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Commentary

# Learning science and science education in a new era

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## HIGHLIGHTS

- Science education difficulties
- Quality of science education.
- Big data in the new era and its effects on science education.

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## ABSTRACT

Today, it takes only a few months for the amount of knowledge to double. The volume of information available has grown so much that it cannot be fully encompassed by the human mind. For this reason, science, learning, and education have to change in the third millennium. The question is thus: what is it that needs to be done? The answer may be found through three basic stages. The first stage is persuading scientists of the necessity to change science education. The second stage is more difficult, in that scientists must be told that they should not place an exaggerated importance on their own academic field and that they should see their field as being on an equal basis with other fields. In the last stage, scientists need to condense the bulk of information on their hands to a manageable size. “Change” is the magic word of our time. Change brings about new rules, and this process happens very quickly in a global world. If we scientists do not rapidly change our scientific learning and education, we will find our students and ourselves caught up in an irreversibly destructive and fatal change that sets its own rules, just like the Arab spring.



Sage: this word may not often be used in our time, but it is the most ancient word that has to do with knowledge. Until the end of the seventeenth century, also known as the enlightenment, sages were regarded as the people who possessed all kinds of knowledge about thought, science, and art. There are no longer sages of this kind in our day. Scientists today are only knowledgeable about one of more than 20 fundamental sciences (and often only a branch of a particular fundamental science), let alone possessing knowledge about art and philosophy in their entireties. There are a great many scientists who devote their lives to only a single subject. For example, a surgeon who studies thyroid surgery would likely tell you candidly that the knowledge he has about the trachea, which is adjacent to the thyroid, is less than that of a medical school freshman.

What is the reason behind this accumulation of knowledge we now face? This is a curious question with three possible answers:

a) We cannot attain knowledge,
b) The cognitive functions of the human species have diminished over time. We can no longer grasp knowledge as strongly as we used to, and we cannot retain that which we do grasp.
c) The amount of knowledge has grown so much that a healthy mind cannot possibly possess it all.

Although the era we are living in is called “the age of information”, we are in fact living in “the age of Internet”. In the 1990s, the question of “whether the printing press or the Internet is a greater invention” was worth debate, or at least the taking of sides. The number of proponents for both sides being almost equal, those who favored the Internet slightly outweighed the others with the addition of a number of scientists. Twenty years since the emergence of the Internet and this heated debate, the proponents of the Internet outnumbered those arguing for the printing press in a landslide. Unfortunately, there is still a small group of scientists who argue in favor of the printing press. Not surprisingly, they are the ones who cannot use the Internet.

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Thanks to search engines, accessing knowledge is easier, faster, and cheaper than it has ever been before in the entire course of human history. Ironically, some propose that the word “Saint” be put before Google; Saint Google!

It is a well-known natural law that the functions of the tissues of living organisms that are not used will weaken, or even disappear, due to atrophy, while those that are frequently or consistently used will thrive, both functionally and numerically. Therefore, because we are a healthy human species living in the age of the Internet, it cannot possibly be the case that our cognitive functions have diminished. Even if there is such a thing, it must be perceived as a pathological process and researched scientifically.

During the 1500s BC, when writing was invented, the speed at which the amount of knowledge doubled was 6500 years. This period dropped to 4 years in the 1980s, which was when the Internet entered our lives. Today, it takes mere months for the total amount of human knowledge to double.

The first encyclopedia was written by Ephraim Chambers et al. (1727) in the age of Enlightenment. Although we do not have that encyclopedia now, if we did, and if we searched for a simple entry such as “knowledge”, we would probably access information consisting of a few paragraphs or around 250 words. Today, however, when you perform a search on any search engine—such as (saint) Google—it will turn up approximately 1,990,000,000 entries for the word “knowledge”. It would be nearly impossible to estimate the sum of the number of words under each of these entries, and even if it could be done, the person performing this calculation would have extreme difficulty expressing it in understandable numerical form.

If we go back to the above posited question with three possible answers and look at why scientists today do not know everything (as did true sages) and are entangled only in a very specific subject, we might be able to find the true answer easily: the amount of information today has grown so much that it cannot be possessed within a healthy mind.

Plato and his follower Aristotle did not need to read books to become philosophers because there were no books at the time. Likewise, it sufficed at the time for Avicenna to read a couple of books on medicine and astronomy. The situation was no different for Galenus.

Then, what is a student of medicine supposed to do today? How many textbooks is s/he supposed to read in order to become a good doctor? Is it only textbooks or books? How many journal databases, how many articles, science websites, question books, scholarly texts, etc.? Is it enough only to read? What about practical applications and the accompanying written sources?

It is because of these questions and this surfeit of knowledge resources that science learning and education has to change in the third millennium. This is primarily because the information mass has grown so large that it cannot be learned in its entirety. So what is it that needs to be done?

Just like the junk DNA (which corresponds to 95–98% of the entire genome) that does not code for protein synthesis, unnecessary (junk) information should be eliminated from educational sources. Eliminating junk information, however, is not enough in itself to rectify the problems facing us. In the same manner as a specific segment of DNA codes for only a certain protein and not others, certain information should be presented only to certain educational actors. Not all information should be presented to every actor; due selection should be made. The first step in this process (as is the case with educational advancement) is to educate the educator. Such an educational program could be comprised of three basic stages; two philosophical and one technical.

The first stage is persuading scientists of the necessity for change in science education. This act of persuasion is composed of two steps: first, the general consensus, and second, the simplification of the educational process. Having overcome the difficult task of “general persuasion”, it is also important to accept that this process must be easy, as it is in most fields outside science. Vertical educational systems, horizontal educational systems, integrated systems, etc. are undoubtedly important, and all of them are going to find their proper place in educational institutions. However, it should not be forgotten that in a global world, particularly one where the Internet has radically changed all kinds of systems (such as commerce, communication, fashion, entertainment, economy, and even national interest), it is impossible to think that science can have a privileged position. After all, is it not the Internet that is the basic cause of the “increase in the amount of information” that is forcing a change in education?

In the last decade, there have been two silent but surprising changes in the world of science. The first change was an increase in the amount of information and a decline in the educational endeavors of students and scientists despite the growing number of scientists and academic institutions (especially universities). Transfer of scientists and the sector of academic congresses have been experiencing a serious recession. Although the large, world-renowned academic institutions have not shown signs of being affected by this problem as yet, the middle- and small-scale institutions are already having an observer problem. The websites of these institutions are now creating attractive advertisements for “observership programs”. Congresses are held with fewer participants, in smaller and more modest halls, and with more humble refreshments. According to the 2009 statistical report by the International Congress and Convention Association (ICCA), medical science is the largest segment of the congress industry. Although the number of medical meetings and participants increases every year as usual, there was a recession between 2000 and 2009 for the first time; the fastest decline of all time in the number of participants at the medical meetings took place in 2009 with a rate of 17.8%. The same decline took place in other sectors as well, with technology taking second place and (other) science congresses third.

A second and more surprising change took place with the stagnancy in the sales of science books. Currently, you will never be able to find a medical book in Amazon's list of 100 bestsellers, which is by far the most visited book sales website and which is updated every hour. Many publishers of science books (especially medical books) are either going out of business or having dire times. The medical bookstores around medical schools and research hospitals that were once staples of the community and go-to locations for students are becoming increasingly rare; the vast majority have been closed and converted into (usually) either cafés or fast-food restaurants. Fewer and fewer science books are being written, and publishers are increasingly reluctant to publish even the highly qualified books, written with so much difficulty, oftentimes asking the writer to meet the publishing expenses. Even if the book is published, it rarely makes it to bookstore shelves because of the lack of interest by distribution companies.

The major factor behind both of these changes in the scientific community is the Internet. Today, the theoretical knowledge that is the main aim of scholarly endeavors can easily be obtained from institutional websites, presentation websites (i.e., Slideshare), free and serious information portals (i.e., Wikipedia), and science journal databases (i.e., ScienceDirect and PubMed). Moreover, one can follow science publications and the latest contributions by other scientists in various well-respected journals.

Practical knowledge, processes, and manipulative sources can be obtained from video-sharing websites (i.e., YouTube) or web-based communication (live presentations through satellite, etc.). Through these means of communication, the loss of labor, time, and money has been minimized.

The fact that books can easily be downloaded in pdf format on the Internet is certainly an important factor in the drastic fall in book sales, though it is not the only one. Likewise, different and more attractive ways of presenting information on the Internet, as we mentioned above, reduces the demand for boring and dull-looking book pages with black letters on white sheets of paper. Additionally, we should not forget the legal online book sales of publishers. Thanks to software compatible with laptops and tablets, as well as smartphones, we can miraculously carry thousands of books in our pockets now. Clearly laying out these facts for scientists, accompanied by striking figures and numbers, will go a long way toward persuading them of the necessity of changing science learning and education.

Despite all these efforts, the first stage might still be considered difficult. The second stage, however, which is rather more philosophical, is even more difficult: scientists must be told that they should not place an exaggerated importance on their own academic field and that they should see their field as being on an equal basis with other fields. This stage is difficult because scholars of fundamental sciences assume that applied sciences cannot be understood, or even exist, without them; likewise, scholars of the applied sciences (especially clinical medical sciences) assume that science cannot reach out to the public without their existence. For example, while the number of course hours for an optician is always inadequate due to the importance of this organ, for an anatomist, the eye might merely be an organ that is a couple of cubic centimeters. Similarly, while the anatomy of the peripancreatic area is quite a short subject to cover for an anatomist, it is one of the most fundamental subjects for a general surgeon, who will go on to perform pancreatectomies. Therefore, both theoretical and practical education in this field is very important. Today, if a professor would like to have a student who can conduct electrophoresis as capably as her- or himself, s/he must be able to interpret electrocardiography (ECG) as well as the student who has completed the class in the department of fundamental sciences and is headed for a cardiology class. In a similar manner, if today's professor would like to have a student who knows cadaver dissection as well as her- or himself, s/he must be as knowledgeable and skillful in pancreaticoduodenostomy as the student who will attend a Whipple operation as an observer.

The last part of the education of the educator, and the part that might take the longest amount of time, is teaching science educators how to condense the bulk of information on their hands to a manageable size. As this is a purely technical subject, they will unfortunately be presented with only some general guidelines. Additionally, as every scientist will be the best to know her or his own subject, s/he will inevitably be left completely alone in the application of its education. This is not an easy task in the least: it is critically important to choose for the learner only the necessary information, while eliminating junk information, and condensing transitional information properly. Moreover, there is also the challenge of ensuring the clarity and comprehensibility of the information during the process of concision. This process resembles learning how to ride a bike: the rules are already set and easy, but when you sit on the saddle of the bike, gravity gets in the way and everything becomes a mess. Knees can bleed and the amount of blood to be shed depends on just one person; the one who rides the bike!

The tasks ahead in this regard can be summarized as follows:

1 The usual class hours of students and the usual departmental seminar hours of residents and staff must be reduced. The remaining hours must be spent between the educator and the educated on a one-on-one basis in order to make up for individual inadequacies, necessities, and demands.
2 Textbooks must be shortened, and their number must be increased. The books to be written in this respect can be divided into two levels:
   Level 1: Condensed textbooks that contain only basic principles and mechanisms (new generation textbooks).
   Level 2: Less basic books, workshops, and course programs on academic disciplines and sub-disciplines for residents and staff that contain more details.
3 New, digital/visual sources of information (extra-textual sources), such as videos, animations, websites, and slides must be developed. It is clear that a knowledge of software and computer graphics is necessary in order to build useful digital databases. For this reason, professional assistance must be sought and necessary funding must be provided.
4 Popular science books must be written in order to attract and encourage keen and eager youngsters (students and residents) who have the potential to become qualified academicians in the future. Written without the use of technical language, popular science books are colorful books with many images that can be understood by the general public and that give the basics of an academic subject, as well as the subject's implications for our daily lives. Writing these kinds of books can be harder for scientists than writing books with deeper scientific details. For this reason, the help of professional publishers and writers of popular science must be sought.
5 Scientists must be educated in the principles of the “science of the management of human resources and professional management”. This education is crucially important for scientists of biomedicine who have no background in social and anthropological sciences. Such scientists might fall in the error of tending to use the pragmatic scientific rules that have long been used in departmental human resources and institutional management. Under these rules, instead of providing a flexible evaluation of candidates according to their personal skills and qualities, candidates can be either rejected due to an evaluation based on “either/or” principles or employed inefficiently.

There may be many scientists who will not agree with the arguments above. Those who do not must be reminded of a single word: Change! “Change” is the magic word of our time. While those peoples, institutions, and sectors who adopt this principle as a mantra, religiously believe in it, and apply it have the advantage to survive and thrive. Who do not believe in it and who see their jobs as exclusively special, different, and/or immune to change are sooner or later wiped away. Change is everywhere today: in art, philosophy, economy, commerce, lifestyle, daily life, and, of course, in science and science education. Change is a liberal and democratic process. Change itself is subject to change. Changes do not take place slowly and according to certain traditional rules as was the case in the past. Today, more often than not, changes do not even recognize the traditional rules. Change brings about new rules, and this process happens very quickly in a global world. If we as scientists do not take immediate action in setting our own new rules in science education, and if we do not put these new rules into practice soon, the inevitable consequence will be that we will find ourselves and our students caught up in an irreversibly destructive and fatal change (i.e., both the loss of scientists in abstract terms and the increase of patient mortality in concrete terms) that sets its own rules, just like the Arab spring.

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## Guarantor

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