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EDITORIAL

Science and Engineering, Theory and Experiment

Addressing gatherings at formal functions and listening to speeches are an occupational hazard for those who hold official positions. In recent times I have sat, uncomfortably and awkwardly, on the dais on many occasions. The declining interest of students in degree courses in science is a common topic on which many speakers hold forth at convocations and institutional days. This is also a topic that is a perennial favourite in committees which worry about the state of science and higher education in our country. Curiously, many committees honestly believe that a well meaning and well drafted set of recommendations may be sufficient to transform the system of science education. There is no doubt that colleges in some states are indeed starved of students for B Sc degrees in physics, chemistry and mathematics. Biology seems to do better by adopting a simple device. College managements rename any course with a moderate level of biology as 'biotechnology', conjuring up visions of an 'engineering' or 'professional' degree. If a B Tech degree is awarded, the transformation of biology into a subdiscipline of engineering and technology is complete. Both students and parents are comforted by the prospect of a degree that certifies 'technological' competence, upon completion of a course of study. Even entry into the 'information technology' industry seems more facile if one has an engineering degree, although it is not entirely clear as to the technical background that is considered most desirable by those who hire for IT companies. Public statements, which pronounce most engineering graduates as 'unemployable', imply that considerable retraining for specific tasks is necessary. The significantly greater employability of engineering, management and commerce graduates undoubtedly makes these courses more attractive to students. Their proliferation has often been advanced as one of the many reasons for the gradual extinction of science courses in colleges.

From my vantage point, I have often wondered: 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. Students of physics seemed closer in their mathematical and analytical abilities to budding engineers. Chemistry and biology students on an average seemed less comfortable with equations and their solutions. I must hasten to add that I write this just after hearing an illustrious seminar speaker in a chemistry department display a cartoon which proclaimed: 'Into every life a little math must fall'. But, the chemists made up for their mathematical innocence by learning the many painful and arduous procedures of practical chemistry and were sometimes even instructed in the art of glass blowing, a rare skill in the modern age. The biologists were specialists in dissection, with frogs and cockroaches as their subjects, in an era where there was little opposition to such experiments. There was a common thread to all the undergraduate courses and that was the emphasis on practical training. For those who ploughed on to enter a research career, the lessons of practical classes have been invaluable. It is here that one learnt that experiments sometimes failed, even when one desperately wanted the right result in an examination, under the watchful eyes of an external examiner. It is here that one picked up the little secrets of the trade from experienced laboratory attenders, mechanics and demonstrators. I have watched the contents of a burette gradually slip through a leaky stopcock onto the table top in a practical examination forever reminding me, in a recurrent nightmare, of the importance of attention to detail in an experiment (and indeed in every other activity). 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.

Coincidentally, I came across an article entitled 'Scientists as Inventors' (Petroski, H., *American Scientist*, 2008, **96**, 368), which 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. Even in the engineering departments which once boasted of large halls full of clanking machinery, the workshops are largely still and silent. The mechanics are largely gone, glassblowers nearly extinct and draughtsmen swept into memory by advancing technology. The lathes stand forlorn and unattended and large structures one used for experiments serve solely to remind us of an era long gone. I have seen many an old engineer look pensively at these relics of a rapidly fading past reminding me of Goldsmith's lament on the disappearance of rural England:

> 'Where once the cottage stood, the hawthorn grew,
> Remembrance wakes with all her busy train
> Swells at my breast, and turns the past to pain.'

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.

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