Society's Needs in Scientific and Technical Information

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ABSTRACT

A second revolution in the transmission of scientific information, perhaps comparable to the advent of the scientific journal is presently underway. Rapid research front communication is no longer dependent upon the journal communication system which remains, however, the key record of the accumulation of scientific knowledge. A modern system might well include a daily newspaper format for high speed dissemination and a restructured set of journals based on the collection of papers into classes on the basis of their citation linkages. The processes of use and validation would thus be separated from that of the cumulation of scientific record, rather than combined as in the present system. Current bibliometric techniques make such a structure possible.

Galileo was embarrassed to find that he had to read books by colleagues so recent that they were still alive instead of being properly dead classics. Newton, a couple of generations later, was outraged to have his work questioned by living peers and resolved never thereafter to publish again one of these new-fangled scientific letters — we call them papers — but to go back to the normal licit process of writing a proper book.

To the accompaniment of such disturbances began the Scientific Revolution which has continued into the present age and been by far the mightiest force in producing all those changes which distinguish us from the people of the seventeenth century. Since diat time there have been several crucial changes, and it is instructive for my purpose to labor the point that so many of them have been dominated by crucial transformations in social and technical means for handling scientific and technical information.

It is my thesis here that we are already in the midst of a new and excitingly fundamental period of revolutionary change, the Scientific Technical Revolution as we are beginning to call it, and that in this too the seemingly passive element of information is actually a crux and a chief causal agent. It may well be that the innocent respectability of mere librarianship and the provision of incomprehensibly arcane journal literature for the egghead elite of scholarship may be the straw that makes or breaks the future of our civilization. It is the business of a professor sometimes to exaggerate in order to inspire or to expose the weakness of an argument for constructive attack, but I shall hope te show now that such an evaluation of present needs in scientific and technical information is no over-statement.

Increasingly and in all countries the lives of mankind are being dominated by what we call the High Technologies; those technologies that contain a high input of cumulating scientific knowledge and are thereby set apart from the more familiar and ancient Low Technologies where the inputs are raw material, energy, and the labors of skilled and unskilled, but not scientifically innovative, manpower. Important though the general notion of "information" seems to be, in most fields of human activity it appears primarily as a means of communication, a conduit or channel that facilitates the prime action. In science, and in particular with all that scientific innovation which is the chief input to our dominating High Technology, the "information" is not only a means of communication but in a curiously paradoxical and McLuhanesque way it *IS* the ultimate product of the work of the creative agent.

Scientific and Technical Information is thus the raw material resource on which our present revolutionary crisis rests, and it is therefore in this light that we must examine its historical evolution and find out first what it is that makes it work the way it does. Then we stand some chance of finding out what it is that is making it stop working like that and take a new route. We may desire to ease its path through that route or we might chose to divert it in new ways; in this case it seems impossible to avoid action and unlikely that we can avoid actions that cause dramatic and far-reaching

effects throughout the entire world.

The root of the whole matter is that scientific knowledge is basically different from all other forms of scholarship and all other forms of creative activity. Science consists of universal, positive, impersonal knowledge, but what matters about all these qualities is not so much any philosophical truth which they may or may not have, but that scientists act in general as if these tilings were true. Science seems universal in that researchers in Tokyo, Philadelphia and Kiev all think they are working on elucidating the same puzzles about superconductivity, immunoglobulin and plate tectonics. They footnote, correct and extend each others' work, tend to get much the same ideas about what to go onto next and when to drop an unfruitful line of enquiry. Work on Marek's disease seems oblivious to any influences of the language, politics, religion or personality of Marek. It may well depend quite a lot on his scientific reputation and the spread of his influence as a teacher or team leader or journal editor, but these are part of a social organization within science rather than exterior to it — at least in intention.

At all events it is a Different position to anything for example in the creative arts. Can one imagine a priority dispute between Beethoven and Mozart or Picasso and Klee to match that of Darwin and Wallace or Salk and Sabin? Darwin and Einstein might be great creative geniuses, but they were discovering a universe they took to be outside themselves and thus however magnificently distinct be their personal style, their discovery is impersonal. Each scientific discovery, large or small carries with it a feeling that it was there to be found, all in its own order and time perhaps, but to some degree inevitably. As science is laid down, piece by impersonal piece, like some gigantic universal jig-saw puzzle devised in the mind of an infinitely cunning Laplaciau creator, the contributions are not always sure-footed, they are far from secure either in the short term or long.

In. the short term, every scientist knows that he is capable of error. Sometimes it is a stupid error of a misplaced factor of 2 // [pi] or a wrong sign, sometimes one jumps to a false conclusion or misreads the meter, sometimes the error is so sophisticated that one docs not discover it until the next pieces of the puzzle fail to fit properly into place. Sometimes too, we do not realize that the contribution has been made before or must be altered to take account of other evidence that has escaped our attention, and at other times we might not realize that a pedestrian comment in the style of Wonder Dog can be the blinding inspiration for some perceptive peer.

These phenomena occur so widely together with all the long term changes in the paradigms of science that the act of creation in science remains incomplete without the assent and critical acceptance by one's peers in the whole scientific community. Not until the work is published, formally or informally, so that it is tested and either rejected or built upon has work been done. The evaluation may not always be fair — every scientist probably suspects that he is a bit of a Mendel and his work has not been appreciated as much as he would like — but it works automatically because there exists an International Knowledge Industry, a universal consensual sensorium. It is with the workings of this sensorium with which we are now concerned, but first we must hedge and explain that not all scientific and technical labor falls within it.

Sometimes when people find something new in the technical areas of scholarship they do not follow this paradoxical law of claiming private property by open publication, but use the normal property-law of keeping their creation and deriving benefit from it as a nation, a company or as an individual. One may invoke secrecy at the national or the industrial level, or one might use the legal devices of patents and licenses which trade a disclosure of information in return for a right to profit from the possession. Clearly this is advantageous in many respects which may be over-riding, though what one loses is the assistance of the rest of the world communication both in the process of validation and in the collaborative enterprise of proceeding further to build on this new advance.

A much larger exception in the world's scientific labors is simply that many people must be concerned not with adding to what we already know and can do, but with using that which we have now. Those that teach at all but the levels nearest the research front, and those that do much of the scientific and technical work of the nation use the knowlcdgc that was built in the past by all this cumulation and testing and communicated to them by the processes of education, training, and the encapsulation of knowledge into textbooks, manuals and work of reference.

Let us now turn to the International Knowledge Industry and see how its machinery has developed into the present crisis which afflicts all those that help generate, manipulate, and use scientific and technical information. The dilemma of Galileo was caused by the Gutenberg Revolution. Quite sharply around 1.500 the printed book graduated from its original role producing artificial manuscripts to become a new force of mass dissemination to a much wider audience than had been available to copyists. Like the windmill it had the property of requiring a large initial investment and then necessitating a steady stream of production, large in volume to amortize the costs.

Numbers of books grew exponentially, rapidly exhausting the supply of previous classics available for reprinting, and developing ever wider circles of readers and writers. As the presses became more and more voracious and easily available, the pulse

of publication quickened. By 1600 some vital time constant of publication had been reduced to *a* magnitude similar to that of the length of a lifetime, and by the middle of the seventeenth century it had quickened dramatically further.

This exponential force of destiny was so powerful that ephemeral publication of many sorts began to abound, political and religious tracts and broadsheets, sermons, and then the newspaper. In science, benefitting enormously already through the many potential authors to be found amongst the artisans and instrument-makers near to the printers, the force was so persuasive that the first two scientific journals were organized almost simultaneously in London and in Paris.

Those two journals, the Philosophical Transactions and the Journal des Sçavans produced very quickly, by the invention of the scientific paper, the major revolution of all time in the social organization and rate of flow of scientific and technical information. Splitting knowledge into atomic entities instead of waiting for it to gel and cumulate into a book obviously makes it run faster and much more cooperatively. There was indeed reaction to the method in the time of Newton, but by the eighteenth century the process settled down to a steady growth. Science encapsulated in papers became a sort of conspiracy that made knowledge run faster than people. And the scientific journals and its papers then grew exponentially much faster than books and doubling in numbers every decade or so, spreading to all countries and all fields.

Thus science burgeoned, as it has to the present day. It must be remembered that the mere burgeoning is 110 new problem. It is one that has ever since been felt and coped with quite successfully. It is true that we have found out as much in the last decade or so as in all previous time, and that 90% of all the scientists that have ever lived are alive now. But that has always been true since the 1660s. If we have problems it is perhaps because the United States is highly developed and cannot perhaps burgeon quite so fast relatively as the rest of the world, or because something other than the burgeoning rate has been changing.

What seems to have happened as a decisive change in science is that by the last half of the eighteenth century it broke through a couple of barriers of absolute size; the sheer magnitude of both the cumulation and rate of growth of papers being published In rapid succession one finds that Natural Philosophy splits into an ever-increasing series of sub-disciplines, such as physics and chemistry. Then the fragmentation and impossible bulk of what is known leads to encyclopedias, first in general, and then in specialized scientific areas. Then to cope with the increased flood come the first abstract journals, publishing summaries of all that has been published this year, then this month, then this week in each of the main compartments into which science has been divided.

The remedies and palliative measures introduced by the beginning of the nineteenth century seem to have been remarkably effective. All have prospered, growing exponentially in virtually perfect pace with the journals and their papers which were enabled thereby to continue their expansion unchecked through this size barrier. During all of the nineteenth century and halfway through the twentieth we have seen the steady growth of the primary literature and the secondary devices for handling it in a comprehensive and organic unity. The burgeoning has been frightening and almost unmanageable at all times but the whole apparatus has held together without radical renovation through cycle after cycle of the professionalization of science and technology, and the many order of magnitude increases in the size of manpower, libraries, and financial costs.

Successive increases by a factor of ten each decade or so have taken us through a factor of a thousand in the last century or so since the system was last overhauled. It is this crude fact that makes me think that what we are going through now is not just an evolution and a perfection nor even a patching-up of the secondary system but a dramatic and revolutionary reworking of the entire primary and secondary apparatus of scientific and technical information. Most experts are agreed that the International Information Industry will continue for at least the next half century or so to grow unchecked. The pay-off of science and technology is too great to leave undone anything that might be done. Even if the old established countries tire when so high a fraction of their manpower and money is devoted to these ends, rather than to other competing priorities, there arc still many countries and vast reserves of manpower that have only just begun their scientific and technical development.

We are faced then with the fact that scientific and technical information will almost certainly continue to grow at its usual exponential rate on the world scale for our generation and the next at least, but that the older established countries and those that have developed the most are scraping the bottom of the barrel in manpower, money and general effort in organization to keep up with the burgeoning. Again it is a matter of absolute size that creates the barrier. Even it the greatest scientific countries slacken their pace the race will go on. As Louis MacNeice has it;

The glass is falling hour by hour,
The glass will fall for ever.
But if you break the bloody glass,
You won't hold up the weather.

It is in this context that we must now examine the present set of crises so as to try and perceive the directions of probable change. We must look for hints of the new processes that can be engineered into providing the radical change that must needs

be invoked rather than being merely a continuation of the old palliatives. We must also remember that we are dealing with an international sensorium where the balance of national powers is likely to be changed quite drastically, and where the needs of the most developed countries are increased as their resources decrease.

The most fundamental change I see is that the time parameter of growth of information has steadily dropped to the point where it has broken through to quite a new sub-level. Since World War II there have been large improvements of old methods and inventions of new ones to keep up with the ever-increasing speed of communication between those at the research front. Traditional journals have been augmented by rapid publication letter periodicals which have taken on a life and a function of their own that transcends already their original function as merely "preliminary" publication. Preprints are systematically sent in mass circulation, and "preliminary" reports are steadily looking like more and more regular publications of their originating agencies. The mail, the telephone, the jet-plane and the tape and videotape recorders are all available technologies of rapid dissemination. Laboratories and institutes have been known to have open circuit communication by phone and computer with distant colleagues as a regular working tool.

Obviously a change has taken place, and equally obviously only a hairsbreadth of technical perfection separates us from the ultimate limit of being in reasonably instant, reasonably universal contact with all peers everywhere. Put that way it might seem startling and a sort of teclmutopia, but I for one believe it to be both inevitable and a good and valid societal need which has to be engineered efficiently and quickly. It is, I believe, even possible to suggest at least one rather grand but perhaps workable scheme which would help this process along well enough to last for another few generations. Before that however we must explore a force that holds back this sort of change.

The last generation of increased speed has been bought at high cost. The unique property of the scientific paper, the thing that made it the very life's blood of science and technology, was that these atoms of knowledge served a double function. As one published the unit contributions to be validated and used by one's peers, quite automatically it laid down the archive of learning. The serried ranks of scientific journals constituted what was called "The Literature." One searched the cumulation of journals and then one knew what was known. Of course, the really old stuff had been packed down into textbooks and handbooks; it had been absorbed with the mother's milk in that process known as graduate education or one could look it up in the Handbook of Chemistry and Physics. Then you were running with the pack and trying with them to do something new.

The automatic double function has been lost in the latest and ultimate round in improving the speed and efficiency of communication between peers. No longer does the process at the research front pack down automatically into a corpus of knowledge. It probably never did it very efficiently anyway. The eighteenth century crisis of encyclopedism and later ones of complete and compendious bibliographies show there were problems then. The more recent concern with textbook writing and the appearance of special journals devoted to "Reviews of Recent Advances in X, Y and *1"* show that dissatisfaction has grown. One must remember that the corpus must be somehow packed down, wrapped up, digested, made available, not only for those on their way to the various parts of the research front. All those who are using what we already know and those who work in any way behind the front need this knowledge for it is the ultimate product of all the effort and creative energy that has been used up to date in all the world.

What I say is that we should cut the anchor and sail clear. Let us admit that communicating at the research front and managing a cumulated corpus of learning are by now separate and distinct functions and do what we can to help each separately and in relation to each other. Our present practice seems like using a total file of the *New York Times* as a history book; it would be attractive but for most purposes it is unmanageable. Perhaps worse, it would be like trying to publish the *New York Times* under the constraint that each issue serve as the next section of a loose-leaf permanent history text. We really want to know more about more things than will eventually need to pack down into the received story of the nation. I chose the analogy deliberately, for as far as I can see, what we are moving towards in the communication function in scientific and technical information is a newspaper form that parallels the *Wall Street Journal* and the *Financial Times.* The most rapidly communicative journals have moved from monthly to weekly, and I must suppose that they will wish to go daily — for highly prestigious hot news one already uses the ordinary newspapers for scientific items unless the anchor is down and "proper" archival publication is jealously conserved. Presumably one could already use the accepted technologies of simultaneous production at several printing centers, just as easy with satellite transmission on an international basis as it is now across a single continent. On a weekly basis and perhaps even on a daily one I see no reason in the comparative cost of alternative services why such a newspaper format could not be produced in Russian and Japanese as well as any other language over and above the English that accounts for about half of the world's scientific and technical information.

Of course such a communication device would be a newspaper only in format and the fact that you threw it away or recycled it each day. The content would not be scientific and technical news stories quite so much as the analogs of the stock market prices which are what make those other newspapers essential. Whatever we do in scientific and technical communication we shall need those monitoring devices of the massive abstract journals — Chemical Abstracts, Physics Abstracts, Index Medicus, Mathematical Reviews, and all the current awareness aids such as Current Contents, the Citation Index, Indexes of Chemical Compounds, and so on. We shall also need more and more of the quicky journals with their letter form of publication.

I calculate that if one were to put all this mix together in a barrel, perhaps cutting out some of the more obviously overlapping entries, and divide it all into a daily dose it would go into a formal the same size and shape as the *Wall Street Journal* with enough room left over for the newsier parts of the journals *Science, Nature, Lancet* and the *New Scientist* and sufficient space for advertising (in the capitalist countries only) to make it no more uneconomic than the present tottering services — only a brave few of which are commercial and survive without heavy subsidy. I am not quite so starry-eyed an idealist as to imagine that anyone will design and deliver to us such a complete package, nor do I believe that the entrenched forces of present services will readily relinquish their holdings to any alternative. I do however suppose that this is where we are probably heading, willy-nilly, and that we might make transitions easier if we took step by step actions that eased rather than thwarted the process.

Assuming then that *SciTech News* arrives every day everywhere and is duly thrown away, how then do we pack down the archive of new knowledge for all the would-be users as the research front and behind? Strangely enough the basic problems and present trends seem to be in the areas oi comprehending, consolidating and ordering the cumulating information rather than in those of publishing techniques. Journals of the traditional sort go on and will continue albeit with new printing technologies such as photocomposition and microform, new economics because of rising costs and a falling affluence of scientists and libraries, because they exist as the end product of work in the field. Journals are for publishing in rather than for reading. In that form it sounds cynical but in so much of the heart of science and technology there is no substitute for the traditional hard copy which is given peer review once it has been found by the communication process.

In publication the trend seems to be with international high status journals of which *Physical Review* has become the paradigm for the whole world community. If you live in Istanbul and do something really good in physics it goes into Physical Review not into the domestic Turkish journal. We still tend to follow the original historic foundations of the various National Academies of Science and consider national journals in totally transnational subjects to be still a matter of pride. Í do not see that this is functional, realistic or economic. Far better it would be if each area of science had its analog of *Physical Review,* and if *Physical Review* itself were universally treated as the single high status journal. Again it is only a hairsbreadth of technology that stops us from multilingual publication and rapid delivery. Again it would be idealistic not to suppose that there are grave economic problems as well as organizational and probably political, but perhaps it can serve as a target towards which we can direct steady change in pursuit of our needs. What of low status journals and even the national journals in fields that have such an international giant? Is there a case for preserving at greater and greater expense with less and less return a medium for papers which have consumed resources without meriting (rather obtaining) high status publication? How much should we be willing to pay for the mere national and personal pride of showing results and giving opportunity and visibility to unrecognized worth and recognized non-worth? I confess I do not know, but I think that these questions must be asked explicitly and answered within the next generation. In this country of all places one knows the value of preserving multiple channels and avoiding monolithic centralization of power. My guess is that a certain element of monolithicness is built into science; in the transnational community there is only the one chemistry and no alternative. My guess, for what it is worth, is that as time goes on we shall be less and less willing to subsidize any publication that is not high status in its own right, and even more unwilling to clutter the communication channels with information pollution so generated.

The trick of ordering all this scientific and technical information so that it can be found in *SciTech News* each day, and comprehended and consolidated from the high status traditional style publications lies in a new research result in bibliometrics which I should like now to explain. Bibliometrics sounds as if it means some sort of book-counting routine indulged in by librarians to tell them how many cataloguers they need to service a flow of readers. It probably includes that sort of practical art, but it has become rather sophisticated of late and in this recent work at least it seems to me that it has produced a result of the deepest philosophical importance as well as just the thing needed to pull a practical rabbit out of this hat.

I'm here today because the main work in establishing this result has been done by Prof. Belver Griffith

of the Graduate Library School, here at Drexcl and by Dr. Henry Small of the Institute for Scientific Information, also here in Philadelphia. What they have done is to look, for the first time empirically, at the natural structure that is packed into the world corpus of scientific papers as they are laid down by the daily cumulations. I must explain why this is important. We used to hope that the computer would come to our aid by some sort of magic capacity to index everything perfectly frontwards, backwards, sideways and upsidcdown and enable us to find all that good information that lay chaotically in all in our libraries. As with the hopes for automatic translation by computer the results have been disappointing, and we have discovered a whole difficulty of which we were ignorant, rather than a practical and perfectibly technique.

There exist some special types of scientific data which may be almost perfectly sorted into a series of pigeonholes because some natural and complete classification scheme occurs in that particular aspect of the universe that is being considered. Such data is called taxonomic, since the paradigm is the unmistakable nomenclature that was devised for the biological genera and species of botany and of zoology. A similarly precise set of pigeonholes covers all the atomic nuclei, and one of the greatest information science achievements of recent decades has been the invention and perfection of the elaborate taxonomic scheme which now can be used to classify unambiguously every one of the many million different organic chemical molecules, no matter how great their complexity.

When a set of scientific papers can be described for all working purposes by such a taxonomic system we can reach thereby perfect indexing, Of course there remain huge difficulties of trying to reconcile results expressed in different units and with techniques that prove incompatible, so that the total information can seldom be integrated automatically into anything like a perfect computerized data bank, but the basic problem of organizing the papers is tractable in that sort of situation. It seems hopeful from this that the most numerous of all classes of papers, those reporting the biological effects of large organic molecules, might be handled in this way and removed from the system which they tend to dominate by their special problems. In all such cases one should try to institute an entirely separate machinery for primary publication and secondary handling and encourage authors of papers to write for this system rather than in the more free and general way that is possible outside the taxonomic constraints.

Most regions of science are not blessed with the perfection of a taxonomic classification for the newthings they wish to report. Even a bird-watcher, normally a very taxonomic information gatherer may sometimes wish to report data that pertain not to any particular species of bird but about birds in general; or he might have data that should be classified so that it might be found by a meteorologist rather than another bird watcher. In this case our papers are nontaxonomic, and it becomes clearer daily that we can never expect even the cleverest computer supplied with the most cunning schemes of indexes and descriptors to give us anything like the powers of recall and of relevance needed by workers at the research front. We even have good reasons for supposing on the basis of information theory that this is one of the fundamental and powerful principles of incompetence built into nature, like Heisenberg's Uncertainty Principle or the speed of light limitation in Relativity.

What Griffith and Small have done is to use the Science Citation Index computer tapes to get the genera] pattern of how papers arc related to each other to a greater or smaller degree by citing each other. W[r]e have known for a long time that something like this should be possible but the difficulty is that the system is very noisy not only because of errors but also because there is very much citation that does not follow any pattern but is smeared out all over the network of papers because we use citation for so many purposes over and above the linking of papers that bear substantive relation to each other.

The actual trick they have used is very ingenious, counting co-citations with suitable thresholds of intensity, but the point is that it gives good clear orderly data for the first time; it works. The spectacular result is that the universe of recent atoms of information are arranged in separate molecular clusters. Papers hang together naturally in bunches, so that each paper in the bunch is related strongly to all the others in the same bunch and only rather weakly to any in neighboring bunches. Not only can one detect the existence of the individual bunches but the relative place of each atom in the molecule can be found, and the arrangement of the molecules relative to each other can also be determined. The work is only still in its experimental stage, and much remains to be done, but it looks as if it not only tells us much more than we have ever known about the nature of knowledge but it also gives the vital clue on how to cope with it after the frustration of indexing.

Fortunately for us the universe of scientific and technical information is not a continuum with every subject bearing upon every other in an indivisible whole. The usual major division we have now, Organic Chemistry, Solid State Physics, Metallurgy, Cosmology, are all much bigger than any natural molecule and may simply be the debris from a once single molecule that has grown and split many times over through history. The actual clusters become obviously identified when one looks through the names of the individual atoms of papers in them. They correspond to subjects like:

mitochondria
super-conductivity
paramagnetic shift reagents
Australia antigen
solid state critical phenomena

In general they are exactly the sort of thing answered when you ask a research scientist what *specifically* he is working on. Doubtless these molecules change with time, evolve and alter the words used to describe the same team of people as it moves on. The nice thing is that we know now how to keep track of the changes and one could even hopefully produce a great Operations Room wall map for world science that charted the new territory of information as it was won and showed with flashing lights and colored markers where the action was and from which laboratories in which countries, which research grants and which key people.

For the present purpose all I need is the knowledge that these molecules of atomic information are the products of the so called Invisible Colleges of people who live in a sort of nutrient fluid supplied almost entirely by each other's work. It is these unique sub-fields that should each be served by their proper journal. Physics or Chemistry or Mathematics are far too large and unrealistic as entities except perhaps in the professional social structure of university departments, though they could reasonably be disected into their component clusters as autonomous sections.

My proposition then is that we use a refined operational version of the Griffith-Small process to take scientific and technical non-taxonomic information and split it into bite-size chunks. Each sub-field, as monitored in its evolution is known to correspond to a rather stable but growing core of key workers in its invisible college with a large floating population of lesser researchers, mostly at the formative stages of their careers. Let us tailor the primary journals to each sub-field separately, trying always to see if an international high status journal can be generated and maintained by such a population of probably not more than about a thousand key people all over the world. Rather less than a thousand, perhaps only a few hundred such journals could probably cover and control the whole of current literature.

Of course we would still have the residual problems, by no means trivial of packing down such material into textbooks and reviews, but the old idea of "divide and conquer" makes the problem seem to me to be far from insuperable. The same constantly changing but constantly monitored classification scheme into the new sub-fields could be used to divide *SciTech News* into appropriate sections and incidentally the new operations room wall map would give instant alert on the occasion of breakthroughs. I think that again we have here a plausible objective rather than an ideal, but I hope by now I have given an outline to show that we may look with hope rather than despair at the needs of society on the brink of this new revolution in scientific and technical information.

RESUMO

Processa-se, presentemente, uma segunda revolução na transmissão da informação científica, comparável, talvez, ao advento do periódico científico. A rapidez de comunicação na frente de pesquisa não mais depende do sistema de comunicação da literatura periódica, que permanece, no entanto, o principal veículo para o registro do conhecimento científico. Um sistema moderno poderia incluir um periódico diário, para rápida disseminação, e também um conjunto de periódicos baseado em uma coleção de documentos reestruturado em classes, de acordo com correlação de citações. Desta forma, os processos de utilização ,e validade seriam separados dos cie acumulação do registro científico, em vez de combinados, como acontece no presente sistema. As técnicas bibliométricas atuais tornam tal estrutura possível.

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