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BODY OF KNOWLEDGE

RE-ENGINEERING - ENGINEERS | ROLE OF HUMAN FACTORS IN ENGINEERING EDUCATION IN INDIA | DILEMMA OF SET SKILLS AND EMPLOYABILITY | THE VALUE OF CONTINUOUS EDUCATION PROGRAM | A SPECIAL FOCUS ON PROFESSIONAL CIVIL ENGINEERING BODIES IN INDIA | INFRASTRUCTURE

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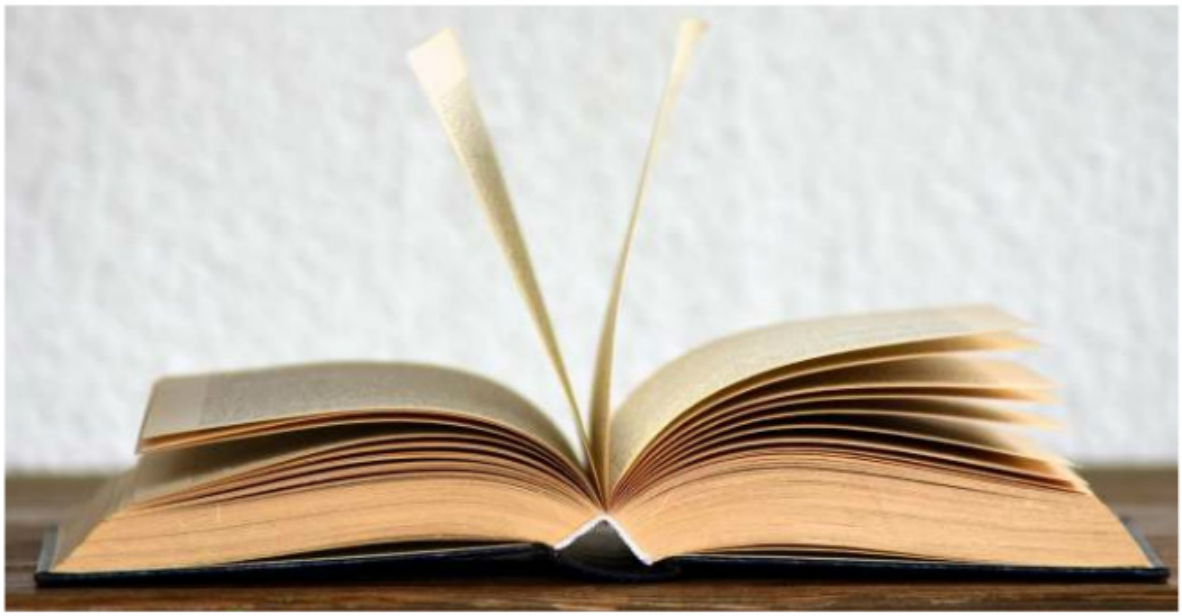
Role of Human Factors in Engineering Education in India



N. Krishnamurthy
Ph.D.
Consultant, Singapore

Introduction

I have been teaching, consulting, researching, and publishing for 57 years in various areas of civil engineering in India, USA, and Singapore. For the first forty years of my career, I was deeply immersed in structural engineering, particularly modern computer-based methods, playing around with theories, formulas, analyses, designs, graphics, and the other trappings of conversion of inanimate materials to human use. But in the last seventeen years or so, I have been intensely involved in matters affecting the physical and mental well-being of people at the workplace. That is how I developed interest and experience in the three areas listed below:

- Engineering Professionalism and ethics
- Risk assessment and control
- Accident investigation and prevention

While most of my experience in the above areas derives from Singapore, I have been exposed to them in USA and India also, to the extent that I believe I am competent to comment upon the relevance of education to the successful practice of engineering and desirable directions for engineering education in India for the future.

Professionalism and Ethics

There have been a lack of professional ethics in many areas of our life in India. Suffice it to say that the latest Corruption Perceptions Index ranks India 79th among 177 countries, exactly at the same level as our only slightly more populated neighbor China.

Figure 1 below indicates an average ranking from two reliable sources, does not cover all the 180 countries involved in the survey ranging from No. 1 (Denmark) to the last (No. 165 being less than 180 because of countries having same rank). It shows 31 nations, including half a dozen South East Asian countries and others as 'benchmarks'.

Perhaps there has been modest but finite gains in recent years, but yet, it is quite bad for a country with international fame in IT and space technology testifying to our excellent knowledge base and implementation efficiency to be rated so low in ethical concerns and professionalism.

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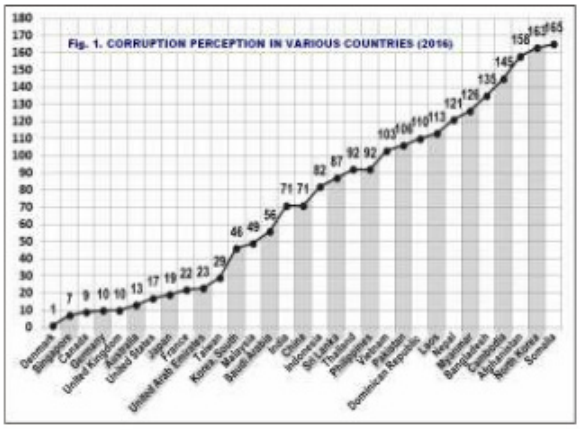

The point here is that the place to start inculcating basic values of honesty and integrity is not the workplace it is too late for that. The money has already been spent to accomplish some allegedly worthwhile end and it 'must' be recouped from the people whom the spender serves.

The first place where ethics education must start is the home.Here we have a dilemma: Both parents work, so the children have little quality time with them. More to the point, both parents face the lack of professionalism to different degrees in their daily life at the workplace, and whatever their own upbringing might be, they cannot in good conscience tell their children not to do what they themselves cannot avoid (or even enjoy) doing. Youth is much more independent today than previous generations were, and by then the parents cannot control them. They will have to find their own motivation and method to curb the anti-social evils.

Youth learns very fast how to get ahead in life, by 'somehow' going round the obstacles rather than struggle to clear them. So who will tell them:

- About the engineer Sir M. Visvesvaraya who laid down his 'official' pen on the table after signing off from his job and returned home in a hired horse carriage?
- About the tailor who was left with one dollar too many by Sir M.V. while in USA and returned later to personally hand over the extra dollar because he had not earned it?
- About a more recent exemplar of President Abdul Kalam who returned home after his tenure with the single box of modest belongings he left home with?

The last bastion in this vicious cycle is the college, the temple of education. What is obvious is that unless the basic principles and tenets of integrity are taught somewhere, formally, youth has no place to source to hear them, and no place to learn them.

I have not had the time or the resources to investigate if and how much of ethics is being taught in engineering colleges in India. But while I was teaching in the USA, I ran into at least one course in engineering professionalism as part of the curriculum. Interest in inculcating engineering professionalism in U.S. schools has not waned but only increased in recent years[2].

There have been several excellent paper[3] on on what the engineering student of the 21st century would need to be successful in his* career, with technical and people skills. Unfortunately the word 'ethics' does not appear anywhere in most of the articles.

I have been lucky in this regard. A few years ago, the National University of Singapore made the course on Engineering Professionalism compulsory for all undergraduate engineering students, and I had the challenge and pleasure of teaching the key introductory module in it to the entire batch for five years. I was also fortunate to teach engineering professionalism as a required course in the local campus of an Australian university. The engineering students in my ethics courses were frustrated by the lack of formulas and computer applications in the course but soon got into the swing of things the course changed their mindset, their attitude.

What is frustrating to me is that the topic is being ignored and neglected in the land which established religion as a practical way of life based on ethical behavior of one human with another. Can anybody argue against the dire need for the youth of this country to be taught the basics of ethics and the various ways of resolving ethical dilemmas apart from the obvious and easy short-cut of literally "give and let give"? Are we going to wait for 'Almighty' to tell us what to do and how to do it? Or are we going to wake up, get a group of serious engineering scholars and practitioners together, set a tight agenda and a tighter time frame, and produce a blueprint for a more ethical engineer who will shape a new India?

Risk Management

There is one basic difference between (say) doctors and lawyers on the one hand and engineers on the other. A doctor or lawyer deals generally with individuals, holding their personal physical or mental (or financial) pleasure and pain in their hands. Any deficiency in their service would affect only one or a few individuals. They have to consider each case as unique, and they have to come up with solutions which will apply to and help exactly the individuals they are servicing at the time.

An engineer does not have these individual and personal freedom or responsibility. He has the exact opposite: responsibility and accountability to groups, to entire masses of people. Engineers may not have to answer to individuals for causing harm, but if and when they err, engineers can place the limbs and lives of thousands or more in jeopardy.

A botched eye operation will mean the loss of one person's vision and adequate compensation. A messed up court case will

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hurt a few unfortunate individuals. But a poorly designed or erected bridge will lead to innumerable loss of lives and limbs. A careless effluent control or a tiny nuclear leak can condemn entire generations to misery. It should be clear now why the doctor and lawyer should be ethical in dealing with individual patient or client, but the engineer needs to have greater ethical responsibility to the entire society he serves and to the environment he operates in.

But an engineer? He is a problem solver, not a problem maker or even a problem finder.

What he does affects the entire society and cannot generally be reversed. Especially in civil engineering where the works are designed for the masses and implemented once and for all, any mistake will lead to accidents with highly adverse consequences.

So how does an engineer anticipate and avoid human harm, property damage and environmental impact and the like from his work?

This is where the art and science of risk management comes in.

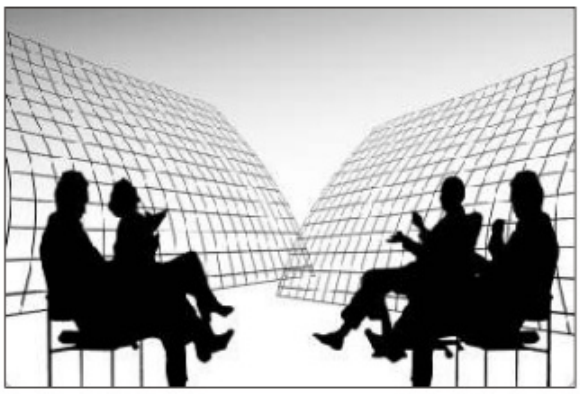
Financiers and punters have always been aware of how many decisions they make have an element of risk in it and they analyse, figure the odds, and then make a conscious decision to go one way or another.

But when it comes to engineering, we believe that our accumulated knowledge of the past will automatically assure us of safety against failure of the products we make or accidents our mistakes can cause.

The problem is that by very definition, 'accident' is an unexpected, unwanted event that leads to some kind of loss. It is because of its unpredictability that we take out life and vehicle-driving insurance. What is forgotten is that designs may be entirely safe on paper because they are usually made on the basis of vast accumulated experience from which the design tools have been carefully provided by experts to circumvent failure.

It is when the design is being implemented that deficiencies show up and mistakes occur. Examples abound:

- The material supplied is sub-standard;
- The concrete is not cured sufficiently;
- The electrical wiring gets shorted;
- The contractor changes wrongly a small item in the design because he cannot do exactly what the designer wanted;



- The maintenance crew fails to do their job or heed the warnings and the leaking gas kills thousands and condemns succeeding generations to deformed births and destroyed lives as happened in the Bhopal tragedy.

So how does an engineer catch these traps and avoid them?

By risk assessment, that is by evaluating when mishaps can happen ('likelihood'), and how bad the consequences can be when they happen ('severity'). Once these two major factors of a mishap can be identified and estimated, they may be combined to assess the resulting risk and loss. Like the diagnosis of a disease is the critical element in treating a patient, once the risk is identified and assessed there are many ways it can be managed by elimination or mitigation.

One can authoritatively affirm that risk assessment is a leading indicator, a predictor, for accidents. By not paying enough attention to it, engineers are passing up the opportunity to anticipate and prevent accidents and their consequent injuries and damage.

Actually risk management is not rocket science. Any high school graduate can understand it, and can be taught the mechanics of applying it to improve workplace safety. The only reason the topic languishes is that industry has not discovered its power for productivity[4] and growth. Once industry wants it, colleges will fall over themselves to prepare young people to take up the work.

Right now in India, the only risk analysis anybody knows of and wants to use is in the banking industry and for stocks and shares business. Maybe a few in defense use it, but they have not shared it publicly. I have tried to change that tunnel vision to the extent one old teacher can.

So what do we do? Most of the advanced nations are using it to the benefit of all involved. Are we saying that India is not advanced enough to afford this luxury? This would be the cheapest of all investments, with Return-on-Investments far beyond our outlay, even if they cannot be predicted or calculated!

I cannot do much more than point to the folly of our educational system not recognizing the value of this simple tool to improve the safety and productivity of engineering enterprises. Some gutsy or far-sighted IIT or Regional College can start a program on this topic and then show the rest of India how useful it can be!

Forensic Engineering

If risk management is a country mouse, forensic engineering is

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the city rat! Forensic engineering is a fancy word for accident investigation which would conform to the legal requirements. While risk management is a leading indicator on how to prevent accidents, accident investigation is a good lagging indicator, to be done after a mishap occurs with the main aim of learning from a mishap and thereby averting a repetition of similar mishaps.

Accident investigation is an absolute prerequisite to accident prevention. Once we learn why an accident happened we will not allow the same thing to happen again, but do everything in our power to avoid the creation of the the circumstances that led to the accident. Only accidents provide us the data from which we can apply them into risk management techniques and draw robust conclusions on how to prevent them which all the brilliant theories from the greatest of scientists cannot provide.

What we learn from accidents can be shocking as indices of our ignorance.

The history of mechanics dates back as far as the Egyptian mathematician Euclid (365-300 B.C.). Euclid's contributions to mathematics were essential to the advances in Newtonian mechanics. The Greek scientist Aristotle (384-322 B.C.) is credited with deriving the law of equilibrium of a lever which was later refined by Archimedes (287-212 B.C.)[5]

India, the land that gave the world the concept of zero and the decimal system, lost its scientific initiative with the invasions from the North-West in the 13th Century. It was the West which gave the world Newtonian mechanics from the 17th century.

With such a rich background in mechanics, on 17 July 1981, two walkways collapsed in the Hyatt Regency Hotel at Kansas City, Missouri, USA, killing 114 people, simply because a contractor substituted two rods to support the two walkways instead of the single rod passing through the upper walkway as originally designed!

The sad part was that the analysis to show that the substitution of two rods instead of one doubled the load on the middle nut has been part of every statics course in every university offering engineering courses worldwide for centuries, at degree and diploma levels, and now at most junior colleges!

Again, when the Millennium bridge at London opened in June 2000, pedestrians experienced so much sway that the bridge had to be closed until 2002, for further modifications against lateral resonance! The bridge had been designed and built by the best brains and hands in the world. It was the accident that highlighted the thus far unnoticed phenomenon of transverse resonance from a normal human activity!

As we progress in our knowledge, we push the envelope and get into uncharted waters.

That is why both in the application of theory and in the erection or fabrication of designed structures, errors are embedded and accidents happen. Thorough investigation of the accidents and getting to the root causes as well as all the contributory and secondary causes are the only way we can find where we went wrong and how we should avoid committing the same or similar mistakes.

That is also why all developed nations have such an elaborate system of accident investigation and documentation, scientific and statistical analysis, identification of the errors and deficiencies, and finally set up a formal methodology to avoid the mishap or mitigate the consequences.

More often than not, accidents lead to court cases, and therefore, it is standard practice to conduct accident investigations oriented towards meeting strict legal codes and regulations so that neither party in a dispute may claim unfair settlements. Hence the term 'Forensic Engineering' applied to accident investigation in modern context.

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Region	Representative Countries
High	Australia, Canada, France, Italy, Norway, Singapore, Switzerland
AFRO	Zimbabwe, Algeria, Ghana, Togo, Tunisia
AMRO	Argentina, Dominican Republic, Belize, Costa Rica, Mexico
EMRO	Bahrain, Turkey
EURO	Croatia, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania, Turkey, Ukraine
SEARO, WPRO	Kyrgyzstan, Korea republic of, Macau, China, Malaysia, Myanmar, Philippines, Thailand

Table 1

Where does India stand on this?

Once again, the statistics speak for themselves. To be brutally honest, there are just no statistics available from India on many common accidents! Only the employer and the family of the deceased know when a worker dies on the job. Any local discontent is neatly quelled by money or power.

In the 2014 issue of global statistics on workplace fatalities[5], the world is divided into six regions as shown in Table 1. Small and large, rich and poor countries are represented. China is present, but India is conspicuously absent.

Even when India reports fatality data it is something like one in a million workers, while some of the safest countries in the world report fatality rates of 1 in 100,000, that is, ten times as much!

How does the International Labour Organisation handle such missing or unreliable data? Very easy! Which is the country with reasonably reliable data and resembling closest to India? Malaysia; fine. Voila, take Malaysia's value and apply it!

But where it hurts is that we are like the proverbial ostrich burying its head in the sand although it is now known that in appearing to do so, even the ostrich has the benign purpose of turning over its eggs. The whole world knows not only how big we are, and how good we can be, but also how we shoot ourselves in the foot, fooling nobody else but ourselves!

Whether we have to impress the rest of the world or not, we must start thinking and planning on reducing and managing our high accident rates at the workplace. Accident investigation is not only a natural corollary to risk management, but also is it a necessity on its own to understand and cut down accidents. Here too, only the

combination of the human element and technology will be essential for progress. Again, this subject is a non-starter both for industry and for academia. When nobody wants to analyse an accident too much (for fear of finding who was responsible!) but simply brushes the facts under the carpet, whom would it benefit to examine it and take it to court? There is no dividend in it, no future in it.

Thanks to a few hardy souls in the Association of Consulting Civil Engineers who organised the First and Second International Conference on Forensic Civil Engineering and in particular to a committee member who took a personal interest in my contributing to the two conferences, I have presented a total of five papers at the two conferences in 2013 and 2016.

Maybe by now some have started courses in forensic engineering if so, good!

Else, should I just give up? Or will some institution of higher education be bold enough to start such courses at least as a specialization?

Conclusion

What is it that keeps us from being organized, from being disciplined? How many Vivekananda-s, Nehru-s and Abdul Kalam-s does it take to wake us up to be like the other nations in engineering education, particularly in these human resource development? What will it take for us to hold our head high, to be proud of our achievements but at the same time to be honest and humble to admit our deficiencies and rise out of the quagmire we are in?

Only two things are missing: professional pride and national commitment. Once our youth and our leaders address these two basic flaws, why, nobody can touch us!

IAs one who has been teaching for 57 years in USA, India and Singapore, I feel that Indian engineering education must rise to the responsibility it owes to itself and the world, in these areas as much as it is already doing well in the high-tech areas. It is time we got over the baggage of the last century and act as the proud, independent, self-sufficient nation we once were and must again become, a nation of high ethics, with good risk management and forensic engineering capabilities soon.

In all my travels and stay around the world, I never gave up my Indian citizenship. As one who has watched first-hand our independence struggle, I shall never give up my Indian-ness. I am passionate that my nation shall shine in more basic, more holistic ways than in IT and space technology!

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* The male pronoun will automatically refer to the female equivalent, unless the context is gender-specific. - NK ▪

Dr. N. Krishnamurthy (known as 'Prof Krishna') has 57 years of (and still active in) teaching, research, consulting and industry experience, with numerous publications in India, USA, and Singapore, in structural engineering, computer applications, professional ethics, forensic engineering, workplace safety and risk management. He was Professor in three American and two Indian universities, Associate professor in one University and visiting faculty in two other universities in Singapore.

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