Propagation
A Journal of Science Communication

Science communication through print media

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Before the invention of printing, dissemination of ideas and thoughts took place mostly through hand-written manuscripts. Indian palm leaf manuscripts and Chinese writings on silk are well known. Modern printing technology had its origin in Europe. German goldsmith and printer Johannes Gutenberg was the first European to use movable type printing, in around 1439, and also the global inventor of the printing press. His many contributions to printing include the invention of a process for mass-producing movable type; the use of oil-based ink; and the use of a wooden printing press (Fig.1). He combined these elements

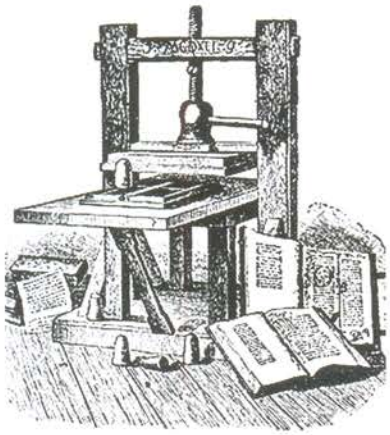

Fig. 1. Gutenberg Press.

into a practical system which allowed the mass production of printed books economically. The use of movable type was a marked improvement on the handwritten manuscript, which was the existing method of written communication in many parts of the world.

Science communication

Science communication can be defined as "successful dissemination of scientific and technological knowledge among a wide range of audiences including non-scientists". There are numerous examples of effective science communication having brought about social change that have transformed the world. From the Copernican Revolution to the Laws of Thermodynamics to the Theory of Relativity, communicating science has historically and will continue to change the world. So effective communication of science is probably as important a skill as learning how to do science, and print media provide a viable mode of mass communication of science.

Science communication through print media could be for a peer science audience or the general public. Scholarly writing involves providing scientific context and lots of text, little graphics, and is focussed on results, data, and interpretation. On the contrary, science writing for a much broader audience is primarily aimed at disseminating information in a non-technical language and creating awareness. The focus is not on results, but rather on the conclusions and recommendations, and social implications if any. In recent years there has been tremendous diversification of communication media, especially with the growth of ICT-based systems, which has made information easily accessible. Notwithstanding these developments, printed journals, magazines and books continues to remain highly effective media for science communication. Although most journals and dailies, and even books are now available online in digital form, they are basically the electronic version of print editions.

Research communication

Communication of science among scientists is very important for the advancement of science and technology. This usually happens in a very systematic and methodical manner through technical sessions, symposia, proceedings and peer reviewed articles in scientific journals. While the research findings from labs need to be communicated to scientists as well as the common man, the styles differ widely. Most researchers communicate through research journals with their peers and other scientists in the respective fields. In contrast popular science communication is primarily targeted at the common man who need not necessarily have any background of science.

The style of writing a research paper is mostly guided by the 'house style' of the journal in which it is intended to appear. Further, the modern scientific paper is a rigidly stereotyped document, with well-defined sections following each other, e.g., Introduction, Methods, Results, Discussion and/or Conclusion, References, together with a relatively free-standing Abstract. While such constraints undoubtedly provide a standardised format and make the task of writing a research paper simpler, it takes away from the writer the freedom to express in his or her own style.

A paper written for publication in a research journal is primarily aimed at other scientists/researchers in the

same field. Consequently, technical terms and expressions, equations and mathematical data can be freely used where necessary. This makes the task of writing a research paper comparatively simpler than writing popular science, in which use of technical jargon is a taboo. A research paper has to bring out the objective, experimental procedure, observations, and inferences and results without any ambiguity, which makes a good command over the language of writing an essential prerequisite.

A well-written research paper is able to convey a lot through judicious use of less words. A classic example is the paper on DNA structure by James Watson and Francis Crick published in *Nature* on 25 April 1953. It was a one-page paper but contained the germ of a whole new world of biotechnology and genetic engineering that has revolutionised the study of biology.

Watson and Crick wrote in their paper:

> We wish to suggest a structure for the salt of deoxyribonucleic acid (DNA). This structure has several novel features which are of considerable biological importance. .....This structure has two helical chains each coiled round the same axis. ....The two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. ....The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical z-coordinates. One of the pairs must be a purine and the other a pyrimidine for bonding to occur. ....
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> .....It has not escaped out notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material. ....

Here the two scientists could bring out the tremendous potential of their discovery unambiguously in just a few words in the last sentence, which speaks of their ability to communicate science precisely and with brevity.

The modern professional pattern of specialised academic journals containing stereotypically structured research papers is not very old; it only matured in the twentieth century, following on the line of a few proto-journals of the Royal Society and other early learned societies. Historically, early scientists (who were known as natural philosophers) preferred writing monographs rather than publishing papers in journals to establish claim for new knowledge. To meet the cost of printing, early printers and publishers required authors to obtain sponsorship (especially for expensive illustrations), or get up a list of subscribers who would pay for the volume in advance. Many of today's research journals too, levy page charges from authors for publishing papers.

Scientific and medical journals started as newsletters aimed at disseminating matters of interest to the community and were not exclusively devoted to publishing fresh research. Specialised journals, reflecting the fragmentation of science, started appearing only from the late eighteenth century. Initially such journals were mostly published by learned societies, whose lectures and proceeding provided the contents. Science journals eventually became the standard media for primary reporting of new research aimed at meeting the increasing pressure of claims for new knowledge from an increasing number of working scientists.

Before the advent of computers and desktop publishing, every research paper had to go through meticulous proof-reading after typesetting, before the pages could be sent for printing. Proof-reading was not only a tedious process that was time consuming, but it was also not completely foolproof. Often typesetting mistakes went unnoticed. As a result authors often had to make corrections more than once, which delayed the publication of a paper.

Today the situation is quite different. Authors are required to send error-free copy of the paper which obviates the need for proof-reading. Some journals even accept papers only if submitted in the same format the journal is printed so that the printer only has to use camera for making the plates for printing. These advances have made possible faster publication of research papers by significantly cutting down the time lag between acceptance and printing.

Popular science communication

Peer-reviewed articles are often the litmus test of a researcher's success, determining tenure or 'fundability'. If the only goal of research is to influence the state-of-the-art, targeting only other researchers, then this is the ultimate objective. However, if the research has to have any impact on society by changing or influencing policy, mere publication of a paper in peer-reviewed journals would be woefully inadequate, because beyond scientists and academics, the

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readership of scientific journals is effectively zero. Decision-makers do not read them. Neither do the media or communities. The language of scientific journals often makes it impossible for the lay person to understand the research. Here lies the importance of popular science communication and the print media plays a major role here.

Popular science writing does not follow any standardised format. The writer has the complete freedom to express his/her thoughts in whatever way he/she feels fit. That is why many popular science writers can be identified by their style of writing. This makes popular science communication more varied than research communication.

There are several formats in which popular science communication through print media can be done. It may be a straight article or essay, an interview, or even a photo feature or cartoon strip (Fig.2). There are even

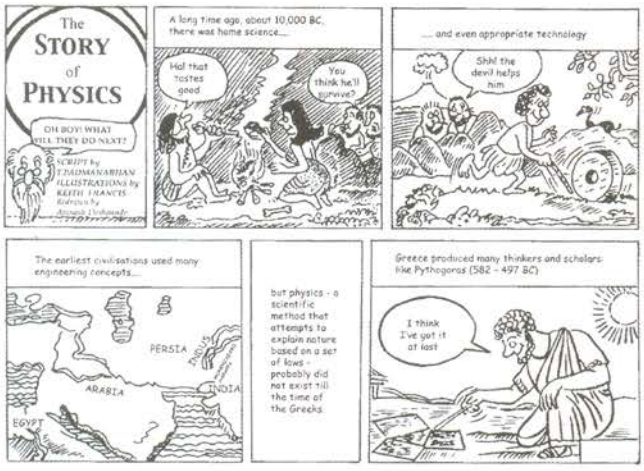


Fig. 2. Science cartoons.

poems and drama/skit written on science themes that provide a novel and effective mode of communicating science.

Print media for popular science communication can be basically of three types, each with its strengths and weaknesses. Daily newspapers offer the fastest print medium for coverage of scientific events, but are constrained by limited space availability, cursory coverage and ephemeral value. There is little scope of detailed discussion on any topic in a newspaper article. Weekly, fortnightly and monthly magazines offer a better alternative in terms of coverage and treatment, but there is a time lag of up to a week or more between submission of an article and its publication. Magazine articles have intermediate value. Books offer a medium for the most comprehensive treatment of a scientific topic. The author has ample room for delving deeper into the subject and bringing out the salient points in a more leisurely manner than possible with either a newspaper or magazine article. Books have lasting value (Table 1).

Table 1. Print media

Dailies	Only cursory treatment possible	Of ephemeral value
Periodicals	More detailed treatment possible	Of intermediate value
Books	Most comprehensive treatment possible	Of lasting value

Daily newspapers

Daily newspapers are often the first source of news about a new scientific development for the common man. Articles in newspapers – news items, features or editorials – reach a wide audience and can generate public debate. The print media in the form of newspaper can thus inform the public about research being carried out in different scientific institutions and labs and help in better public understanding of the research.

The style and format of a newspaper article is markedly different from an article in a scientific journal. In the case of a newspaper article, not only must the title grab the reader's attention, but the article itself should be constructed like an inverted pyramid, starting with the most important information and working down to the individual supporting details. While this applies more to a news story than to a fuller feature article, the logic is important to understand.

Unfortunately, despite their wide reach, the space devoted to science in Indian newspapers is insignificant. While a few Indian newspapers publish weekly science columns and have regular science correspondents or science editors in the staff, items on science and technology published in Indian newspaper mostly are based on press releases and agency stories.

Few studies have been done on coverage of science in newspapers and its impact on public perception of science. In a study carried out in 2000 by Bharvi Dutt of National Institute of Science, and K. C. Garg of NISTADS, items on science and technology in English-language newspapers published in different parts of India during January-December 1996 were analysed. Results indicated that the greatest proportion of newspaper space was devoted to nuclear science and technology, followed by defence, space research, and astronomy. *The Pioneer*, *The Hindu*, and *The Times of India* were the newspapers that together

accounted for about 23 percent of the total space devoted to items on science and technology. The sources for most of the articles (97 percent) on policy issues originated from within India, while for other stories foreign sources, including those from the United States and the United Kingdom, also contributed. The study indicated that, on average, Indian newspapers devoted far less than one percent of the total printed space to articles and stories related to science and technology. This situation needs to be improved.

Popular science magazines

Compared to daily newspapers, the scope of popular science magazines as a medium of science communication is manifold. However, from commercial and economic considerations sustaining a popular science magazine is often an uphill task for the publisher. The constraint is mainly financial. Advertisers do not consider popular science magazines viable media for advertising, although the readership of a few popular science magazines is quite large. As a result, most of the popular science magazines published in India, like *Science Reporter* and *Vigyan Pragati*, both published by Council of Scientific and Industrial Research and having reasonably large readerships, are heavily subsidised. Another popular science monthly *Dream 2047*, published by Vigyan Prasar, an autonomous organisation under Department of Science and Technology, is distributed free to interested readers. It has built up a large circulation and continues to be in great demand, as evident from mail received from readers. *Science Today*, a widely read popular science monthly published by the Times of India group, and *Science Age*, another widely read popular science monthly published by Nehru Centre, Mumbai, carried top class popular science articles. Both had to close down in view of financial unviability.

There are a few popular science magazines published in a few regional languages including Hindi, Bengali, Odiya, Malayalam, Tamil, Telugu, Marathi, Assamese, to name few. But most have meagre circulation and are partly subsidised.

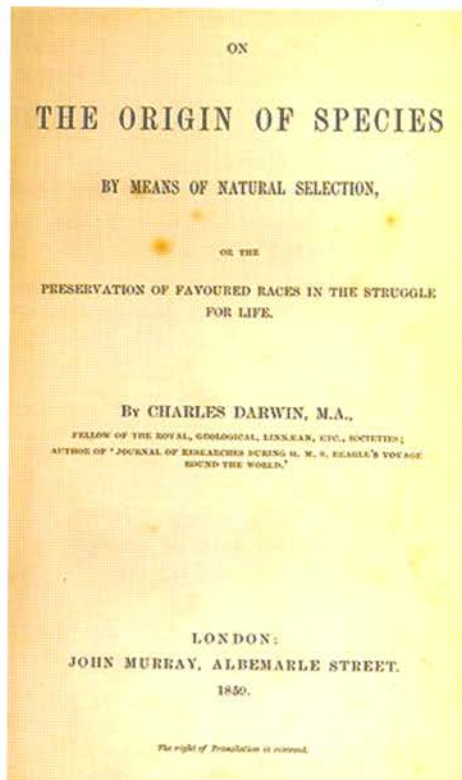
Quite a few foreign popular science magazines such as *Discover*, *Scientific American*, *Science Illustrated*, and *New Scientist* are available in India, as is *National Geographic* magazine which often carries excellent popular science articles. But all are quite expensive by Indian standards and are beyond reach of the average Indian reader.

Despite being one of the most effective modes of popular science communication for non-specialists, the cost of producing popular science magazines in India is quite high, which makes keeping the price low a difficult proposition unless heavily subsidised. This constraint can be removed if the Indian private sector comes forward to take up publishing of low-priced popular science magazines as a social responsibility.

Popular science books

By their very nature, books offer a unique platform for communicating popular science provided by no other print medium in terms of detailed treatment possible. Popular science books have been at the forefront of science popularisation for more than a century.

Charles Darwin's *The Origin of Species*, published in 1859, was a trend setter in popular science communication (Fig.3). The book was written for non-specialist readers


ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNEAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

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Fig. 3. Title page of The Origin of species.

and attracted widespread interest upon its publication. In his book, Darwin introduced the scientific theory that populations evolve over the course of generations through a process of natural selection. It presented a body of evidence that the diversity of life arose by common descent through a branching pattern of evolution. Darwin included evidence that he had gathered on the *Beagle* expedition in the 1830s and his subsequent findings from research, correspondence, and experimentation.

The lucidity of his text can be judged from the introduction he wrote for *The Origin of Species*. Darwin wrote:

> When on board H.M.S. *Beagle*, as naturalist, I was much struck with certain facts in the distribution of the inhabitants of South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to me to throw some light on the origin of species – that mystery of mysteries, as it has been called by one of our greatest philosophers. On my return home, it occurred to me, in 1837, that something might perhaps be made out on this question by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on it. After five years' work I allowed myself to speculate on the subject, and drew up some short notes; these I enlarged in 1844 into a sketch of the conclusions, which then seemed to me probable: from that period to the present day I have steadily pursued the same object. I hope that I may be excused for entering on these personal details, as I give them to show that I have not been hasty in coming to a decision.
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> .... In considering *The Origin of Species*, it is quite conceivable that a naturalist, reflecting on the mutual affinities of organic beings, on their embryological relations, their geographical distribution, geological succession, and other such facts, might come to the conclusion that each species had not been independently created, but had descended, like varieties, from other species. Nevertheless, such a conclusion, even if well founded, would be unsatisfactory, until it could be shown how the innumerable species inhabiting this world have been modified so as to acquire that perfection of structure and co-adaptation which most justly excites our admiration.

As Darwin was an eminent scientist, his findings were taken seriously and the evidence he presented generated scientific and philosophical discussion. But more than that, it showed the power of the printed word in changing the mindset of people.

In India, eminent personalities like Rabindranath Tagore, Bankim Chandra Chatterjee, Jagadish Chandra Bose, Satyendranath Bose and many others wrote excellent popular science. Tagore's *Vishwa Parichay*, and J.C. Bose's *Avyakta* are outstanding popular science books that enthralled a whole generation of young readers in Bengal. In recent times the works of Jayant V. Narlikar, D. Balasubramanian, Bal Phondke, G. Venkataraman, have become best sellers. Among notable international popular science authors, George Gamow, Isaac Asimov, Arthur C. Clarke, John Gribbin, Richard Dawkins, and Richard Feynman have wide readership in India.

As is the case with popular science magazines, the price of foreign books in India is usually high, although Indian reprints of many titles are available at low price. To make popular science books available at affordable cost, several government agencies have taken up popular science book publishing. Notable among them are National Book Trust, Vigyan Prasar, Publications Division, and National Institute of Science Communication and Information Resources (NISCAIR), a unit of the Council of Scientific and Industrial Research. Among themselves these organisations have brought out excellent popular science books that have gone into several reprints.

Graphics in print media

Tables, graphs, diagrams, and sketches or photographs are essential components of a research paper, popular science article, or a popular science book. In the past every illustration and diagram had to be hand drawn, which was not only time consuming but also could not provide uniform quality. Techniques of making scientific illustrations have undergone sea change with the advent of various computer graphics software. Be it the structure of a complex molecule, a bar graph or pie chart, there is computer software available that can easily convert data into the required graphics.

Before the advent of the present digital age, processing of graphics material for printing involved the complex and expensive method of block making. Colour illustrations necessitated multiple block making that greatly increased the cost of printing. Moreover, once a block was prepared there was no scope of modification – a reduction or increase in the size of an illustration to fit the available space in a page. Modern techniques of digital scanning and processing have totally eliminated these constraints. Photographs and diagrams can be processed at any stage – even after the page is made up – to make final modifications.

Modern printing technology

Be it daily newspapers, journals and magazines, or books, printing technology has also undergone a revolution across the world. Gone are the days of setting type by hand or machine. The traditional system of galley proofs and art pulls are totally eliminated. Typesetting is universally done today on computer and pages made up using a variety of software such as PageMaker or CorelDraw. In a publishing house the error-free text matter and

graphics are directly imported to the DTP station for page making and final made-up pages with text and graphics are delivered for plate making and printing. Printing is often carried out as a large-scale industrial process, and is an essential part of publishing and transaction printing.

Books, magazines, and newspapers are printed today using the technique of offset lithography (Fig.4). In this technique the inked image is transferred from a plate to a rubber blanket, then to the printing surface. When used in combination with the lithographic process, which is based on the repulsion of oil and water, the offset

Fig. 4. A modern offset printing machine.

technique employs a flat image carrier on which the image to be printed obtains ink from ink rollers, while the non-printing area attracts a water-based film, keeping the non-printing areas ink-free. Offset printing has not only made the printing process faster but has also significantly improved the quality of printing, especially colour printing of popular science magazines and books.

Print media vs electronic media

While science communication through print media has existed from olden days and still continues to be quite effective, the spread of electronic media has brought in a new dimension in the technique of science communication. The Internet today provides almost instant access to almost any kind of information including scientific information that the print media cannot provide. At the same time, however, the convenience of reading that a printed newspaper, magazine or book can provide is not available with the electronic media such as e-readers and iPad that often involves access to the Internet and is powered by battery. Besides, constant reading on the screen that can be quite tiring for the eyes.

Nonetheless, in view of the quick accessibility the Internet provides compared to the print media, most daily newspapers and many research journals and popular science magazines are today available in digital form on the Internet. But in most cases the matter appearing online is the same as in the print editions. In this respect the electronic forms can be considered only an extension of the printed form, although in terms of faster accessibility the electronic media is ahead. That is why many scholarly journals as a rule have advance online publication before they actually appear in print in the journal. This gives researcher faster access to new research not possible through print media.

Despite the faster accessibility of information compared to the print media, research has shown that comprehension, especially of popular science, is better with printed material compared to online reading. A study by Mônica Macedo-Rouet *et al.* of Methodist University of São Paulo, some years ago to determine the effects of print and online presentations of a multiple document report on reader's comprehension, perception of cognitive load, satisfaction, and attention revealed that users of online media show poorer results compared with print users. An experimental protocol was used to assess readers' performance using print and online versions of a popular science magazine. The researchers found that hypertext led to higher perceived cognitive load and poorer comprehension of the complementary documents. The results suggest that presenting graphics in long hypertext increases effort and reduces text legibility. The data supported theories of disorientation and cognitive load in hypermedia learning. In a way, online reading with too many hyperlinks can be said to cause 'information overload' that often distracts the reader from the main topic and reduces comprehension.

Conclusion

Despite the spread of the Internet and electronic publishing, the print media is likely to hold sway as a powerful vehicle for science communication - especially popular science communication - for several reasons. Electronic media is no doubt becoming the preferred media for fast exchange of information, especially scientific information, and of course, blogging. But the convenience of reading a printed book or magazine, especially popular science, any time at any place is a big advantage with print media that the electronic media may not be able to provide. The growing number of popular science titles being printed worldwide every year and their expanding readership point to the popularity of the print media despite the global spread of the electronic media. It may be a question of getting used to a new media, but reading a book or magazine in print form still remains more comfortable and convenient than reading a magazine or book on a laptop, iPad or e-reader. Further, reading a printed book or magazine can never be interrupted by a low or run-down battery!

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