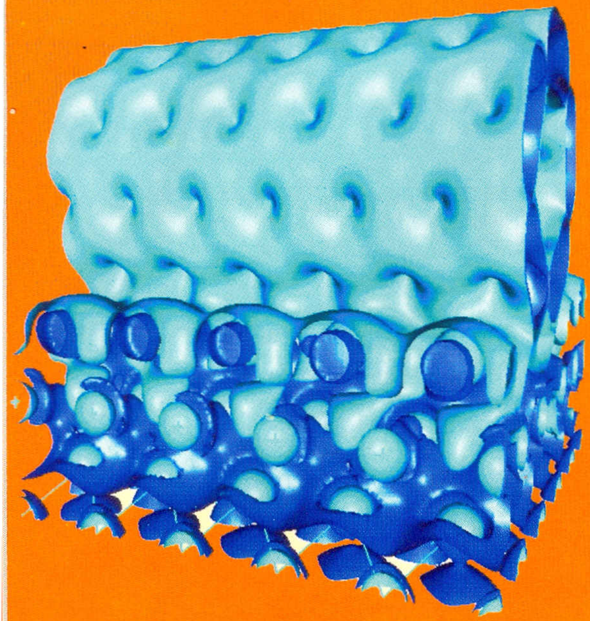
Integrating Education at the Nanoscale

— Prof T Pradeep



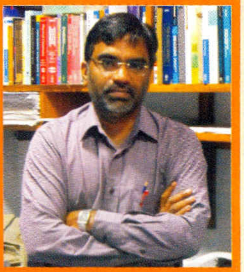
Nanotechnology is a discipline of convergence. Every branch of science and engineering happen due to processes at the nanometer length scale. At that length scale, all phenomena become pure science. Biology in detail is a collection of molecular events occurring at this length scale. This is true of chemistry, physics, electronics, etc. How should such an integrating discipline be understood, taught and appreciated?

Nanotechnology enables every branch of science and engineering to achieve newer vistas with improved efficiency, reduced material resources or efforts so that more can be achieved with less. In several areas, altogether new avenues have been achieved which were otherwise impossible. Nanotechnology does not create anything in isolation, as it is not a technology which can stand on its own. On the contrary, it overlaps with any branch of science or engineering, thereby enabling it. Consequently, applications of nanotechnology would be possible only when knowledge of science and engineering concerning that branch is acquired.

Nanotechnology by itself does not bring in fundamentally new changes in basic sciences. It allows, however, new kinds of physics or chemistry or biology or material science to be pursued. It enables such science. Therefore, what one does is indeed new kinds of basic sciences. This can only be done better with a thorough understanding of what had happened in those areas in the past. The larger impacts of nanotechnology could be felt in materials and biology in the immediate future. Nanotechnology enabled biology is biology itself. It requires an appreciation of biology than nanotechnology. This may be said about any area of application.

The foregoing implies that a curriculum in nanotechnology should be built over a foundation strong enough to absorb the superstructure. That superstructure can be built on any branch of science and engineering. Just as nuclear magnetic resonance has found inroads into physics, chemistry, biology, medicine, etc, the tools or outcomes of nanoscale science can be applied to any area. The extent of application and the benefits one derives depend on how nanotechnology can be adopted to the discipline. In several areas of relevance such as materials, catalysis, environmental engineering, sensors, plastics, photovoltaics, etc., applications of nanotechnology are based on the adaptations of new materials to these disciplines. In certain other areas such as diagnosis, drug delivery, super hydrophobic coatings, etc, new kinds of processes enable nanotechnology. What one sees in all of these applications is a combination of several branches of science and engineering. A link between materials and biology or electronics and materials or biology and instrumentation makes nanotechnology possible. As a result, education should reflect the growing interdependency of disciplines.

The ideal nanotechnology program should be built only when the foundation is sufficiently strong and broad so that it absorbs new knowledge. The behaviour of materials and systems at the nanoscale can be understood only with inputs from quantum mechanics. Several of the phenomena at nanoscale can be studied with principles of classical mechanics as well. The creation of nanostructures and their stability



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require an understanding of thermodynamics. Synthesis of these structures will need materials science. Integration of such materials with living systems requires biology. Linking them requires electronics. All their properties are integrated and measured with newer tools of instrumentation. Many processes at atomic details have to be studied with computational techniques. Thus, a wholesome understanding of emerging science is very much needed in this area.

As a result, a programme in nanotechnology has to be taught in an academic setup capable of providing each one of those inputs. It is obvious from what is presented above that a time-bound programme cannot provide all of these in any significant detail. In view of this, nanotechnology programmes are always oriented with specific interests in view, in specialised disciplines. This leads to nanotechnology programmes with narrower focus in disciplines such as biomedicine, electrical sciences, materials, biotechnology, etc.

Unlike several other branches of science, observation of systems at the nanoscale is central to the understanding in this area. It may be the study of a collection of such objects, their properties or observing single nano objects. Both of them require specialised tools and it is necessary to integrate such observations as part of the curriculum. This calls for investment and the lack of it therefore produces only partial knowledge and inadequately trained human resources. In view of the above, a student planning to take up a nanotechnology programme should ask the following questions:

1. Do I have adequate training in my chosen area of science and engineering?
2. Am I prepared to learn advances in the boundaries of my own and other disciplines?
3. What is the specialised area of nanotechnology that I may find useful or interested in?
4. Does my chosen institution have adequate human resources in the areas of expertise?
5. Does it have well equipped teaching laboratories?
6. Does it offer possibilities for research in a few areas?

Many a time these can be assessed even without visiting the institution. Just as in any aspect of human activity, seeing is believing. Verification of the facts by yourself will give you greater faith in choosing the programme of your choice.

Choose wisely. ■

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