The Information Explosion


Every once in a while I come across a statement that the totality of human knowledge is doubling every N years. Depending on the author, N might be as little as four years or as many as 12 years. All of the authors are trying to capture the idea that we have increasing numbers of researchers who are using increasingly sophisticated tools to build on the work of previous researchers. We have an explosive, geometric growth of accumulated knowledge.

Generally, people don't carefully define what is meant by the totality of human knowledge. I suspect that this is difficult (if not impossible) to do, so I won't attempt it in this short editorial. However, I have a picture in mind that comes from my days as a student of mathematics. I picture mathematics as a broad-based, but relatively vertical discipline, with the research frontiers built on hundreds or even thousands of years of solid progress. Researchers in a university discuss some of their new ideas in graduate research seminars. A few of the ideas filter down to regular graduate courses. Over a period of decades some of these ideas enter the undergraduate curriculum. Over a period of hundreds of years, some of the ideas enter the precollege curriculum. For example, most of the precollege "new math" movement of the 1960s was based on math that was well over a hundred years old.

A troubling factor in this information explosion is that the capabilities of the human mind do not appear to be increasing. This leads to the situation that a student beginning the study of a particular discipline will be able to learn a decreasing percentage of that field. Scholars who want to become researchers in a particular field respond by selecting narrower and narrower areas of specialization.

But what is the ordinary student or the generalist to do? How can one gain a solid grasp of a wide variety of fields, understand progress that is occurring, make use of the new knowledge that is being developed, and feel intellectually comfortable with the rapidly growing base of human knowledge? These questions are fundamental to the Information Age.

The answer lies in learning to build on the work of others—to avoid reinventing the wheel. This is the guiding principle of much of our academic coursework. The goal is to help students rapidly learn what researchers and scholars struggled with for years. For example, Newton and Liebnitz invented the calculus about 300 years ago, and this was a monumental achievement. But some high school students now learn more calculus than these initial researchers knew, because we have very good calculus books and calculus teachers.

Mathematics provides a good example of the progress we can make through coursework, but also illustrates the major dilemma. As a rough estimate, I would guess that over the past 100 years a significant percentage of the college mathematics curriculum has been moved to two years earlier in the curriculum. That is, freshman and sophomore mathematics majors study a great deal of material that was common in the junior and senior curriculum of a hundred years ago.
But unfortunately, during that time the totality of mathematical knowledge may have increased by a factor of several hundred! Moreover, there has been an explosive growth of knowledge in many other disciplines. And new disciplines have arisen, such as computer science and genetic engineering. Thus, there are ever-increasing demands on the student's time and learning capabilities.

Continual development of new curricula, better texts and learning aids, and better teaching methods are all essential and helpful. However, the fundamental issue is whether we can find still other ways to build on the work of others.

Computers offer a new, two-part answer. The first part of the answer is computer-assisted instruction. Research evidence strongly supports the contention that via CAI many students can learn significantly faster. For this reason it seems inevitable that CAI will eventually be commonplace in our schools.

The second part of the answer lies in computer-as-tool for the storage, processing, and retrieval of information, and as a general-purpose aid to problem solving.

One can view a computer system as a passive information storage and retrieval device. In that sense it is like a library. But it is a significantly changed library. A 12-cm CD-ROM can store the equivalent of 500 books. A videodisc can store 54,000 pictures. Our telecommunications systems can provide easy access to computerized materials stored at distant locations. It is evident that computers, telecommunications, and storage technology are significantly improving our access to information. Such access is essential to building on previous work of others.

However, the key to dealing with the information explosion does not lie just with improved (passive) access to information. The key mainly lies with the ability of computers to process the information. Computer storage of information differs significantly from library storage of information precisely because computers can also process the stored information.

For example, a computer can store demographic information along with maps, programs to represent the data on maps, programs to graph the data, programs to extrapolate trends, programs to perform statistical analysis such as correlating sets of data, and so on. These software tools can help solve some of the problems one addresses through use of the data. Such computer capabilities truly represent an extension of the human mind.

Essentially all of computer science is concerned with such extension of the capabilities of the human mind. However, artificial intelligence focuses specifically in this area. Recent progress in artificial intelligence, including knowledge-based expert systems, is exciting! In essence, AI researchers have given us a method for capturing some of the knowledge of a human expert in a form so that the computer can use it to solve problems. A human can learn to use such a system, and thus to solve some problems at the level of an expert in a particular discipline, without spending the time necessary to become an expert in the discipline.

All educators should be following this progress, since it is at the very heart of a new interface between education and the information explosion.

I draw two conclusions from the line of reasoning discussed above. First, schools should focus increased attention on information storage and retrieval, and they should place particular attention on computer-related improvements in this field. Second, within every discipline, students should learn to use computer-as-tool as an aid to solving the problems of the discipline.
The capabilities and limitations of computer-as-tool should be a clearly defined part of every academic course. This capability is our current best new aid to coping with the information explosion.