary methods of scientific communication in use today remain journals, books, letters, and the spoken message.

The most significant change during the last two centuries in scientific communication is the actual volume of the scientific literature being produced. The burgeoning scientific periodicals,[1-4] summarized in Table I, created a situation where no one could keep abreast of the published literature. Scientists needing studies could neither identify them nor locate them. This served as an impetus to the development of the abstract journals in the mid-1800s. At this time, there were about 300 scientific journals, and over the years, there has emerged approximately one new abstract journal for every 300 scientific journals. Abstract journals act as a net, capturing all the new papers, patents, reports, etc. that are published. The abstracting and indexing services then publish a variety of tools to aid scientists: alerting tools that lead to the current research and practice and retrospective searching tools that inform of the developments reported in the past.

SYMPOSIUM THEME

To explore some of the present-day pathways used for scientific communication, a symposium was organized at the 189th National Meeting of the American Chemical Society. Because of time restrictions, we could examine only a few of the many methods and avenues of communication. The three following papers in this issue discuss some of them. The publication of scientific journals has been, and continues to be, one of the main dissemination routes of new information. New communication technologies are vastly affecting the many processes involved in journal production. Parallel with the publication of scientific information is the exchange of ideas among members of the various "invisible" colleges, groups of individuals with a shared, common interest. The effectiveness of this mechanism as well as that of communication at scientific meetings may be measured quantitatively by using scientometric methods. The proliferation of scientific specialties has led to the proliferation of jargon in each such field. Outsiders—other scientists as well as the general public—encounter considerable difficulty in understanding new scientific and technological concepts and achievements. Experiments have been conducted to attempt to measure the degree of technical literacy, and special educational programs have been devised to improve this literacy.

Today's challenge in communicating scientific achievements is making them understandable to the nonscientist. Today's public is more educated than in the past and wants to be involved in world happenings but does not always understand the implications of scientific technology. Effective science education and fostering the development of rational approaches to solving scientific problems instead of prejudicial or emotional reactions are essential if people are to understand and participate in the advancements of science.

In most instances today, the authors of scientific messages know or perceive the intended audience. Occasionally, an interesting case arises when we have no clue if our message will be received, who will receive it, and if it will even be understood by the receiver. This is the case of the engraved plate placed some 13 years ago aboard Pioneer 10, the first spacecraft to leave our solar system.[5]

We have reached the stage when scientific communications can be transmitted in a fraction of a second from points on earth or outer space, enabling us to be better and more quickly informed.

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