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Modern science and the explosion of new knowledge [1]

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Abstract

The technological evolution of mankind accelerated enormously after the institutionalization of science in the 19th century. In parallel with the vast number of beneficial effects derived from the scientific revolution, the explosion of new knowledge and its centralization in only a few countries has generated a number of complex situations that present major challenges for the modern science. These include the asymmetrical distribution in the planet of young people and science, the super-specialization derived from the information overload and the difficulties in teaching the vast amount of new knowledge generated each year by science. © 1997 Elsevier Science B.V.

Keywords: Modern science; Science education; Information overload; Super-specialization; Education and development

1. Background

From the beginning, human beings have sought to understand the natural phenomena around them. Science as we know it grew out of these early efforts to understand nature, and the history of science is intimately linked to the history of humanity itself. Science in its present form originated from the 14th century. The combination of historical movements such as the Renaissance and the Reformation in Europe led to profound changes in man's view of himself and the world around him. As formulated by Francis Bacon the scientific method set aside empiricism and the supernatural in favor of observing a phenomenon, classifying it and determining its causes. The scientific method was established definitively in René Descartes' *Discourse on Method*, in 1637. In this work, fundamental to modern science, Descartes breaks with the ideas of Aristotle and scholasticism, where observation and logic alone were considered adequate basis for a satisfactory explanation of natural phenomena. Descartes set forth a scientific philosophy similar to mathematics, where observations and their interpretation were legitimized by demonstration.

In the 17th century, science flourished on the universities of Europe and later North America. At this time, the first scientific societies and academies were created, gathering experts from different fields and publishing the first scientific journals (Table 1). In England, the Royal Society developed a system for evaluating the quality of scientific endeavors, forerunner of today's peer review system and currently in use for evaluating research proposals as

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Table 1
The first institutes and scientific academies

Year	Institute	
1560	Italy–Academia Secretorum Naturae	Founded in Naples by the physicist della Porta. Closed by the 'Inquisition'
1650–1690	England–Cambridge University	Founded in 1209, originally under strong religious influence. In the 17th century, emphasized mathematics and natural sciences due to the group of scholars known as the 'Cambridge Platonists', which included Isaac Barrow and Isaac Newton.
1660	England–Royal Society of London for Improving Natural Knowledge	In 1645, a group of English scientists began to meet regularly in London to discuss different subjects related to natural sciences. One of the major participants was Robert Boyle. In 1662, during the reign of Charles II the Royal Society was founded by royal decree. Its goal was to promote scientific excellence and to stimulate scientific research and explore its applications.
1666	France–Académie des Sciences	Created to promote mathematical and physical sciences (geometry, astronomy, chemistry, botany and anatomy.
1701	USA–Yale University	Founded in Brandford, received it official name only in 1887. In the early 19th ecntury, established its first professional schools; in 1861, it conferred the first PhD degree in the US.
1780	USA–American Academy of Arts and Science	Founded in Boston. Supports projects designed to relate the intellectual resources of the learned professions to problems of science and of social and technical change.
1863	USA–National Academys of Sciences	Created in accordance with a law passed by the American Congress, with the objective of stimulating and publicizing the scientific research of interest to any American federal institution.
1865	USA–Massachusetts Institute for Technology	Founded by the geolists W.B. Rogers, with the primary objective to advance the fields of science of interest to industry.
1876	Brazil–National Museum	Founded in 1818 in the city of Rio de Janeiro. Originally its purpose was 'to disseminate knowledge, to promote studies in the natural sciences and to preserve material of interest for observation'. In 1876, it was restructured into three sections: (1) Anthropology, General and Applied Zoology, Comparative Anatomy, Animal Paleontology; (2) General and Applied Botanic and Botanical Paleontology; and (3) Physical Sciences (Mineralogy, Geology and General Paleontology).
1900	Brazil–Oswaldo Cruz Institute	First Brazilian institute of scientific research to achieve international recognition.
1901	USA—Rockefeller Institute	Founded in New York. The first biomedical research center in the US for Medical Research
1920	Brazil—University of Brazil	The first Brazilian public university. Originally, it brought together schools operating in the state of Rio de Janeiro: the Medical School, the Polyechnical School and the Law School.
1921	Brazil–Brazilian Academy of Sciences	Organized in 1916 as the Brazilian Society for Sciences. The name was changed to its present form in 1921, but received permanent housing only in 1960.
1930	USA–National Institutes of Health	Agency of the US Department of Health and Human Services, the NIH seeks to improve the health of the American people. It supports and develops biomedical research in to the cause and prevention of diseases.
1934	Brazil–University of São Paulo	The Brazilian university with the greatest international prestige at present.
1945	Brazil–Institute of Biophysics Carlos Chagas Filho	First research center founded as a part of the University of Brazil.
1951	Brazil–CNPq[a] and CAPES[b]	The first federal agencies to support Brazilian science (CNPq) and to promote graduate programs in science (CAPES).
1960	Brazil–FAPESP[c]	State agency for the promotion of science in the state of São Paulo. Receives 1% of the state's tax receipts to spend on scientific activities.
1964	Brazil–COPPE[d]	Graduate course in engineering created in the Federal University of Rio de Janeiro. Currently considered one of the best programs in this area in Latin America.
1967	Brasil–FINEP[e]	Supports research projects in science and technology.

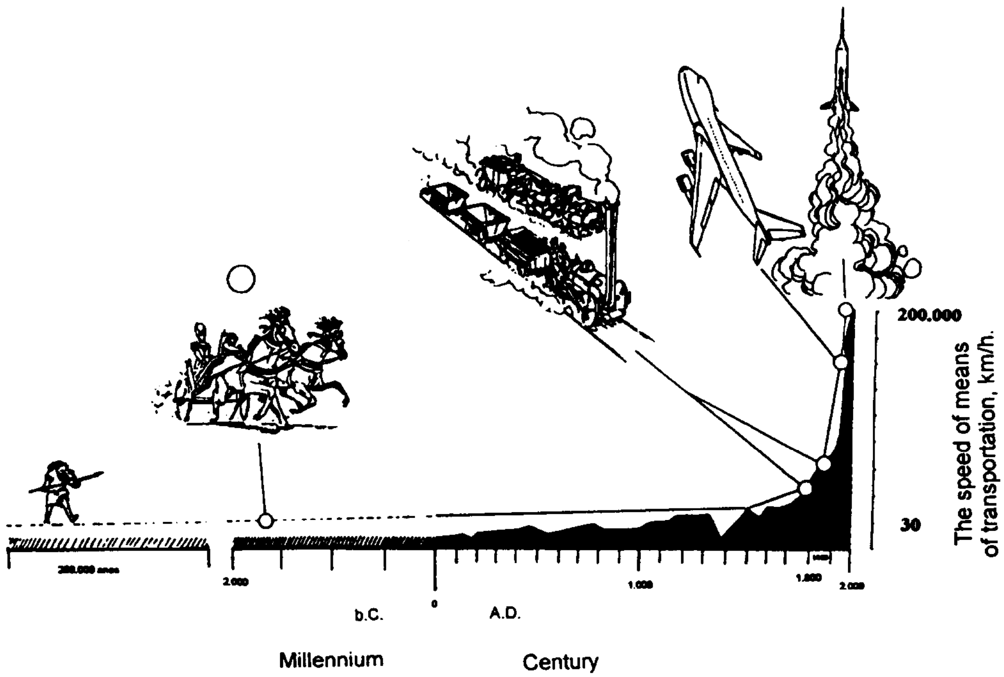

Fig. 1. Evolution of means of transportation. The abscissa shows the passage of time (on a variable scale) and the ordinate shows the speed of the means of transportation on a logarithmic scale.

well as scientific publications. Western science was finally institutionalized in Europe and in the USA during the 19th century, when financing by private groups and by federal governments began, which set aside part of the national budget specifically for science. Since then, the practical consequences of scientific activity have became evident, and it is clear that science has had a profound impact on the lives of everyone on the planet [1–3].

The technological evolution of mankind accelerated enormously after the institutionalization of science. In Figs. 1 and 2, this acceleration is illustrated by two indices: The means of transportation and the population growth on the planet during the last 5000 years. For centuries, *Homo sapiens* and his predecessors depended on their own physical efforts to move from one place to another, walking and carrying the few belongings that they needed for survival. *Homo sapiens* took almost 250 000 years to invent the wheel, and about 5000 years more to attach it to a steam engine (Fig. 1). No one knows who invented the wheel, or where. The oldest drawings and sculptures that depict vehicles with wheels date from 4000 bC, from Elam, in Mesopotamia. From this time until the beginning of 19th century AD, there were few technological advances in land transportation.

Notes to Table 1:
[a] Conselho Nacional para o Desenvolvimento Científico e Tecnológico.
[b] Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.
[c] Fundação de Amparo à Pesquisa de São Paulo.
[d] Coordenadoria de Programas de Pós-Graduação em Engenharia.
[e] Financiadora de Estudos e Projetos.

Thus, the maximum speed reached by the war chariots used by Tutankhamen against the Asiatic peoples (about 1300 AD) was similar to that of an American stagecoach in the early 1800's, neither one was able to move faster than 30 km h^{-1}. The first steam engine able to pull several cars as fast as a galloping horse (20 to 26 km h^{-1}) was invented only in 1825, by George Stephenson. From then on, the evolution of transportation was extremely fast, and in 1957, just 132 years later, the first space-rocket was launched carrying the 'Sputnik'. Only a few years later, the space-rocket 'Helios' reached 240000 km h^{-1} in less than 10 min [4] and 'Galileo', launched toward Jupiter by NASA in 1989, traveled for six years at an average speed of 70000 km h^{-1}. After this long journey, it ejected a probe onto the surface of Jupiter at a speed of 170000 km h^{-1}. For comparative purposes, if we condense mankind's existence during the last 250000 years into just one day, the invention of the wheel would have occurred in the last 29 min, Descartes' treatise on the scientific method would have been published in the last 2 min and George Stephenson's steam engine would have reached the speed of a horse in the last minute of the day.

Regarding the world population (Fig. 2), it has been estimated that at the time of the birth of Christ there were about 300 million people living on the planet. At the beginning of 19th century, the world's population reached 900 million [4] and in 1990 it had grown to 5.6 billion [5]. Thus, it took 19 centuries for the world's population to triple and then less than two centuries for it to increase sixfold. Among the discoveries that allowed such an exponential growth curve were antiseptics, vaccines, antibiotics, fertilizers and new agricultural techniques that led to large increases in food production. Population growth in the last 150 years is certainly related to the increase in life expectancy, which has risen from 30 to 60–80 years old, depending on the region. By and large, the behavior and social views of people 40 to 80 years old are quite different from those who are 15 to 30

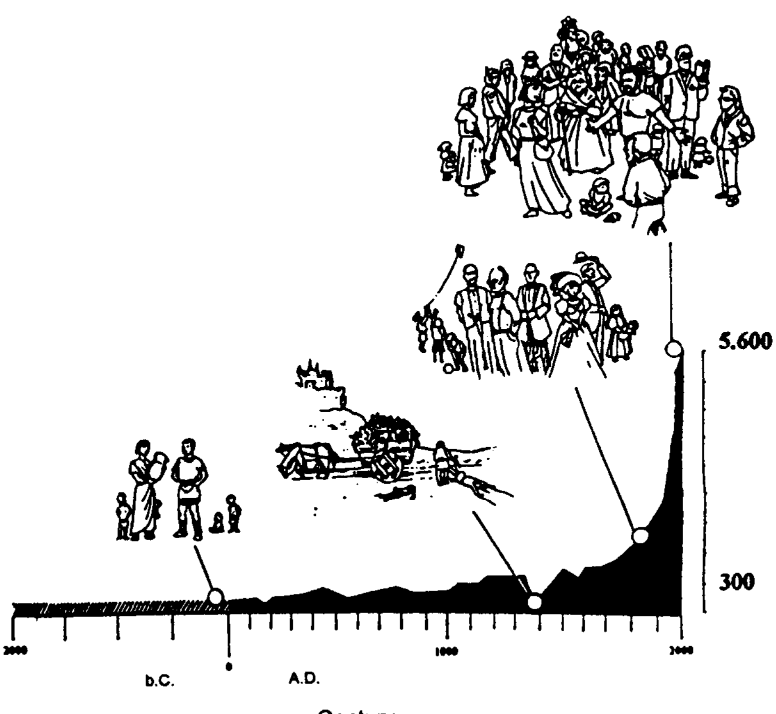

Fig. 2. Population growth. The abscissa shows the passage of time (on a variable scale) and the ordinate shows the number of inhabitants on the planet on a logarithmic scale.

years old. The increase in the percentage of the world's population in the 40- to 80-year-old age bracket during the last two centuries has led to changes in habits and social practices, especially in large cities.

2. Centralization of knowledge and challenges for the next millennium

The explosive production of new knowledge that has occurred since the 19th century has not been distributed equally around the world. The increase in new knowledge was, and continues to be, centralized in a few countries in the Northern hemisphere: the USA, England, the countries of the former Soviet Union, Germany, France, Japan and Canada (Table 2). These countries are primarily responsible for the discoveries that have led to the greatest changes in the world during the last two centuries. The concentration of intense intellectual activity in a few places on the planet that characterizes the scientific revolution after Descartes is not a unique event in mankind's history. Similar 'hot spots' can be identified in the 7th century bC, when philosophy and the arts flourished in Greece and in the 15th and 16th centuries AD, during the Italian Renaissance. Both of these historical periods were characterized by a blooming of ideas and knowledge in a restricted region of the planet, followed by a gradual dissemination to the rest of the world.

In parallel with the vast number of beneficial effects derived from the scientific revolution, including the increase in life expectancy, the explosion of new knowledge and its centralization in only a few countries has generated a number of complex situations that present major challenges for the modern science in the planet. Among the more critical of these challenges are:

Table 2
The centralization of knowledge

Countries	% of published articles		
	1981	1984	1989
USA	36.9	36.9	35.1
England	8.4	8.1	7.7
Soviet Union	7.6	7.6	4.2
Germany	6.3	6.0	5.6
France	5.2	5.0	6.9
Japan	7.1	7.6	7.5
Canada	4.1	4.3	4.0
Rest of the world	24.5	24.9	29.0
Brazil	0.29	0.34	0.47
Total number of publications	783339	867819	859946

Data from the Institute for Scientific Information (ISI). Includes all the scientific articles published in journals indexed in the ISI database.

3. Technological distortions

The countries responsible for the scientific revolution continue to be those where the majority of new discoveries are made each year. Thus, more than 70% of the scientific reports published each year originated in these countries. This number can be estimated from the number of scientific publications in journals catalogued in the Institute for Scientific Information (ISI) database (Table 2). In 1990, the population of these countries accounted for 14% of the world's total [5]. The rest of the countries, with 86% of the world's population, produce altogether only 25% to 29% of the new knowledge each year (Table 2). Thus, there is a pronounced dichotomy: On the one hand, a small group of countries producing a large amount of new knowledge and on the other hand, a much larger group of countries that consume it [6]. We consume new knowledge every time we buy new drugs, or travel on the latest model airplane; when we use telecommunications facilities, or when we receive information from satellites for predicting the weather. In most of the 'consumer' countries, the trends that led the institutionalization of science appeared almost two centuries later than in the 'producer' countries. This is shown in Table 1, where Brazil is included as an example of a developing country where science has grown rapidly during the last decades. Considering how recently the exponential growth of knowledge has occurred (Figs. 1 and 2), a delay of only a few decades during this process represents an enormous difference in scientific and technological development. The capacity to produce new knowledge has been a key factor in determining the current distribution of the world's economic power. Thus, the centralization of science in a few countries encourages social and economic tensions that may seriously retard progress toward establishing world peace and laying down foundations for the 'global village', two of the major goals for mankind.

4. Asymmetrical distribution of young people and science

Countries that have achieved a more advanced scientific and economic development have learned how to control their population growth (Fig. 3). This fact has enhanced the discrepancies that characterize the distribution of young people and adults in developed and developing countries. As shown in Fig. 4, the difference in distribution of young people between the countries of North America and Latin America has increased from 1980 to 1995. A comparison between Table 2 and Figs. 3 and 4 reveals the great challenge that confronts modern education: *Countries with the lowest scientific development are responsible for educating the majority of the world's young people.* The everyday demands of the new technological era require that young people enter the workforce armed with increasingly sophisticated scientific and technological skills. As an example, banks

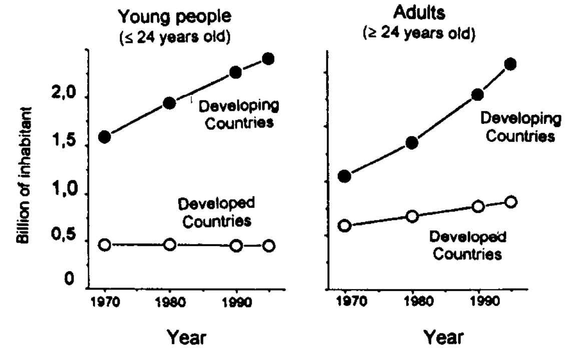

Fig. 3. Number of young people (left) and adults (right) in developed and developing countries. Data from Unesco [5].

are replacing their cashiers with automatic tellers. As a consequence, even the simple act of withdrawing money from an account is more difficult for someone who does not have a rudimentary notion of computers. On the other hand, the great demand for new products in the world's markets, and thus the demand for new knowledge, leads to a progressive increase in the demand for workers in fields related to science in developed countries, especially in the industrial sector. In the USA, for example, this increase in demand has not been accompanied by an increase in the number of young people or in the

Table 3
Science in the United States

Indicator	Year 1975 (a)	1985 (b)	1991 (c)	Ratio b/a	c/a
(I) *Workforce*					
Employed scientists and engineers	2.3×10^6	4.6×10^6	–	2.00	–
Employed scientists and engineers with a PhD degree	213 507	334 505	367 440	1.57	1.72
(II) *Unemployment*					
Among scientists with a PhD degree	3.4%	1.6%	2.8%	0.47	0.82
Among all careers (average)	7.2%	7.3%	6.6%	1.01	0.92
(III) *Annual salary* (in dollars)					
Average	22 600	42 500	59 000	1.80	2.61
Average for a PhD ≤ 5 years of experience	21 500	40 800	43 700	1.9	2.03
(IV) *Human resources*					
Number of people ≤ 24 years old	97.6×10^6	96.1×10^6	91×10^6	0.98	0.93
Number of PhD degrees awarded	32 951	31 211	31 770	0.95	0.96
Median age of employed PhD's scientists.	35 to 39	40 to 44	45 to 49		

Data from Refs. [8,11]

number of PhD students graduated each year (Table 3). In order to meliorate this situation, the US government has adopted measures that facilitate the entry of foreign young people who want to work in science and technology. This policy has been so effective that American young people with PhD or post-doctoral fellowships are in the minority in the country's research laboratories. The majority of foreign students in these positions come from the Orient, the largest source of young people on the planet. In spite of this trend, the increase in number of non-American young people with PhD degrees in the USA has not been sufficient to meet the needs of the American market [7]. As a result, the unemployment indicators for science are low, the average annual salary is increasing and the average age of the scientific workforce is increasing yearly at an alarming rate (Table 3 and Fig. 5). After their post-doctoral training, the most highly qualified foreign students enter the American job market. Data from the US National Science Foundation [8,9] show that in 1982, foreign scientists employed in the US represented 13% of the nation's scientific workforce, whereas in 1991, this fraction had increased to 17.2%. The increase in absolute numbers is even greater, since the total number of employed scientists increases every year (Table 3).

The unequal distribution of scientists and young people among different parts of the globe allows us to imagine several different scenarios: (1) The few competent scientists now working in developing countries, attracted by the facilities offered where the demand is high, may migrate in increasing numbers to other countries where science and technology are well established. This migration would empty out the laboratories in developing countries and aggravate the socio-economic contrasts between 'producer' and 'consumer' countries. (2) Private industry in developed countries will promote a progressive transfer of its research and development to developing countries, as a means of compensating for the deficit in qualified workers at home; (3) The rate of production of new knowledge in the next millennium will decrease.

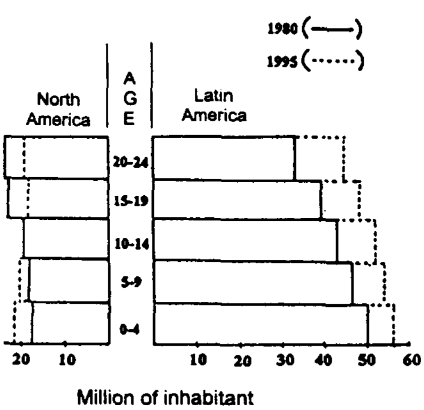

Fig. 4. Pyramid of young people (≤ 24 years old). Distribution of young people in different age brackets in North American and Latin American countries. Data from Unesco [5].

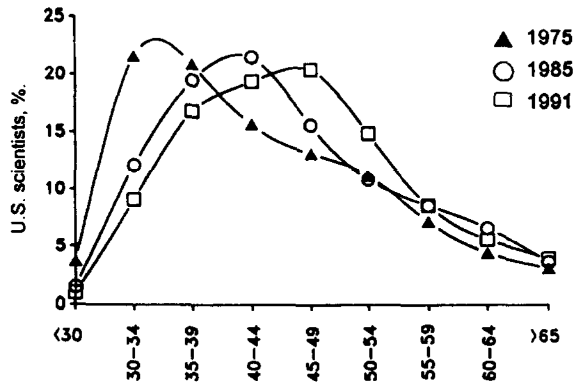

Fig. 5. The aging of American scientists. Data from NSF [8,9].

The happening of scenarios like these, or others generated by the discrepancies in the distribution of science and young people, clearly will depend on the policies adopted by the governments of the 'producers' and 'consumers' of new knowledge.

5. Information overload, the decoding of knowledge and super-specialization

In the 18th century the library of University of Oxford, one of the largest in the Western world, had approximately 200 books dealing with various aspects of science. If one of the university lecturers at that time wished to update his knowledge by spending 8 h a day and reading seven to eight pages an hour, resting on Saturday and Sunday, in the course of a year he could read all 200 books. Thus, he would have at his fingertips all of the facts in that library, and he would not have to worry about keeping abreast of new publications: The rate of producing new knowledge at that time was very slow, and it would take years to add even 10% to the total number of books. Today, taking into account only the scientific journals listed in the ISI database, there are almost one million scientific articles published each year (Table 2). If we consider only one field, biochemistry, for example, the 151 journals indexed by ISI in this area publish about 60 000 articles per year. The Journal of Biological Chemistry, the official journal of the American Society of Biochemistry and Molecular Biology, publishes 440 to 480 articles each month. If a university professor who wishes to update his knowledge of biochemistry reads an article per hour for 10 h a day, every day of the year, including Saturdays and Sundays, he will read only 6% of all the articles published in biochemistry in that year. In this example, the professor will not have time to teach or to carry out any other academic activity. Worse yet, if he persists in trying to keep up with the literature in biochemistry, he will somehow have to assimilate the remaining 94% of the articles for that year and an equal number of new articles of the following year. This example reveals the necessity for super-specialization. In order to remain productive, the professor in this instance will have to be content to keep up with new developments in only one particular area of biochemistry. Thus, in his own specialty he will be familiar with most of the accessible information, including the latest information published in the last two or three years. In general biochemistry, he will have notions of what happened in the last two decades, whereas in the physical sciences he will be restricted to well-entrenched concepts such as those elaborated by Sir Isaac Newton during the 17th century, and in mathematics he will probably be conversant with concepts that were first set forth at the beginning of this millennium. Thus, the enormous volume of information produced yearly leads people to attain different levels of knowledge in each field. In his specialty, the biochemist in our example acts as a 'decoder'. He is able to select from the large quantity of new information just items of interest in his specialty and, during seminars or in the classroom, he is able to summarize for his colleagues and students, in a succinct and cogent way, the advances made in his subject. For this reason, the scientific research carried out in a university context plays an important role not only in the production of new knowledge but also as a means of providing students with access to this knowledge, and thus to the latest advances in science. Thus, the modern scientist also acts as a 'decoder', and the importance of the University increases with its capacity to 'decode' new knowledge in a broad range of specialties in different fields, for a large number of students.

6. Science education

Among the different fields of knowledge, education is one that has advanced at a relatively slow rate during the last two centuries. The great discrepancy between the search for new knowledge and the way in which it is taught is exemplified by the reduced number of scientific journals and articles on education. In 1993, there were 7421 scientific journals listed in the ISI database and only 92 (1.2%) dealt with some aspect of education in different subjects. During the period from 1981 to 1993, 7 756 888 scientific articles were published in the journals covered by ISI, but only 36 212 (0.5%) were related to education. Science today is taught more then two centuries ago, using lectures and laboratory classes and, in the best institutions, tutorial instruction. The primary goal is still one of transmitting the largest number of facts to the students. In this context, the expectation is that the students who graduate will be familiar with the current concepts in their chosen fields. However, the explosion of knowledge in recent years has made this task impossible and, in fact, we do not yet know how to prepare our students to deal efficiently with the large amount of new information that is produced every year, a capability that seems to be essential for a professional at the cutting edge of science.

7. Hidden knowledge

For strategic and economic reasons, a significant fraction of the new knowledge generated by industries and in government-sponsored projects is not available to the public; obvious examples can be drawn from nuclear physics and other projects related to space programs. It is difficult to estimate how much of the new information produced each year is not published. By comparing annual expendures for science, number of scientific publications per year and number of authors per publication from 1975 to 1985 [7] it is estimated that unpublished scientific findings in the USA represent about half of the total body of new knowledge produced each year.

In some science areas that are especially important to industries, research in the private sector has grown so remarkably that today industry has replaced the university as a point of reference for students who seek advanced training in these areas. This situation is more prevalent in the exact sciences and computer sciences than in the life sciences. The explosion of knowledge described above has made it essential for an aspiring scientist to receive post-doctoral training early in his career. In a recent study by the US National Science Foundation (Table 4), it was observed that from 1980 to 1986, the fraction of students who returned to the universities for post-doctoral training in the life sciences increased from 75.9% to 86.0%. In chemistry and physics, this fraction was lower, and in the same period it decreased from 60.0% to 52.3% in chemistry, and from 40.6% to 32.8% in physics. The percentages were even lower in engineering and computer sciences; where the return to the universities for post-doctoral work was less than 8%. In these areas, the majority of new discoveries were made in research institutes of the industrial private sector. Therefore, it is not surprising that students seek additional training in these institutes, rather than in the universities.

8. New discoveries and the emergence of new ethical values

In developing countries, there are in fact two kinds of hidden knowledge. In addition to the findings that are confidential for proprietary reasons,

Table 4
The number of students returning to US universities for post-doctoral training

Year	1980	1981	1982	1983	1984	1985	1986
Life sciences							
PhD	15477	15925	15825	16061	17229	17657	18991
Post-doctoral	11743	12855	12725	13756	14473	15191	16328
% return	75.90	80.70	80.40	85.70	84.00	86.00	86.00
Chemistry							
PhD	4539	4730	4838	5118	5312	5727	6103
Post-doctoral	2710	2870	2805	2973	2906	2995	3151
% return	60.00	60.70	58.00	58.10	54.70	52.30	51.60
Physics							
PhD	3455	3516	3569	3626	3865	4097	4374
Post-doctoral	1398	1445	1326	1350	1320	1342	1497
% return	40.60	41.10	37.20	37.20	34.20	32.80	34.20
Engineering							
PhD	13928	14394	14595	15581	16206	17858	20407
Post-doctoral	978	1040	978	1102	1195	1349	1420
% return	7.05	7.20	6.70	7.10	7.40	7.60	7.00
Computer science							
PhD	1023	1068	1151	1367	1582	2020	2284
Post-doctoral	43	34	46	82	63	74	74
% return	4.20	3.20	4.00	6.00	4.00	3.70	3.20

Data from Ref. [8].

there is also a large volume of new information that is published every year (Table 2). In practical terms, most of this new information is also inaccessible, since the developing countries do not have enough specialists to decode it. Taken together, these two factors exacerbate the differential between developed and developing countries, not only with regard to their capacity to produce new knowledge but also in their capacity to make use of it. Many new concepts that circulate freely and are assimilated into the culture in developed countries are noticed by the majority of the world's population only after the introduction, in their own countries, of products derived from these concepts. Frequently, these products create new habits and customs. As a result of the quantity and complexity of new knowledge, its implications, even in developed countries, are evaluated adequately only by a limited number of people, usually analysts from government or productive sectors. Examples include nuclear energy, techniques of contraception and artificial insemination, and genetic engineering. The nuclear era began with a secret program that culminated in the dropping of the first atomic bomb in Japan, in 1945. Nuclear weapons have multiplied and became more sophisticated, but they confer a significant advantage militarily in a very few countries. Nuclear power plants, however, are spread the world over even though the advantages and disadvantages of using nuclear energy for this purpose have never been fully understood by the general public, and not even by the majority of the intellectual elite. Although the complexity of this technology makes it difficult to understand, society has become accustomed to the advantages derived from a larger production of energy, while a full discussion of its impact on the environment was postponed for a long time and the question of environmental effects had little or no influence on policy decisions. This situation persisted until a nuclear accident occurred in Chernobyl in 1986 [10]. Nowadays, the nuclear waste that accumulates at an alarming rate worldwide, continues to be an uncomfortable subject and it is still not adequately discussed or understood.

The advantages of contraceptives are so obvious that their use became widespread before any consensus was reached on the possible social implications, and also before a clear picture had emerged of the deleterious effects of their prolonged use. Similarly, the new techniques of artificial insemination are changing the traditional concepts of paternity and maternity. This change will be even more profound if the techniques currently being used to improve plant and animal stocks come to be used with human beings. The social implications of genetic manipulation have so far been examined only superficially due to the evident advantages to be derived from genetic therapies, in addition to numerous products of modern biotechnology.

Before the scientific revolution, the concepts of 'good' and 'bad' were mainly ratified by the governments and religious authorities. The profound changes that originated from modern science have led to a new set of norms, based on the concept of what 'works' and what 'does not work'. If a new product turns out to be useful, then it may be adopted for everyday use and cause ethical and social changes, independently of any discussion of its possible implications. Once again, modern contraceptive methods provide an example: They have been in use for decades and are sold in every drugstore. Meanwhile, practicing Catholics and Catholic church have not reached a consensus on the moral issues. The moral values and the advantages inherent in both sets of norms, 'good'/'bad' and 'works'/'doesn't work', are obviously debatable. Nevertheless, the second one has acquired greater significance since the scientific revolution. The social changes promoted by the products of new knowledge and the test of whether something 'works' or 'doesn't work' are usually initiated in countries that produce new knowledge and know how to use it; and subsequently, the products and the social consequences are disseminated worldwide. Nuclear power plants, the routine use of artificial insemination in humans and genetic therapy all began in developed countries and were adopted only recently by the rest of the world.

9. Conclusions

The fast evolution of modern science has brought many advantages to society, as for instance longevity, an old dream of mankind. However, the explosion of new knowledge generated the following complex situations that must be carefully dealt by society

(i) The growth of science was and continues to be centralized in a few countries of the Northern hemisphere enlarging the dependence of developing countries from the developed ones.

(ii) The countries with the lowest scientific development are responsible for educating the majority of the world's young people.

(iii) A large fraction of the new knowledge produced is not accessible, either because of national or industrial security reasons and, in developing countries, because there are not sufficient professionals with the scientific training needed to decode and use the large amount of new informations that appear in the library every year.

(iv) The new products derived from modern science continuously create new habits and customs leading to the emergence of new ethical values.

These situations encourage social and economic tensions that may retard progress toward Nations equality and the world peace.

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