Convocation Address

Indian Institute of Technology, Kanpur
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Chairman of the Board of Governors, Prof. M. Anandakrishnan, Prof. Sanjay Dhande, Director, IIT Kanpur, Faculty, Students and distinguished guests.

To stand before you today is a very special honour for an alumnus. It is almost exactly 44 years since I arrived on this campus, a long ride by cycle rickshaw from Kanpur's railway station, as a wide eyed student seeking admission. I left two years later with a Masters degree in Chemistry; transformed in every way by my exposure to an institution which was young, intensely active and quite unlike anything that my contemporaries and I had experienced earlier. This institution was where I was first exposed to the pleasures of research. I came in hoping to make a career in the civil services or in journalism. Instead I was seduced by science. Kanpur in the 1960s was an uninviting place; the IIT was an oasis. I am sure generations of students since, have been transformed by their experiences here. Those of you who graduate today will join a band of alumni who will always remember their days here, sometimes fondly when they think of friends and favourite teachers; sometimes with a touch of relief when they recall courses, tests, exams and theses, which convert the task of acquiring a degree into a formidable obstacle race. I recall that my class was completely puzzled when a rather intimidating faculty member handed out a surprise quiz, within a few days of our arrival. None of us had ever heard of a "quiz".

What can I say to you that can have any relevance on an occasion like this? Coming as I do, from the Indian Institute of Science, I thought this might be an opportune moment to reflect on science and engineering and the changing face of research. What are the differences between science and engineering? Is it not true that science and engineering are two sides of the same coin? What causes the huge difference in perception at the level of college degrees and why is this gulf less evident in the great universities of the West? Are the growing number of computer modellers, 'engineers'? Why are 'computer science' departments so named, especially when they are always staffed by faculty with engineering degrees? Curiously, it is this area which is most sought after by students in many institutions, its attraction undimmed by association with science. Several decades ago, before the electronic and digital revolutions hit science like a tsunami, it was easy to differentiate engineering students from those who studied science. The former carried T-squares and slide rules and spent time in workshops and were even taught to operate lathes. The latter carried 'log tables' and went to practical classes, which involved considerable physical labour. In the pre-computer era, both science and engineering courses seemed to emphasize experimental work, as a critical component of training. I suspect that practical classes are much less rigorous nowadays for both science and engineering students. Even a cursory glance at most college laboratories today will reinforce this feeling. There is a new future that epitomises the modern age. All colleges, even the most poorly equipped, boast of a 'computer laboratory', with dozens of desktop computers (laptops in some places) stacked in neat arrays in well furnished rooms. The distinctions between science and engineering students seem to blur in the computer classroom.

In an article entitled 'Scientists as Inventors' H. Petroski (*American Scientist*, 2008, 96, 368), draws attention to a distinction between scientists and engineers, attributed to Theodore von Karman. In many ways von Karman's definition of a scientist as one who 'seeks to understand what is' and an engineer as one who 'seeks to create what never was' does not correctly describe today's researcher in science and engineering. Petroski is quick to acknowledge that 'often considered distinct, engineering and science are frequently difficult to distinguish'. A long time ago there was indeed little distinction. There were scientists and inventors and disciplinary boundaries were much less pronounced. Michael Faraday can indeed be claimed by physicists, chemists and electrical engineers as one of their own. Louis Pasteur was an organic chemist, a microbiologist and a biotechnologist. Then there were the inventors: George Stephenson, Thomas Edison, Alexander Bell and Nikola Tesla among others. J. C. Bose was a physicist, biologist, physiologist and inventor, but these terms were much less well defined in his time. In his essay, Petroski highlights the story of Einstein as an inventor. He notes that 'Einstein himself made numerous forays into the form of engineering known as design and invention'. Einstein held many patents for practical devices, undoubtedly helped by his early experience in a patent office. His partner in later years in his excursions into 'engineering' was Leo Szilard who was, as Petroski notes, 'capable of working on scientific and engineering problems virtually simultaneously'. The 'Einstein–Szilard refrigerator' was the testing ground on which some of the technologies for later day nuclear reactors were conceived. Petroski concludes his essay by observing that 'science and engineering are – and always have been – coequal partners in the development of the world of thought and things that define civilization and culture'.

In institutions like my own, the Indian Institute of Science, where research is a prime focus, the distinctions between scientists and engineers are indeed blurred. Are there two distinct species of researchers who can be identified, whose characteristics mark them out as decidedly different? I might venture to suggest that a contemporary classification may separate theorists from those who do experiments.

Computer modelling is the key thread which binds diverse disciplines. The structural integrity of buildings and bridges, the design of molecules and machines, the simulation of monsoons and blood flows, the analysis of networks, both electrical and biological, appear to be drawn together by high performance computing. There are indeed few theorists who walk around with paper and pencil, armed only with mathematical skills and physical concepts. The terms computational chemistry and biology describe an increasing tribe of researchers far removed from the pain, excitement and thrill of experiment. In the area of materials research, scientists and engineers work on similar problems sometimes claiming that their approaches are different; practitioners of religions into which they were inducted at an early age.

The winds of change have long swept over the frontiers of science and engineering, destroying walls and eliminating boundaries. In the new world of research, success may require a facility to easily bridge the gaps between disciplines. It may indeed be critical to think of new experiments in undergraduate education, where science and engineering merge seamlessly to build a new generation of professionals and researchers.

In the sciences the challenges of modern day research pose formidable problems for educators. Interdisciplinary skills are essential for solving all the major scientific and technological issues that confront us. This is true of modern biomedical and agricultural research; it is true of the areas of pharmaceuticals and diagnostics; it is true of research in the area of solar energy or climate change. Indeed compartmentalization of disciplines is a major impediment for progress. Breaking disciplinary barriers and breaching the concrete walls that separate departments and subjects must be a major challenge for universities in the near future. We must recognize that our Universities have been impoverished by separating engineering and medicine from the sciences, social sciences and humanities. Compartmentalization of learning is contrary to the very basis of a university. We must ensure that innovation and enterprise are encouraged for both faculty and students. Moving towards "Pasteur's quadrant", a phrase used to describe research that is both fundamental and applicable, is something we must aspire for. This is a term that derives its origin from the work of the famous French scientist Louis Pasteur, who contributed fundamentally to chemistry and biochemistry and whose work in microbiology led to great advances in our attack on infectious disease.

I have so far spoken of general issues. But I am sure some of you may look far ahead and ask: "How does an individual become successful?" I can only consider this in the context of scientific research, a limitation imposed by my own experience. The best advice was given many years ago by Richard Hamming, a computer scientist and mathematician. I like to call his set of rules "The Hamming Prescription". There is, of course, one cardinal Rule –

work very hard. Productivity requires hard work and total commitment. Hamming quotes Newton: "If others would think as hard as I did they would get similar results". Hamming says: "Knowledge and productivity are like compound interest. Given two people with exactly the same ability, the one person who manages day in and day out to get in one more hour of thinking will be tremendously more productive over a lifetime".

Finally I must turn to the students again. Why do universities need students? The answer was given to me in a recent seminar at our Institute where the speaker quoted the famous physicist John Archibald Wheeler who said: "Universities need students in order to educate the Professors". One of Wheeler's students was the famous physicist Richard Feynman. Indeed our academic institutions have a great internal resource, which is the community of students. The students who are graduating today and those who will do so in the years to come must become agents of change and progress.

I do hope that all of you will have plenty of opportunities to think and act in the years to come. You are living in exciting times and the future will challenge you. May I wish each and every one of you the very best in the years ahead.

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