The Impermanence of Knowledge

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Abstract. Knowledge is essential to our existence. Without knowledge life is almost impossible. So we need to care about what we know. In the recent past mankind has managed to collect enormous amounts of scientific knowledge. This era is now nearing its end. Knowledge is intimately connected with energy. We are in for a severe energy crisis, which translates into a knowledge crisis. In other words: the science boom is over. But not only will it be next to impossible to continue increasing our knowledge, even keeping the knowledge we already have will become a great challenge.

1. Introduction

The central thesis of this essay is that the availability of knowledge is proportional to the supply of energy. As we face peak energy so we are facing peak knowledge. This might sound counterintuitive: surely knowledge is not burnt like oil or coal, once we know something we now it forever. But such an account of knowledge is too simplistic to be useful. As I shall argue, knowledge consumes energy not only when it is acquired; we also need energy to maintain it.

Knowledge has been a fascinating subject ever since Greek philosophers started to look at it. Great minds have studied with great intensity what knowledge is and how we acquire it. But philosophy is one thing. Knowledge has also been a key to well-being. Even hunter-gatherers or farmers need to know a lot. Nowadays, the situation is much the same. We need to know a lot just to function in our society. But there is more. Knowledge, in particular science, means business. The more you know the more you can produce. Like everything else around us, knowledge is exploited. Today, knowledge is for the most part considered a vital ingredient of economic success. We do not so much care about knowledge of God as we do about knowledge of nature. To us, the debates that raged the Middle Ages (like the edict of 1270 by Bishop Etienne Tempier concerning key doctrines of the church) seem like a mere curiosity. What could one get from inhibiting the spread of knowledge? More knowledge is more progress, or so we think.

Nowadays, the connection between knowledge and well-being is beyond doubt. That doesn't mean of course that more knowledge equals better life. What counts is not only the quantity that but also the kind of knowledge that we possess.[1] That we have a lot of useless knowledge however has not worried people so much. Indeed,

[1]Of course, there is an issue of quality as well: you may have false knowledge. But for my purposes here knowledge is only true knowledge. I will not go into the details of knowing which is which.

the idea that we need to distinguish useful from not so useful knowledge seems to many a dangerous idea, ultimately leading back to the Middle Ages. Yet it is one thing to feel uneasy about it and quite another to be able to afford a completely agnostic stance vis-a-vis the question. Western societies for example have simply avoided even seriously raising it. There are two reasons for this. One is that for some decades knowledge has been really cheap. Whatever question you have here and now, you can get an answer right away—so who cares what people know? The other reason was that science was believed to be free of value judgements. Science has its own criteria to evaluate knowledge, which is, let us say, certified truth. Science does not inform us about usefulness. So far that has not appeared problematic. If research leads to a lot of excess knowledge, so be it. There will be enough for everyone.

Now however our attitudes will be shaken. The myriads of articles and papers turned out every year by scientists are not likely to survive two decades from now, let alone this century. The reason is that the enterprise of a society of science and engineering cannot function without a massive infrastructure which in turn is predicated on the availability of energy. Precisely this energy is now running out.[2]

This is disconcerting, to say the least. We are used to think that knowledge basically comes for free. But deeper reflection reveals that this is not the case. Even maintaining knowledge needs constant care and attention. Thus with diminishing energy at our disposal the amount of knowledge that we can effectively use is shrinking. Though this may mean that many treasures will fall into oblivion, this is not the moment to resist what needs to be done: assess what is important and what is not. Without a clear sense of what is worth keeping we shall most likely end up with nothing at all.

2. Knowledge and Truth

To know something means among other things that it is true. This is why knowledge is so eminently useful. We base our actions and further beliefs on our knowledge. Essentially, the way Western society pictures its own culture is that our beliefs form a pyramid whose foundation consists in certified knowledge of the kind science provides. Though scientists inevitably have opinions and instincts about what may or may or not be right, what counts in public and from what they derive their self-esteem is their knowledge.

Therefore, nothing is more dicsoncerting than to find out that what you held to be knowledge is actually false. Every once in a while this actually happens, not only in empirical sciences but also in mathematics. Every now and then it turns out that one proves a theorem only to realise later that this was a complete red herring. If you look back at the great foundational debate in the 19th century you see the biggest minds agonize over the problem of rational thought and certainty. After discovering that there could be such things as non Euclidean geometries mathematicians were asking themselves why this wasn't clear to them in the first place. If mathematics

[2]As scientists themselver have found out...

was the pillar of science, they thought, at least it should be free of any potential doubt.

From an intellectual perspective this period is very interesting. It led to a reappraisal of logic as a cornerstone of science (Frege, Peirce). Further down the road it also led to logicism, analytic philosophy and philosophy of science. The deeper people looked at the matter, however, the more problematic it became. Gödel showed that there could be facts that we cannot prove from our assumptions though they are true. Brouwer denied mathematical entities exist independently of the mathematician's mind, and hence argued that there are claims that are neither true nor false. Empirical sciences only added to this confusion. Every now and then it turns out that what we once knew does not qualify as knowledge any more as it has now been disproved. Of course, any of these disproved claims may be rehabilitated so that all we can say for sure that nothing is settled forever. Socrates would be delighted.

In addition to the foundational agenda logicians also applied their techniques to philosophical problems. Philosophical logic (which I myself have been doing for almost three decades now) has tried to shed light on the properties not only of knowledge but of a host of other so-called propositional attitudes (knowledge, belief, certainty, disbelief, and so on) and modalities in general. It is just one angle from which to study them. Philosophers have done that for much longer, and now computer scientists are joining in. The questions and attitudes of these groups are often different. While a philosopher will be more inclined to think about what knowledge *is*, a computer scientist will end up worrying more about how you manipulate it. Of course, both are valid research questions. However, for my purposes it is the second one that is more pressing.

In what follows I shall simplify matters by adopting the computer science perspective on knowledge. Basically, one thinks of knowledge as consisting of a database and an algorithm to retrieve facts from it. So, in spite of all dissimilarities, we may consider our entire body of knowledge as a collection of certain strings of letters, in other words sentences. To get an idea of the magnitude, just think about how much has to go into mastering a language, then think about our maps and encyclopedias (electronic and otherwise) and the millions of scientific papers, not to mention the individual knowledge people have, for example, about their neighbourhood, society and the recent history. Here are now the basic problems we need to address.

- Where does all that knowledge reside physically?
- How do we access that knowledge physically?
- How do we get answers to our questions?
- How do we keep that physical knowledge from degrading?

I shall look at each of these questions in turn. We shall see that from an abstract point of view modern technology has not changed much about the organisation of knowledge. It still needs to be kept in physical containers, we still need to be able to find it on need, and we still need to worry about its impermanence. The only difference is that the infrastructure that performs all this is now largely

inconspicuous. You will have to understand something about computers and how they function to know that these problems are real and cannot be made to go away.

3. The place of knowledge

It may sound strange to say that knowledge has a place. One would rather think that it is data not knowledge that can be located. But to think of knowledge as placeless is not the best way to think about it. It is certainly clear that not all knowledge is literally stored. I know that 23 + 12 equals 35 but I doubt that this is stored somewhere in my brain. I know that because I know how to calculate. But even if not everything we know is stored verbatim, there still is a lot that is stored in this way. Consider all the encyclopedic knowledge we have. And mathematical knowledge may be abstract, but it too is encoded in some way and stored. So, we have to assume that a lot of knowledge resides in us, perhaps even in the form of sentences of some language. In that sense it exists, physically, in us. Take for example the fact that the capital of France is Paris. I know that, you may know that, but there are people in this world who do not know that. So, we think that the knowledge is not with them. In this way knowledge can be said to have a place. It resides in the heads of people who possess it. We may also attribute knowledge to groups of people, but that requires more than the existence of members with that knowledge. I shall discuss that point below.

Still, physical talk of knowledge strikes one as odd. We can copy inscriptions or data, but can we also copy knowledge? Yes and no. No, because knowledge isn't literally copied. If you tell me a fact, what happens is that I come to know it. I change my propositional attitude. On the other hand, it is useful to see knowledge as being copied. It then assumes a further location. For it is not the same to have knowledge in several locations than to have it only in one. The infrastructure is a crucial element in the equation.

Knowledge can also be stored externally. Clay tablets, manuscripts and books are the earlier forms of storage. Modern forms include tapes, microfiche, hard drives and microchips. Storage in the electronic media is localised as well. Also the internet or the *cloud* consists of down to earth servers that store the data. We may have the impression that it no longer matters where knowledge is, but that is only so because the computers do all the searching and transfer for us. It is similar to our brain. We do not know how it performs the job for us, as long as it works. I do not need to care where my brain stores all the information as long as it puts it somewhere and hands it to me on need.

4. Accessing Knowledge

If knowledge has a place, we need to get it physically when we do not happen to be there. This may be quite a difficult task, as we find out the minute our computer is on strike and we have no idea why. In the old days, you needed people like Antonio Magliabecchi (1633 - 1714). He was by all means an extraordinary man. He knew by heart all catalogues and lists of books that existed in his time. People asked him for advice on where to find certain books. Although he never travelled

he still knew where to find them. This man obviously was an invaluable resource. Think about some manuscript that you needed. How could you find out where it was? Travelling in those days was time consuming and expensive even if you just had to go to the next city. Before you made some costly trips it was obviously better to ask someone who knew exactly where to look for.

This shows that having possession of knowledge and being able to access it when needed are two different things. Moreover, when you have a question you want an answer to it is not even clear that an answer can be found somewhere. And knowing that it exists still is of no use unless you also know where to look. This was a big challenge even a few decades ago. The knowledge of a society is not simply the sum of the individual knowledge. For if I need to know what you know I need to know first and foremost that you know it and then talk to you in order to get an answer.[3] It is evident that knowledge needs to be administered. This is why libraries had inventories, which they printed and sent to other libraries.

Nowadays the problem is much the same but we hardly get to see the details of that adminstratration. When you send out a query into the internet, it is directed to a search engine. The search engine keeps an inventory of web pages that it matches against your query. It then identifies the web adress and shows that to you. Below that level there is mmuch more that needs to be taken care of. For example, knowing an internet address is not enough, you also need to know how to find this engine physically. Also for that task there are dedicated machines, so called domain name servers.

And so we see that knowledge can only be accessed if there is a certain infrastructure and administration around it. The administration is needed to identify the location of the knowledge, and the infrastructure is needed to access the knowledge once it is found.

5. Using Knowledge

Now that we have looked at ways of finding knowledge we also need to look at the way the knowledge can be stored and used. Recall that I talked you into the idea that knowledge is stored in forms of sentences. These sentences can be in an artficial language, it does not matter. However, whatever format we choose we need to be aware of the fact that the sentences are just ways of putting down, or encoding, the knowledge.[4] The code must also be known. For our purposes we may happily assume that it is.

Consider that you have just discovered Ernst Cassirer and you think it is a good idea to study his work because it is very attractive for you. Today, with some luck you might find someone who has all that work on his hard drive. No problem, go ahead and copy it. But then what? You haven't read a single line yet. And though initially you feel you have made big progress you soon realise that it was but a small one.

[3] And, to repeat, how do I talk to you if you are far away? Until a few decades ago that too was a major problem. Distance matters even in questions of knowledge transfer.

[4] So, we need to distinguish the form of knowledge from its expression.

The reason is that the knowledge is both there (you have the data) and not there (you cannot use it). This is a problem known in computer science as well. Consider a big database. Now think of a question that you have. How is it that you can have your question answered by means of that data base? In the easiest cases there are what is known as query languages and applications that allow to check your queries and try to come up with an answer. This is fine for phone books, railway connections and internet search (which is largely based on string matching). However it is not applicable to something like tax law. To understand how much taxes you have to pay is not just a matter of matching strings and adding numbers; it is a matter of understanding the technical terms and concepts and organising your data accordingly. In the latter case people have come up with the idea of expert systems. These are machines that work with a set of rather intricate rules, and may be able to answer rather tricky questions concerning, for example, eye diseases or laws concerning traffic accidents (these are real applications I know of).

If you compare the computer with a human you will not be surprised that the task is extraordinarily difficult. It takes years to educate someone to the point that he can reliable diagnose your eyes, or tell you what the law says concerning some traffic accident. It is also not enough to just feed people with the rules, you will also have to make sure they know how to use them. The more one looks at the problem the more it becomes fascinating just how intelligent human behaviour is and how much goes into knowing simple things. Let us suppose, for example, that you decide you want to learn breadmaking. Nothing easier than that. You get a recipe, buy the ingredients and off you go. But as matters evolve, you will find that you have to make decisions along the way. The recipe calls for fresh yeast, you can only get dried yeast, will that do? You have inadvertently added more flour, is that a problem? How do you have to knead the dough? And so on. It turns out that only after you tried it a dozen or so times that you understand fully. Usually, you find that there are things that the recipe doesn't bother to tell you; and second, you learn just how much you may deviate from the standard procedure.

And so now we understand better the problem with the collected works by Cassirer. Of course, if your problem is only to write a term paper on Cassirer and you can't be bothered to read too much the temptation is there to just search for catch words and copy as much material as you can find into the paper. Chances are, however, if your professor knows his Cassirer he will not be pleased with the result. The difference is this: his knowledge is active, yours isnt't. He understands, you don't. It is not a matter of just possessing a library you also need to *read* the books.

When I went to school it was commonplace to say that it is no longer important to know things by heart. You only had to know where to look.[5] Nowadays even that is no longer necessary. Thanks to internet search engines, you may just type in your query and you get what you need. You do not need to know where to find things, the

[5]I sometimes imagine someone speaking French constantly flipping the pages of his dictionary to look up one word after the other. I guess no one wanted to suggest that you do not need to know anything at all.

search engine does that for you. Of course, this is a great advantage. But it solves only one problem, that of retrieving the knowledge. The knowledge however still remains dead. Until it passes through your consciousness it is not alive. Your consciousness is the bottleneck. And, as we have often experienced, just reading isn't going to do the trick either. You need to work through it. Otherwise your knowledge becomes pretty sterile.

6. Maintaining Knowledge

So now we have an understanding how we get access to knowledge let us see where the problems are for a society that wishes to use its knowledge. It needs

- to make sure that the knowledge remains physically intact,
- to keep an infrastructure that allows to get access to knowledge, and
- to have people (or machines) available with an active command over the knowledge so that it can be used effectively.

All this of course must in some sense reproduce itself. A software dealing with a particular tax law is a one time solution. It is not general enough for the purpose of maintaining easy access to the tax law.

Keeping knowledge intact is no trivial affair. As we rely more and more on electronic devices we need to worry about their lifespan. I am not sure whether data storage on hard drives is such a good idea. While it is true that the majority of data could not even be processed without a computer, books and articles are best preserved on paper.[6] It may not suit our infrastructure (think about search engines), but then nothing speaks against doing both. But machines are not our only worry. People carry lots of knowledge and need to pass it on, too. Also, each and every human needs to be educated so as to be able to read, write and think in order to even understand what is written in the books. This is one reason why we have schools, libraries and universities.

Next look at access. Search engines are one thing. However, there is much more. When you have specific questions concerning your car or taxes, you will try to find some expert. Thus, being able to get help means knowing who to ask and being able to physically talk to them. Phones and computers are not always the answer. Or you may decide to visit the local library and check out a book. There are many ways to success.

Finally, and most worrying, is the problem of keeping knowledge alive. I talked briefly about expert systems, machines that you can ask for advice. I think we can at this point dismiss them as something that can offer significant help without human assistance. These programs in effect must be constantly updated and no one so far has found a way to convert e. g. the tax law into a computer program.

[6] Acid free paper lasts several decades, archival paper 500 to 1000 years (http://en.wikipedia.org/wiki/Acid-free_paper#Archival_paper). CDs last a few years (libraries used to calculate with 12, but recent estimates are even lower, probably due to declining quality, http://www.computerworld.com/s/article/107607/Storage_expert_warns_of_short_life_span_for_burned_CDs), for hard drives I have seen 5 years as a reported average life span, see http://www.data-recovery-tools.net/faq.html#faq-dlp-lifespan.

Until that is achieved practically the only way to keep knowledge alive is to have a sufficient number of experts that can give us advice.

7. Knowledge and Energy

So now ask yourself what happens if energy becomes an issue for society. This is by the way precisely the situation we are in right now: energy is getting more and more expensive. This cuts people's budget and therefore also puts the finances of the state under pressure. So energy scarcity is an economic issue as well and a very important one. Our levels of consumption are so high that the rising price of energy is a big concern.

Normally, one would think energy scarcity only means less transport or less heating. But in fact it means less of everything. In fact, it also means less knowledge. And very substantially less in my opinion. Let me give you a few ideas of where to look.

- The entire internet is a big energy consumer. Not everything stored may be counted as knowledge, maybe only a small fraction. But still the energy it uses are substantial. Add to that the costs of manufacturing the hardware.
- Books are printed in massive amounts and are still relatively cheap. When people stop buying them, however, we need to invest into local libraries so that people still get access to them when they need them. As with the first point we may not think that a large part of books are sources of knowledge but even so the infrastructure must be maintained.
- Universities are not only research and teaching institutions. They are also responsible for keeping the knowledge alive. They are the ones having all kinds of experts around to deal with often arcane topics.
- Companies often do possess very specialised knowledge. Some of them have large research and development centers where they constantly try out new products or technologies.
- Schools ensure that basic knowledge is taught to the children so that they will be enabled to access and use the knowledge in the form that it is provided.

This is an impressive list. It means that the few percent of GDP spent on research are by far not enough to pay for all of the above. Therefore, when we have less money, what will be affected? I guess, no one will propose to close schools: if children do not go to school there is no point in having all these universities around. So it will most likely be the universities and the companies that will take a hit.

At first the loss will be just temporary. A manufacturer of drugs goes bust and the people will be on the streets. Some will find work elsewhere, but many will not. After a while, much of the knowledge that the company once had will effectively have disappeared. This is a problem they know too well; if you sack your people during a downturn it will be hard to get them back once you are on the way up again. However, unlike a typical cycle of boom-and-bust this is a permanent decline. The companies will not even want the people back. They will lose the impetus of continuing with what they were doing. They will close some departments

or go bust altogether. This is one way in which knowledge will get lost practically forever.

Another, and also very serious problem, are the universities. As public funds dry up there will be less money to pay for intellectuals. Universities will be shrinking, some will be closed. And similarly the intellectuals will now be on the streets, trying to find work elsewhere. But as the other universities are also not hiring, sooner of later these intellectuals will have to do something else. Their expertise will get lost. Additionally, new students will be discouraged from entering disciplines where they see no future. And so universities will become less attractive.

8. Going Down the Spiral

This is our predicament: energy is in decline and so is our ability to keep up the knowledge infrastructure that we have. I have already indicated that this is by no means a temporary phenomenon. The knowledge lost will be lost forever with few exceptions. The reason is that fewer people means effectively less knowledge "at our fingertips". We may still keep the books in the libraries, hoping that when the need arises we shall send someone there to study them. But that is getting harder the more time passes. Take something like elementary particles. That isn't an easy subject; understanding it requires tons of difficult maths. I doubt that without expert physicists around you will be able to make much of your books, not to mention the fact that the accelerators and other equipment have meanwhile been turned off. Also, most likely you will not be able to just hire someone in the hope of reviving that lost knowledge. Other universities may have done the same as you, namely close their elementary particles section. There simply won't be anyone to hire. Lest you think this is an unknown problem just look at Indoeuropean studies and other small departments. University reforms have made it hard for them to survive, so they are being driven into extinction. Not long and there will be no one to explain to you what Indoeuropean studies is all about. The difference is that the energy scarcity will hit the big, established disciplines: natural sciences, medicine, and engineering.

Problems do not stop there. At some point, libraries will discover that their electronic access will be of not much use. Publishers will either charge too much or discontinue the service, mainly because the electronic infrastructure will become less popular. Maintaining the electronic infrastructure in itself will become an expensive affair, so it will be concentrated around a few essential applications. Data stored on CDs or hard drives will start to decay. Computers will be getting expensive and so physical access to just a computer screen will be difficult. Books on the other hand are easy to access and will become more popular. They too have their limitations, but at least they will continue to "function".

9. Conclusion

The future we are facing is a future of less knowledge and less research. We will collectively forget much of what we know today. It is impossible to compile a roadmap of how that process unfolds, but it is clear that technical domains will be

hit that are deemed indispensable right now. Soon there will be much less research in astronomy, elementary particles, nanoparticles and so on. First we will struggle just to keep the knowledge. Then, as the situation worsens, we shall have to let go of that as well.

Of course, in a world that can't afford to run huge particle colliders there is little hope of continuing research in elementary particles. We may want to know more about them but alas there will be no way to run experiments. First we may resent this; but then we shall lose interest. Other issues will become more important. Let's not forget: the time of energy scarcity is the time where people worry about shelter, basic health and food much more than about the Higgs-boson.

Where does that leave us now? The conclusion to be drawn is that society needs to start to think seriously about which knowledge is essential and where it still wants to make progress. There are areas where the knowledge we have accumulated is vital for us. We need to know about agriculture, engineering, thermodynamics and so on so as to do the best of what we have. When we lose that in the struggle to maintain expensive telescopes or elementary particle colliders we will be in big trouble.

Let the discussion begin now.

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