



Views & Comments

The Beginnings of Wisdom: Challenges in Engineering Education

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What does it take to form an artist? And what forms a great musician? What more does it take to educate an engineer of international standard, who can bring their expertise to bear on the global grand challenges but, what is more, be effective in bringing solutions into being? How do we help our young people to grow, not only in their technical knowledge, but also in their judgment, in wisdom?

The UK has a major skills gap opening up with nearly a million engineers and scientific professionals required to enter the economy between now and 2020 to replace those who are retiring and to drive economic growth (source: EngineeringUK). The challenge for engineering educators is not only to enable students to gain techni-

cal knowledge and understanding but also to grow in judgment and wisdom.

Firstly a few words about the key characteristics of engineers.

The Royal Academy of Engineering has undertaken a recent piece of research with the University of Winchester in the UK to identify the key characteristics of engineers. The report, entitled *Thinking Like an Engineer: An Active Learning Approach* was published by the Academy in 2014 and is available on the Academy website[†]. It highlights six engineering habits of mind—key thinking and practical attributes of engineers (Fig. 1). These are:

- (1) Problem-finding;
- (2) Creative problem-solving;



Engineering habits of mind

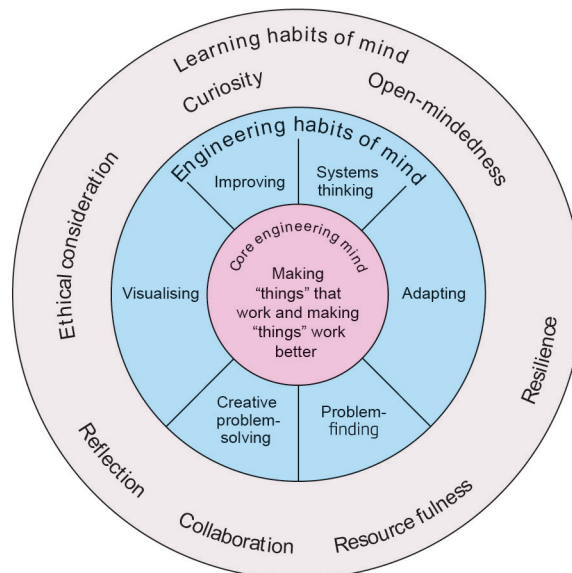
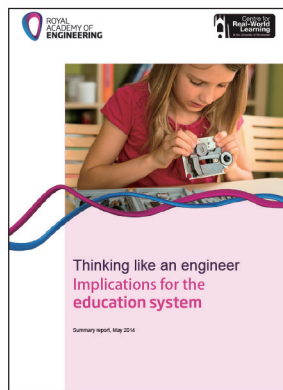


Fig. 1. Engineering habits of mind (courtesy: Bill Lucas, Janet Hanson, Guy Claxton of the University of Winchester and the Royal Academy of Engineering, 2014).

[†] <http://www.raeng.org.uk/publications/reports/thinking-like-an-engineer-implications-summary>

- (3) Visualising;
- (4) Improving;
- (5) Systems thinking; and
- (6) Adapting.

These are the traits which make us who we are.

To an extent, all children are born engineers, but the education system, if we are not careful, dismantles these creative and problem solving characteristics in favor of solely promoting knowledge acquisition and recall (which of course an engineer also needs). An education system which nurtures and develops these six characteristics alongside core academic knowledge is essential for the global economy in high-value activities.

It is important that our students gain knowledge. I do not want to cross a bridge which has been designed by engineers who do not know the equations for load bearing and wind resistance. I do not want to fly in a plane where the physics of lift has not been properly applied. None of us wants to live near a dam which has been built without proper understanding of soil mechanics. But to design for those great technologies—and to meet the global grand challenges—we need engineers who can exercise judgment, both technically and in their social relationships.

And so to wisdom. What is wisdom? Wisdom is the quality of having experience, knowledge, and good judgment—the ability to discern inner qualities and relationships. It is insight. The key words are Judgment, Discernment, Insight, and Understanding. These qualities are valued in all cultures. I quote here both Confucius and an American President. Confucius said:

By three methods we may learn wisdom: First by reflection, which is the noblest; second by imitation, which is the easiest; and third by experience, which is the bitterest.

Calvin Coolidge, the 30th President of the United States, added:

Knowledge comes, but wisdom lingers. It may not be difficult to store up in the mind a vast quantity of facts within a comparatively short time, but the ability to form judgments requires the severe discipline of hard work and the tempering heat of experience and maturity.

Wisdom comes from years of experience as practising engineers, but we need to enable our young engineers to experience situations where they can grow in wisdom. In the UK we are doing this largely through teamwork and design challenges. We also help our students to think through the role of the engineer in society (and indeed this is a requirement for accreditation for professional engineer qualification, i.e., the Chartered Engineer designation).

For example, at my own university, Leicester, we set the students the challenge of designing and building a wind turbine to a certain specification but that challenge must be achieved in a team. If one member of the team is not pulling their weight, the others must decide how to handle that. If the students encounter a dispute within the team, how do they discern the way forward as a team rather than allowing the loudest voice to dominate? And what if they fail? There is now tendency to be a culture of not allowing our young people to fail, of sometimes cushioning them from the harsh realities of the world, but it is through our failures that we really grow. Surely it is better to fail in a university context at a design challenge, but to learn some very important lessons along the way, than to fail when you design the bridge or the plane or the dam where human lives are at risk?

In the lecture course “Engineer in Society” at University of Leicester, we examine issues of engineering ethics. A very helpful guide can be found at the Royal Academy of Engineering website[†].

In the guide on engineering ethics in practice, there are a series of case studies on engineering ethics which draw out the core ethical principles:

- (1) Accuracy and rigor;
- (2) Honesty and integrity;
- (3) Respect for life, law, and the public good; and
- (4) Responsible leadership: listening and informing.

These are the four fundamental principles which, in the words of the *Statement of Ethical Principles* which governs the engineering profession “should guide an engineer in achieving the high ideals of professional life.” A typical case study (which is entirely fictional) from *Engineering Ethics in Practice: A Guide for Engineers* is laid out as follows.

Professional engineers should “avoid deceptive acts, take steps to prevent corrupt practices or professional misconduct, and declare conflicts of interest”

Scenario

Sudobuild is an international civil engineering consultancy that undertakes work all over the world. They have been assigned to direct a project in a developing country involving the development of a large hydroelectric installation that will in due course provide power for a town of several hundred thousand inhabitants. In conjunction with a business manager, the project manager negotiates the terms of the deal with the client, who is the construction company that will be building the facility.

The client agrees the contract with Sudobuild, and they inform the project manager that the funding for the consultancy work will be coming from a donor-backed central government fund dedicated to the development of energy production facilities. A small team from Sudobuild, including the project manager, flies out to provide guidance on the plans that have been developed, to give specific direction on ensuring that the facility can cope with a wide range of flow variation.

After the work is complete and the project manager is submitting an invoice, the client asks the project manager to invoice for twice the original amount. The client explains how this specific government fund operates; the fund is supposed to pay for 50% of the fee, and the client company is supposed to pay the other 50%. However, key individuals involved in the administration of the fund have developed a practice whereby consultants bill for double the amount, thus ensuring that the government covers the whole cost of the work.

The fee for Sudobuild's services in this situation is £370,000, of which only £185,000 was supposed to come from the government fund. The client is proposing that Sudobuild invoices for £740,000, and Sudobuild will then receive the full £370,000 that the government pays. The client points out the benefit of this from Sudobuild's perspective: they are paid in full, and on time. This is rare in consultancy work of this kind, and will save both time and money for the accounts department. The benefit for the client company is clear, as they receive the services without having to pay for anything. The government is none the wiser, as the administrators of the fund conceal the procedure from senior government officials.

On being informed of this unilateral change of procedure by the client, the project manager expresses surprise, and some anger. The project manager does not wish to participate in the theft of state funds however “normal” it is, and the manager explains

[†] <http://www.raeng.org.uk/policy/engineering-ethics/ethics#ethicsinpractice>

Sudobuild's position to the client company. The client company then breaks some disappointing news; they say that they do not have the money to pay the consultancy fee. They claim to have available only a quarter of the 50% that they were scheduled to pay Sudobuild, and they urge the company once more to follow the process they have outlined so that Sudobuild can receive their full payment.

Dilemma

You have undertaken some consultancy work with a foreign company, under a scheme whereby half of your fee comes from the central government. However, the client company informs you after the work has been done that they are in financial difficulties, and that the only way you will be paid in full is if you falsify the invoice document so that the government pays 100% of your fee. You are also told that this is the standard practice, and happens with the cooperation of the administrators of the government fund.

What should you do?

1. You could agree to the process as described by the client company. It is important that Sudobuild get fair remittance for the work they have undertaken, and administrators of the government fund have approved the practice of doubling the invoice.
2. You could refuse to participate in the practice, and accept whatever funds that the client company have available. You do not want to engage in corruption, but you do not want to sever your relationship with this company and others in the region.
3. You could refuse to double your invoice, and take the client company to court to recover your fee. It is important to take

a stand against corruption, and to ensure that companies face up to their financial obligations.

The students work in groups on the case study to decide on the best course of action. This helps them to think through the dilemmas around this kind of situation so as to develop their judgment for the future. The four principles give them a framework to check a situation against and so enabling a balancing of what are often very "grey" areas in terms of making a decision.

This takes us back to Confucius and Coolidge. How do we learn wisdom?

For Confucius, we learn wisdom:

- (1) Through reflection—so in educating our young engineers we must provide a framework for reflection, including on failure;
- (2) Through imitation—so we must be good models ourselves, we must be mentors;
- (3) Through experience—which "is the bitterest" but also the way which sears itself into us.

For Coolidge, "the ability to form judgments requires the severe discipline of hard work and the tempering heat of experience and maturity."

This is the challenge of engineering education.

Acknowledgements

The author thanks the Royal Academy of Engineering for permission to quote from *Engineering Ethics in Practice: A Guide for Engineers* and for permission to use Fig. 1 from *Thinking like an Engineer: An Active Learning Approach*.