
Four-Stage Development of Scientific Information

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John Ziman in his book *Public Knowledge* drew attention to the obvious fact that science is knowledge which only gains significance once it has been published and made available to the public (Ziman, 1968). In contrast to public knowledge, we can assume the existence of private knowledge, or private information. For the purposes of this paper, publicly available publicized information will be termed “knowledge.” Privately transmitted learning to a select audience will be referred to simply as “information”.

Knowledge including science is usually public knowledge, and by virtue of that fact only attains significance and meaning and the ability to be transmitted after it has been published. The form and medium of publication is called the media. Though contents and types of knowledge are the main considerations in selecting a suitable media, we cannot overlook the fact that the medium itself can help shape knowledge. In view of the recent trend of digital media, there may be a danger that the public nature of knowledge will decline. This paper aims to trace the history of the relations between science and media and critically examine the way in which these two will develop in the near future. There are many rumours

about the social effects of digital media. Though it is certain that this new media will influence the transmission of scientific information we cannot foresee in which direction it will go. It might even to our surprise change the whole structure of science. Let us consider this possibility by reviewing the past history of the media.

Four-stages of the development of the media

The existence of writing or documents demarcates the history of science from its prehistory. Various long-lasting materials such as stone, clay, papyrus, cloth, parchment and paper were used for writing. This stage is called the manuscript period. Since the materials for writing were relatively scarce and expensive, the variety and bulk of preserved documents and manuscripts were restricted in kind and quantity.

The second stage is the age of printing. The salient characteristics of printing is the ability to print a great number of copies in a short time. When it is costly to publish, it is not possible to publish just anything. There has to be a need for many copies before printing becomes viable. These factors ensure that printing is a media of public nature, limited in kind but abundant in quantity.

Printing may sooner or later be replaced by the new media. From the beginning of the twentieth century, with the spread of the typewriter, it became possible for anybody to write alphabet languages in print style. Furthermore with the spread of xerox copies in 1960s it became possible for amateurs to xerox copies of typed pages and distribute them without recourse to the professional printing media. As everyone was able to publish materials, the range of publication increased. As professional

printing was bypassed, the cost restrictions associated with printing a small number of copies were removed. This signalled the coming of an age in which a wide range of publications became available in small quantities. Thus, in some fields of science, preprints came to be common.

Finally, in the late 80s to 90s, the Internet became a major medium of academic communication.

The above four stages of the development of media are summarized in the following table.

	Range of types	Quantity
1. Manuscript period	small	small
2. Printing period	small	large
3. Preprint period	large	small
4. Internet period	large	large

Next let us look at the relationship between the media and knowledge in these four periods in a little more detail.

The Manuscript period

It can be said that the custom of eponym in which the ancestors of schools are honoured by ascribing classical works created the pre-concept of paradigm in Thomas Kuhn's sense (Kuhn 1962). In the West Plato and Aristotle and in the East Confucius and Mencius appeared in almost the same age and a paradigm presented itself to the scholarly groups in each of these cultural spheres because the statements of the masters attained the status of a scholarly medium, even a tradition, which was transmitted by manuscript copying. This tradition was similar to that of a religious group in which there is strong devotion to the founder. Let us examine in detail the structure of the devotion in the manuscript period.

At present it is unthinkable for only the founder in a group of researchers to be famous and all the others to be obscure. But it was different in an age when there was no printing. First when learning began the founder formed a group of leading disciples to whom he transmitted his teaching orally. That was adequate while disciples had direct contact with the founder, but for later disciples there was no direct oral transmission and secondhand information tended to be inaccurate. It was at this point, forced by the need to make written records, that the work of compiling the founder's statements began. The tradition of testimonies about Aristotle known as doxography and the studies devoted to the Chinese Confucian classics are examples. Mistakes always occur when people copy books by hand. Moreover while copying it the copier's own thoughts get mixed in with the copied text, or are written in the margin. When the next copyist comes along he finds it difficult to distinguish between the thoughts of the founder and those of the last copyist and the annotations are incorporated into the text. Thus in the process of copying it becomes impossible to determine which is the standard text.

With movable type print many copies can be printed at one time. If a reference is given, for example to a certain page in the first edition of Newton's *Philosophiae Naturalis Principia Mathematica*, it has the possibility of becoming the common knowledge of all the people who possess that book. This is not possible with manuscripts.

If someone writes a note on the page of a printed book later scholars will quote it as an annotation. That type of referencing, however, is very difficult with manuscripts, the standard texts of which are often unknown, so everything including the annotations of later generations are carelessly attributed to the founder.

As with Aristotelian writings and Confucian Analects, only the name of the founder and his works become the common symbols among scholars, under which the names of other predecessors, disciples and commentators are all subordinated.

There are even forgeries which from the start use the founder's name as a disguise. In the contemporary world of the printing media publishing is proof of the author's identity. So there are not many cases of forgery apart from ghost writing which is done for money anyway. Thus, today we do not fully understand the psychology of annotators and forgers who engaged in such activities. It seems anyway that knowledge or information transmitted via the manuscript media was an extremely authoritarian type of scholarship.

It was in this context that the *Mechanica*, a forgery of Aristotle, appeared and that even the commentaries on *Chunqiu* (The Spring and Autumn Annals) attributed to Confucius were now considered to be forgeries. Both the *Hermetica* with its paradigms of a magical tradition and the statements of Pythagoras are probably not solely the work of one founder but was completed by a scholarly group and even contains later additions.

In the manuscript age people sought to compile a standard text, but it was not until the classics came to be printed that such work really got underway when standard texts were made by collating many manuscripts and classical studies were established as a field of learning.

Since manuscripts were a medium limited in quantity they could only circulate amongst a small number of people. As the information obtained from manuscripts was the monopoly of a select group of people, contemporaries must have secretly got an esoteric thrill out of having access to

this sort of private information. Even today one of the pleasures of classical studies is the sharing of this esoteric thrill of the ancients.

The Art of Printing

The knowledge media underwent radical change upon entering the age of printing. In the manuscript age the only method of transmission was to go to the master and beg to be allowed to copy some passages from the books he held secretly. The market value of information increased in proportion to the degree of monopoly. Once information is made public and accessible to anyone, its value is reduced to zero. While transmitted orally or secretly by manuscript, private information circulated amongst an extremely limited group of people. Groups that monopolized information feared that the value of their information would be lowered if it was indiscriminately leaked out to non-members and created group rules in an effort to defend the authority and vested interests of their learning.

In the age of printing, however, due to the mass production, monopoly is impossible and what formerly constituted private information turns into public knowledge. Academic publishing could be undertaken on a mass scale and journalism for the general reader also developed.

The nature of knowledge changes once hundreds and thousands copies of academic journals are published. Private information in the manuscript period was something like a secret the mastery of which was either transmitted from master to disciple within a special group, or from father to son within the family. As a result manuscripts were not exposed to criticism from outside, which meant that they lacked universality and objectivity. But when hundreds and thousands of copies are printed,

writing becomes public knowledge. Its objectivity will have currency within an equal numbers of readers. Indeed, printing media is indispensable to guarantee the objectivity of modern science.

The beginnings of modern science can be traced back to Copernicus. Heliocentric theories had often been debated by the scholastics in the Middle Ages, but one of the reasons for calling the heliocentric theory of Copernicus the Copernican revolution was that his *De Revolutionibus orbium Coelestium*, published in 1543, gained wide circulation by being printed in movable type, which was still new at the time. Also the Church authorities could probably tolerate people discussing the heliocentric theory which was opposed to the teachings of the Bible as long as it was disseminated in manuscripts and private letters, but once such criticism got into print its power of influence was alarming. The notions and behaviour of Copernicus and his followers became a question of social responsibility. The writer may also come to feel that he has such a responsibility towards society.

Even in the age of printing, drafts were written by hand. At this stage they still remained private information, but once the manuscript was published in printed form it immediately turned into public knowledge and its social status underwent a drastic change. In the process of changing from its private to public roles knowledge is often subjected to screening tests of one kind or another. Government authorities fearing the social effects demanded manuscripts be censored before going to the printers, and learned societies also set up refereeing committees to check the scientific objectivity of that knowledge.

Not just any handwritten manuscripts were printed. First of all it is expensive to print even works as thin as a journal article. The publishers

of scientific journals realize that with something like public knowledge, which is going to be seen by hundreds and thousands of people, articles must be based on good solid information and that they cannot print unreliable information at random.

To check the quality of information learned societies set up referee systems as a selection mechanism. Usually a referee committee consisting of about three members is organized and they examine manuscripts submitted for publication. The manuscript is only sent to the printers after the referee committee who represent the member readers have recognized it as being worthy of publication. In such a situation a distinct difference arises between the social role and significance of a handwritten manuscript and a printed one. A handwritten manuscript is unconfirmed and unappraised information, while a printed work gains the status of public knowledge, information available to society at large which has been assessed by an independent referee. For the writer this means that his work will be permanently recorded and honoured as a contribution to scholarship and will become an invisible asset.

One of the indispensable conditions in the screening test conducted by the referee committee is that the article is sufficiently original. In the Middle Ages during the manuscript period it was not easy to see what was original, nor was originality valued. As everything was copied out by hand other people's theories became mixed up with those of the writer and in the end it was impossible to distinguish between them. With the advent of printing, however, all previously printed works constitute public knowledge and academic work is only regarded as original when it is published for the first time. Repetition of previously published work is not regarded as original but sometimes professionally unethical. To gain the status of

originality hitherto unpublished idea or material have to be added. In the age of printing a clear distinction is drawn between originality and repetition by checking past publications.

As printing spread in the modern period, a researcher had to read all the articles printed so far in his field before publishing his own research. Researchers also had to take it for granted that since previously published articles constituted public knowledge other people would have read them as well.

If a researcher ignores this rule and unknowingly publishes work that has already been done he would be infringing on predecessors' works, and therefore liable to reprehension by colleagues and even repulsion from an academic position.

Historically speaking, however, many disputes have arisen over the priority rights to research discoveries. Some well-known examples are the friction between Newton and Leibniz over the discovery of differential calculus and the question of who discovered the law of conservation of energy in the nineteenth century. As shown in the above examples, the course which paradigmatic works were to follow was not yet fixed and it was often difficult to decide by comparing published work who made the discovery first. But it was possible to clearly establish priority rights for work done in normal science, the course of which was fixed. For example we definitely know who was the first to discover the atomic weight of sodium the deciding factor can be the date that the editor of the journal received the manuscript. The custom of specifying in journals the date on which the manuscript of the published article was received arose during the nineteenth century. Furthermore from the late nineteenth century onwards science abstracts were published for the purposes of clarifying

priority rights and to help scholars avoid repeating research that had already been conducted. Thus it became necessary before commencing research to search through the abstracts to check that proposed work had not been previously done.

After World War II this type of research competition became even tougher and researchers in some fields were no longer able to depend on such a slow media as printing. At this point the need for preprint media arose.

The Age of Preprint Media

The typewriter appeared in the last quarter of the nineteenth century and became popular in the twentieth century. As it was different from handwriting, it may be regarded as movable type printing of a single page in one copy or several carbon copies. The author was able to print words himself, without having to go through the trouble of typesetting, a task which requires the labour of many people. More significant in view of disseminating scientific works is the invention of easy duplication technology. Since the late 1950s copying technology advanced to a great extent and became so popular that the expression Xerox Revolution even appeared.

Typing and duplication can be done by an individual without recourse to a printing press. In the age of printing a distinct difference in social role and significance arose between handwritten manuscripts (private information) and printed publications (public knowledge). Barriers and procedures of appraisal which transformed private into public knowledge such as the referee system had existed between the two types of media. But

this distinction disappeared with the advent of typewriter and xerox machine and scientific information reverted to being something private.

What happened in cutting-edge research such as in physics after World War II was that instead of relying on academic journals for information, the results of the latest research were transmitted by preprints. As soon as someone made even a minor discovery it became customary for them to immediately type, xerox and post it by airmail to researchers all over the world in the same field. This was the way in which they claimed priority rights for their research.

The main merit of the preprint was its rapidity. In the normal form of publishing it takes even at least half a year from submitting the article until publication which is only reached after being screened by the referee committee, printed and proofread. If the journal is congested with articles submitted for publication, you have to wait your turn. If it is a monthly journal the situation is not so bad, but with quarterlies and bi-annual publications it is quite common to be kept waiting for a further one or two years if your timing is bad. Under such conditions it was impossible to keep up with the tempo of frontline research in the sciences and the pre-print was able to bypass those procedures and the individual could do all the work from typing through to mailing by oneself.

Furthermore since scientific journals are at the frontline of a ruthlessly competitive society there are countless scandals and complaints. There are even cases of members of editorial committees intentionally delaying the publication of articles under consideration so that they may steal ideas contained in them for publication elsewhere. Scandals that arise in the maze of closed screening organizations can be prevented by simultaneously sending pre-prints to numerous people in the same profession

thereby gaining witnesses.

Typewriters and xeroxes are not necessarily essential for making pre-prints. I do not follow the theory of technological determinism, but rather I propose that pre-printing arose because the tempo of learned societies had quickened after the War under the ruthless competitive conditions. Here, the sociology of science is badly needed for the evaluation of the role of preprints. Even from the viewpoint of technology it was the development of air travel and airmail services after the war rather than typewriters and xeroxes that made the most decisive contribution to speed up the tempo of priority competition. In other words, the transmission of scientific information leapt forward from the speed of pre-war boats and trains to that of aeroplanes in the postwar period.

There are some misgivings however. If the referee system, which the modern scientific journal has built up to maintain the quality of articles, is by-passed, in preference to the rapidity of modern information flow, preprint media will disgorge large quantities of carelessly produced articles and there is every danger that the scientific information transmission network will go into confusion; as we are inundated with unreliable information there will be no way to distinguish between good and poor quality reports. In the absence of intervention of third persons such as referee, proofreaders and editors in the process to turn private manuscripts to printed knowledge, the objectivity of knowledge, the most important feature of modern science, is no longer guaranteed and jeopardized.

One of the means to prevent it from happening involves researchers writing twice: preprints for information flow and priority in “the context of discovery”, and review articles in refereed journals for assessment and

public recognition in “the context of persuasion.”

There is another problem. While movable type printing produces great quantities of a small range of publications, the preprint media are suitable for producing small quantities of a wide range of information types, a trait which accommodates the highly specialized situation of frontline scientific research. In the first place, as preprint media make it possible to disseminate small quantities of diverse scientific information, the trend towards high specialization will be spurred on still further. Since with the printing media it takes at least two to three hundred readers for a publication to be economically viable, there is an inherent brake on overspecialization. Whether conscious or not, the authors aim for topics of a wider and more general nature, rather than addressing specific issues to one or two readers. But with preprint media the number of readers is of little consequence. Indeed, the return to an esoteric manuscript tradition is the obvious consequence of this trend.

Finally there is the fear that by making knowledge private will once again revive exclusiveness which was a feature of the manuscript age. Preprints in academic science differ from manuscripts in that historically they have passed a merit system based on the openness of modern scholarship. They cannot be used by an individual to enhance his prestige by surreptitiously turning information into his own private property. Even though the printed journals of learned societies are really for specialists, they can be still read in libraries by the general public. Preprints on the other hand constitute private knowledge or community knowledge limited to a small community of research professions. There is no formal channel to the outside, even though research findings in academic science is not of a classified nature and not by its nature exclusive.

The Age of the Internet

While typewriters and copying machines have already technologically reached closure and been established as indispensable in our daily life, the development of digital media is still ongoing. Digital media, as reported in daily newspapers, is now called multimedia and covers word processors, facsimile, data-communication. It will develop in future as an open form of science communication.

Such new media will strengthen the reverse trend from public knowledge to private as occurred with typewriters, xerox copy machines and preprints. While printing creates many copies and small variety, digital media are, like preprints, a media of many varieties and small amount of copies. In this respect, there are no major changes in the transition from the days of preprints to the Internet age. More importantly, however, speeding up of dissemination of information is the condition of technology choice. Fax and what is more, the Internet is the means of real time academic communication. As it happens, the media now influences on not only the assessing mechanism but also the very style of scientific research. It is the age of the Internet when we realize that science is nothing but information. As the flow of information is now conducted in real time, and geographical boundaries like national borders become less and less meaningful, the flow of information becomes more important than the flow of material property. Accordingly, the style of science is subject to change.

The Internet network, which has a cloud-like coverage over our globe, is primarily developed by academic scientists and installed free and in the

open tradition of the modern scientific world. Though the Internet, as an academic network, is primarily that of academic researchers, it is open to everybody else. If scientific articles are shown on the web, it invites everybody else's attention and assessment, thus excluding the trend of being esoteric but open to the general public for their assessment. The ivory tower is now gone. What sort of assessment mechanism can be employed for the Internet? Priority problems would be liquidated, in principle, when scientific works are made available to everyone on the Internet. Namely, anybody can be a referee.

At the time of the birth of modern science in the seventeenth century, the advent of printing separated professional writers from general readers but this never happened in academic media. Researchers read papers for citation and write to be cited. Such a bilateral medium is more suited to the Internet rather than printing.

Many rules are necessary for internet articles to be adapted to the academic world. For instance, at the present time it is hard to quote articles on the web as it can be easily revised and often disappear. It cannot be used for permanent reference. Casual ideas can be easily put on the Internet, and there can be confusion in information gathering. Review articles should be introduced for screening and editing such informal writings.

Since it is possible to revise new media manuscripts very easily at any time, there will be no distinction made between a completed final version and an unpublicizable draft, or in other words, between public knowledge and private information. Therefore, we will be compelled to reinvent the means to direct the flow and assessment of information.

Or else, the structure of the academic world would be influenced by or

adjust itself to the new Internet media. In some areas of research, the traditional journal will be replaced by a data-bank, in which all new findings are stored. On the other hand, excerption from the treasury box of classical tradition was major style of traditional Chinese scholarship that is rapidly dying with the digitalization of all official dynastic histories and other classical compendia. Now, various trial-and-error attempts have been made and sooner or later they may find an appropriate niche and finally a new system will emerge.

So far I have discussed the effect of Internet communication within the academic community. Now the latter community in turn is expected to exert influence on the real world with the same Internet technology.

It is a distinctive feature in the history of post-war science that science in governmental and industrial sectors has taken over the mainstream position at least in terms of expenditure, to which academic sector has been subordinated. Internet technology is the only major work that academic science could develop to fit its value system of freedom and openness. It can be effectively employed toward establishing a free and open society. This is an instance of how meeting with an academic leader turned a mere hobby club of a personal computer network into an internationally known NGO group.

The free and open value system is commonly held in both the academic as well as citizen sectors. In reality, a number of groups have started in which socially minded academicians participate in community movements and took a lead in opening networks for democracy by using internet technology.

On the other hand, with the initiative of the citizens sector, they will utilize the Internet as a means to assess science and technology. Though

no appreciable trend is found on the part of scientists at large to share viewpoints with the concerned citizenry, there are some groups of people in the STS (Science, Technology and Society) movement who tried to bridge the viewpoints of citizenry and scientific community.

There are a number of scientists in the academic community who are close to governmental and industrial sectors mainly for research funds. Those people may be in a position to persuade governmental and industrial sectors that their hierarchical organizations are essentially incompatible with the free and open society that the Internet will bring about in future and it can be utterly impossible to privatize information space where Internet networking is in reality dominantly at work.

Scientific information in government as well as private enterprises has been in principle classified but with the advent of Internet networking it will move toward disclosure with the advent of two-directional Internet communication. In order to survive in Internet society, governments and enterprise, or capitalistic society itself, have to adjust themselves and convert their structure toward a free and open society.

References

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