

How to study science

Mayank N Vahia

Tata Institute of Fundamental Research,
Homi Bhabha Road, Mumbai 400 005, INDIA
www.tifr.res.in/~vahia

During my various discussions with children and students, I am often asked how to learn science. After discussions with a lot of my colleagues, friends and teachers I have been able to pinpoint some of the basic requirements to become a good student of science and it gives me a great pleasure to share them with you.

- Think Physics: The only rule for all human activity is that one should be able to *instinctively* understand and recollect all relevant items connected to any problem. To be a good scientist it is necessary that such activity on the part of your brain becomes automatic. However, in order to achieve this, it is necessary that the brain gets a lot of practice doing this early on. So this is the age when you must make it a habit to consciously think in scientific way. For example the different ways in which a pendulum can be used to measure the height of a building and the movement and problems of cycles in a smooth, slippery road and quick sand.
- Understand the importance of algebraic formulation: Algebraic formulation of a problem may seem cumbersome initially, but it has a power of its own. For example it may sound easier to say that something oscillates than to say that it moves under a force that is proportional to displacement. However, the former statement reveals no further information while the on the latter version you can apply the full force of mathematical formulation and get a lot more information.
- Understand relations: Science is a study of dimensions, relations and their interplay. Rather than remembering facts, it is more important to understand relations between various interdependent parameters and how some quantities relate differently to different items. Understanding this relation is understanding science. This is not taught in any formal course in science because you need to know a lot of basic information to appreciate their interrelations. Education in science is understanding and appreciating these relations.
- Solve problems: Solving problems gives you deeper insights into the way physical laws work. For example it is easy to say that the smallest living organism is a virus and the smallest physical body is an atom. But of the two, which is smaller? If you have been thinking about it, you will know that a virus consists of several million atoms and therefore the smallest living being is millions of times larger than an atom.
- Historical perspective. Science normally appears a very dull collection of facts while, in fact, it is a very dynamic field with lots of false starts and errors. All this is very instructive and gives us new ways of thinking.
- Understand language: It is a surprising but true suggestion that in order to master understanding in science, it is necessary to understand language. Not just the grammar and vocabulary but the inherent logic of language. No language likes to have redundancy. No two words ever mean the same. And yet, there are several

books of synonyms. The logic of the language is clearly seen in the differences in the synonyms. For example, the word 'do' has synonyms of perform, achieve, contrive, manage; solve, finish or work out as listed in Roget's thesaurus. Yet none of them really match up to the concept that the phrase 'to do' conveys and it is an interesting exercise to see why and where these words are similar and where they are not. Another interesting example is the famous statement 'God is truth'. Depending on which of the three words you put an emphasis on, you get a different meaning. This kind of understanding of language is necessary so that you can understand and express yourselves better, to others and also to yourself, and that is a prerequisite to being a good scientist.

- Read different books: Each author explains a subject as best as he or she understands and even within a book, the author may understand different parts differently. Therefore all explanations may not be easy for you to follow, not because you are not good, but because sometimes the author himself may be confused or the language may be confused or simply the style may be different. Hence it is useful, almost necessary that you read as many different books on the same subject as possible. This will improve your understanding and perspective. Also, different authors will address the same problems in different ways and this also improves understanding. You don't have to read all books like text books, even browsing through different books help.
- Concentrate: Any study is a full time activity. You need to make a complete commitment to it and make the subject your own. It is a full time, all consuming love affair. So, if you are serious about research, it should always be at the back of your mind, no matter what you are doing, so that when ever your brain is free it should go back to understanding what you had read in the last book or heard in the last lecture.
- Don't work too hard: Give the brain time to think things over, meditate and relax, leave some time away even from pleasurable activities.
- Be original: No body ever succeeded by trying to be someone else. Each of us is special and unique. We must therefore accept ourselves, try to improve on our weaknesses but not try to imitate someone else.
- Be open to criticism of your work: Science is easy since it is logical. As long as you insist that your thought or claims can be logically derived from fundamental principle, you cannot be wrong. On the other hand you can make a mistake. There is a fine line between confidence and arrogance. The best way to check yourself from going from one to the other is to listen to your critics, try to answer and convince them and even if you fail, you should be able to recreate your critics' line of thinking and see where they may be wrong. If you can't do that it may be a good idea to go back and reanalyse your own stand so as to see if you are correct. In case of doubt it is better to try a totally different approach to see if your assumptions and logic are correct.
- Ask questions: It is necessary to ask questions so that not only can you understand better but also so that the person talking to you may be able to explain things in a way you like.