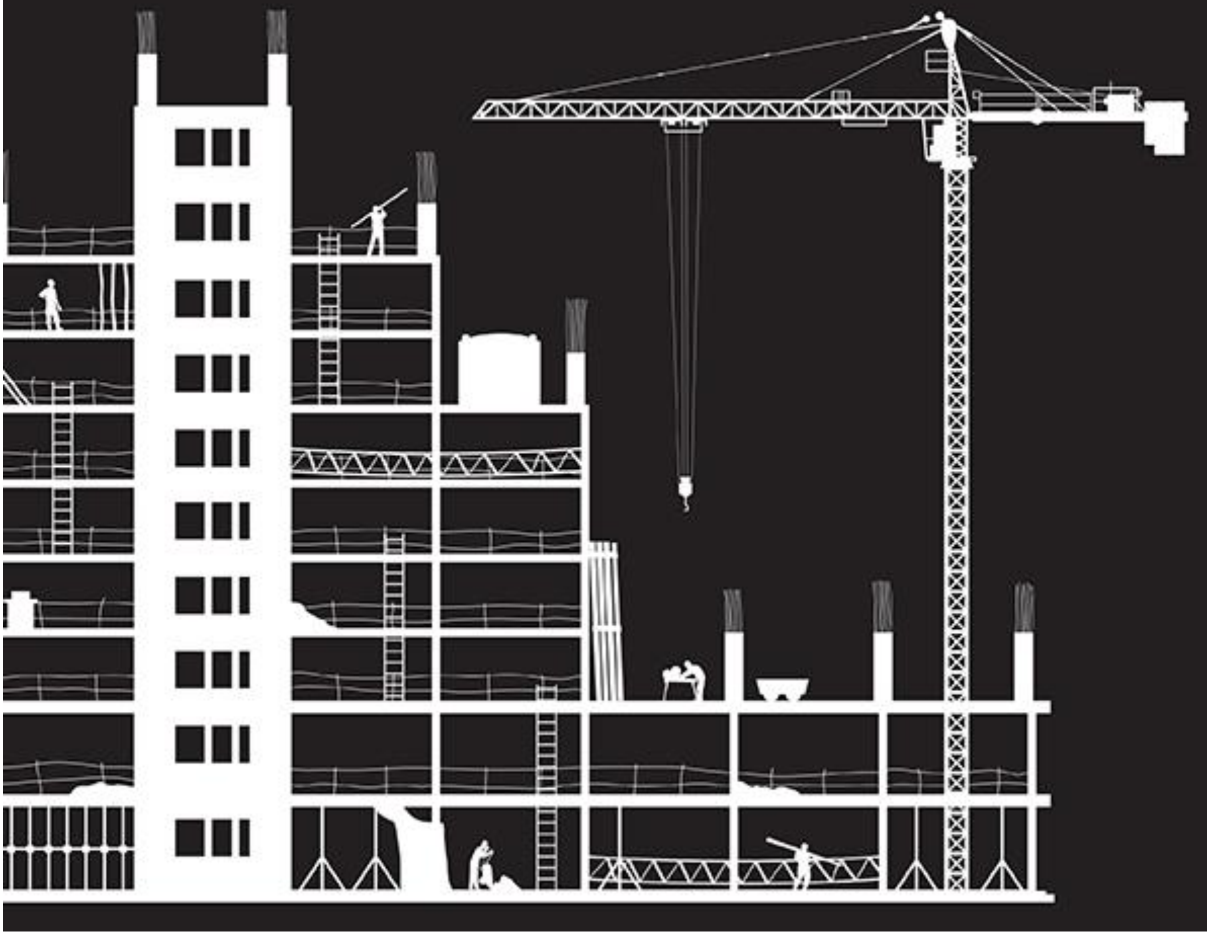
ROYAL ACADEMY OF ENGINEERING

Inter-Disciplinary Ethics Applied
A Centre for Excellence in Teaching and Learning

Engineering in Society

Edited by Rob Lawlor



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Inter-Disciplinary Ethics Applied – A Centre for Excellence in Teaching and Learning

University of Leeds

Introduction

There is a good chance that you have chosen to study engineering because you perceive it to be a good career, and because you have skills that you believe will be well suited to a career in engineering.

Nevertheless, it may still be the case that you don't have a clear idea of what a career in engineering will actually involve.

Students often have misconceptions about a career in engineering. They often underestimate the amount of report writing involved; or they underestimate the importance of communication, and negotiation; or they don't realise the amount of responsibility that they are likely to have, and the extent to which they will have to use their own judgement, and make their own decisions, rather than just doing what they are told.

One lecturer commented on how often students would ask where they could find the answer: "What book do I need to read?" The lecturer's response was that there was no book that had the answer. "You have to work it out for yourself." Engineering involves imagination and innovation.

The purpose of this ebook, therefore, is to give students new to engineering an initial insight into the profession of engineering, and to give students some idea of what their future career might look like.

Essentially, it is important to understand that engineers don't just work with machines, designs or circuit boards, and engineering doesn't only require a good understanding of science and mathematics. Engineering needs to be understood in the context of its role in society, and your role as an engineer has to be understood in the context of your work within a company, and ultimately within society. As an engineer, you may be involved in negotiations; you may become a manager, supervising the work of a team of engineers; you may have special responsibilities to ensure that work is safe, or to ensure it is not damaging the environment.

You may have a lot of responsibility, and be required to make financial decisions and ethical judgements, as well as mathematical calculations.

Creativity in Engineering (Sarah Bell)

Sarah Bell teaches environmental engineering at UCL. She began her career as a process and environmental engineer on an aluminium smelter in Australia. Her research now focuses on how engineers can contribute to improving the sustainability of urban water systems.

Engineering is a profoundly creative activity. Thomas Edison created electric light. Alexander Graham Bell created telephony. Ove Arup created the Sydney Opera House. Tim Berners-Lee created the world wide web. Engineers bring ideas to life.

Engineers are creative both as initiators and implementers of new ideas. Engineers invent new technologies, such as the telephone or the silicon chip, and they help to make other people's ideas work, such as structural and geotechnical engineers creating technical solutions to make an architect's design for a building stand up. The creative work of engineers is often hidden in the details of everyday life, invisible precisely because it works. Car braking systems, water treatment, gas turbines and mobile data networking, are just a few examples of continuous, creative innovation and improvement by engineers that keep us safe, drive the economy and support our modern lifestyles.

Engineers are creative problem solvers. This can come as a surprise to those who imagine engineering to be formulaic problem solving – analysing a problem to come to a known, single solution. Many of the problems facing society and engineering today are new and complex. As a society we have never before faced a problem like human-induced climate change. Never before have we had the capacity to produce and share so much data about our world, our lives and our finances. Never before have had we had a human population of 7 billion people, all needing food, water, shelter, education, employment and healthcare. In a competitive global market, engineers must constantly innovate to create new solutions and invent new ways of solving problems. Engineers who expect to provide the same, standard answers in an ever changing, complex world, will soon be out of work.

Engineers have been highly successful in creating the complex technical systems that make modern life possible. Unfortunately, we have been less successful in anticipating and addressing the negative consequences of our creations. Creativity comes with responsibility. Engineers have devised ever more efficient ways of extracting fossil fuels from the Earth and burning them for human benefit, and so must take central responsibility for addressing the urgent problems of climate change through energy efficiency and renewable energy. Engineers have designed and built cars, roads and motorways, and so must face up to the social and environmental problems of congestion, urban sprawl, emissions and rising fuel costs. We have built water systems that provide endless supply to homes despite fresh water being a scarce resource in many places, and now engineers must help people find ways to reduce water wastage. Engineers have created technical systems that have transformed society and the environment. Whilst we should celebrate our achievements we must also acknowledge our failures.

Engineering creativity emerges within the constraints of physical laws, commercial considerations, the needs of the client or employer, society, the law and ethics. Constraints provide boundaries within which to explore problems and propose engineering solutions. Ethical considerations in relation to safety and the environment can provide opportunities and inspiration for engineers to devise innovative solutions, directing their creativity to improve the performance of engineering technologies and systems. Ethical concerns about climate change drive engineers to devise creative solutions to the problem of providing reliable, cheap renewable energy. Ethical concerns about global poverty lead engineers to work with local communities to develop new technologies for water supply and sanitation in the developing world. Engineering ethics is a constraint to bad practice and an inspiration to innovation and creativity.

When working to devise creative solutions to complex social, economic and environmental problems, it is vital that engineers have a good understanding of the context of the problems they are trying to solve. This requires engineers to work with clients, users, communities and other stakeholders to establish a clear understanding of needs, constraints and potential impacts of any proposed solutions. Understanding the needs and requirements of users, communities, society and the environment, is as important to ethical engineering as meeting the needs of clients or employers. Working with a range of stakeholders can provide additional constraints and inspiration for creative design, leading to solutions that are more likely to have positive outcomes.

When the needs of the wider community and environment are in conflict with the requirements of employers or clients, engineers are faced with creative and ethical dilemmas. In some circumstances it may be possible to devise creative solutions that address seemingly conflicting requirements. For instance, specifying energy efficient lighting or building materials can save money for the building owner and reduce carbon emissions. In other situations, the engineer may need to bring the ethical implications of harmful systems and technologies to the attention of their client or employer. Professional engineers can raise their concerns with their employers or clients and demonstrate the value in ethical practice, they can raise concerns with external organisations such as regulators or professional associations, and they can choose to work only with ethically sound clients or organisations.

Engineering creativity is often understated and unrecognised, including by engineers themselves. Engineers depend on established science and methods for analysis to ensure their designs are safe and reliable. Creativity is usually associated with risk taking, while engineers are required to reduce risks to the public, environment and the commercial success of their clients and employers. However, finding innovative solutions within the boundaries of safety, reliability and efficiency requires considerable creativity. Working with communities and clients to deliver sustainable solutions to complex social, economic and environmental problems requires a diverse set of engineering skills. Creativity is the key to finding inspiration for new engineering designs and solutions within the constraints of ethical engineering practice grounded in science and engineering methods and standards that have evolved over generations.

The Virtue of Engineering (Kevin Macnish)

Kevin Macnish is a teaching fellow in applied ethics at the Inter-Disciplinary Ethics Applied centre. He has been teaching engineering ethics since 2009 and is completing his PhD on the ethics of surveillance.

W. Richard Bowen begins his book, *Engineering Ethics: Outline of an Aspirational Approach*, with an anecdote about a "young woman with outstanding academic achievements in science and mathematics" who applied to study engineering, motivated by the thought that, as an engineer, she could "make a contribution to the well-being of others." However, after visiting the university she had applied to, she left with the perception that engineering was a discipline more focused on technical ingenuity for its own sake, rather than a discipline that was focused on changing the world for the better, and she decided to study medicine instead.

The following (tongue-in-cheek) debate between an engineering student and a medical student develops this idea, considering whether engineering can compare with medicine as a profession that people might choose if they are motivated by the thought that their profession, and their own individual work, will make a valuable contribution to others.

ENGINEERING STUDENT: I can't believe I had to endure another engineering ethics lecture! Do they ever end?

MEDICAL STUDENT: You should be so lucky. We have far more ethics taught to us in medicine than you guys. Then again, in medicine we have issues to do with consent, confidentiality, abortion and euthanasia. What is there to talk about in engineering ethics?

ENGINEER: I don't know. I wasn't really listening.

MEDIC: In my case, if I make a mistake, someone could die. In your case, someone might end up with a dodgy phone!

ENGINEER: Are you joking? Engineers can kill people every bit as well as doctors. In fact, I bet we kill many more people than doctors. Think of all the weapons we make that kill thousands of people.

MEDIC: Fair enough, I hadn't thought of that. Hey, maybe you do need ethics teaching to stop you from making weapons.

ENGINEER: Then a number of doctors would be out of a job patching up the people we blow up.

MEDIC: I think we'd be quite happy with that.

ENGINEER: But there are good reasons for making weapons. Unless you're a pacifist – and you're not – then you agree there are situations in which we need a military. And they have to be armed somehow.

MEDIC: Maybe.

ENGINEER: But we don't just kill people with weapons. More than a million people are killed *a year* by car crashes.
(http://www.who.int/mediacentre/factsheets/fs358/en/index.html)

MEDIC: But that isn't the engineer's responsibility, is it.

ENGINEER: I'm not sure. But don't forget about plane crashes, dodgy bridges, nuclear disasters, mining accidents, oil spills. Even when a doctor *tries* to kill people, they typically only kill a dozen or so. An engineer can kill hundreds – or thousands – without even trying!

MEDIC: Wow. By comparison, we are paragons of virtue. Come to think of it, I can't imagine a more virtuous profession.

ENGINEER: I wouldn't be so quick. I mean, sure, doctors are there to help people, but generally you work one person at a time. We can affect the lives of millions.

MEDIC: So finding cures for leprosy, TB, puerperal fever and smallpox were small fry, were they? And what about antibiotics? Any one of those has saved thousands if not millions of lives. What does engineering have that comes close to those?

ENGINEER: OK, so it's not just one person at a time. However, engineering isn't just about cars and bombs. Think about irrigation, which has led to the draining of huge areas of land such as the Netherlands or East Anglia, and the watering of other areas which would otherwise be barren. Without engineering, people would still be using medieval strip farms. They could barely feed themselves, let alone everyone else.

MEDIC: You do have a point there.

ENGINEER: Even in the field of health care, I bet that engineers have a greater impact than medics.

MEDIC: That's pushing it a bit.

ENGINEER: Not at all. The British Medical Journal had a vote in 2006 about the greatest advance in medicine, and do you know what their answer was?
http://news.bbc.co.uk/1/hi/6275001.stm

MEDIC: Antiobiotics?

ENGINEER: No! I'll give you a clue. It wasn't the medical profession that can take the credit.

MEDIC: I don't know.

ENGINEER: Sanitation. Clean water. Think how few cases of dysentery you have to deal with. People used to die from sicknesses which have been largely eradicated thanks to flushable toilets. And then there are advances in building technology allowing people to live and work in better quality houses rather than Victorian slums, heating for those houses in winter and air conditioning in summer. There are also better quality roads and transport systems, thanks to engineers. You may laugh at me wanting to work on cars, but doctors these days rely on patients and medicine coming to them in ambulances and refrigerated vehicles respectively. You couldn't perform a heart transplant without engineering!

MEDIC: OK, OK. I get it. You do some good stuff as well.

ENGINEER: And who do you think makes the artificial heart valves you put into the patients? Or the pacemakers? Or the artificial hips and knees? All come from engineering!

MEDIC: Okay, I said. Okay.

ENGINEER: And don't think that medics can take all the credit for drugs either! That's us too – that's the chemical engineers. And how about the future? What can medicine offer down the road?

MEDIC: The sky's the limit there. Now that we're getting a better understanding of genes and have the human genome mapped we can really look at engineering humans so that we have fewer diseases. We may be able to completely eradicate genetically-inherited disease, and accurately predict a person's chance of getting cancer or heart disease in a way that helps them modify their lifestyle in time to avoid the worst. The drugs and technology we're developing can extend both the length and the quality of life. And you?

ENGINEER: Those are some pretty good things, I'll admit. But aren't they just toys for the rich? I mean, who benefits from them? Rich people in rich countries. What are you doing for the poor in less wealthy countries? Engineering offers solutions to less wealthy countries through designing cheap wells, providing irrigation and enabling the building of hospitals and transport systems.

MEDIC: Yes, but *other* engineers spend *their* time working on luxury cars and private jets. And come to think of it, it's cars, jets and other so-called "feats" of engineering which have led to the mess we're in with the world's climate. That's a pretty big stain on the profession's reputation, I'd say.

ENGINEER: I don't think that you can blame a profession for the unintended consequences of its past actions. We don't hold doctors today responsible for the deaths of people who were prescribed leeches in the thirteenth century!

MEDIC: No, but there is a slight difference in the time delay between medieval blood-letters and 20th century polluters.

ENGINEER: Fair enough. And I accept that engineers may still be contributing to global warming by not finding solutions quickly enough while continuing to produce goods that make the situation worse. However, short of returning to living in houses of wattle and daub and farming with the family cow, how are we going to resolve the problem of global warming without engineers?

MEDIC: So society paid you to get us into this mess and now society should pay you to get us out of it? I think you've missed your vocation – politics sounds more your thing.

ENGINEER: Ha ha. Seriously, though, if we want to maintain anything like our current standards of living, the solution will come from engineers. Wind farms, solar power, more efficient vehicles... it is engineers who will be developing these technologies.

MEDIC: Hmmmm. I don't know. Fancy a beer?

Making a Difference (Emily Cummins)

Emily Cummins is an award-winning inventor with a passion for sustainable designs that change lives. As a result of her work, Emily was named as One of the Top Ten Outstanding Young People in the World 2010.

When I was four, my granddad gave me a hammer and began to teach me how to make toys from leftover materials in his garden shed. I loved the fact that we could make something useful out of scraps, and my interest in sustainable design was born. My granddad ignited my creativity, and this is something I will never lose.

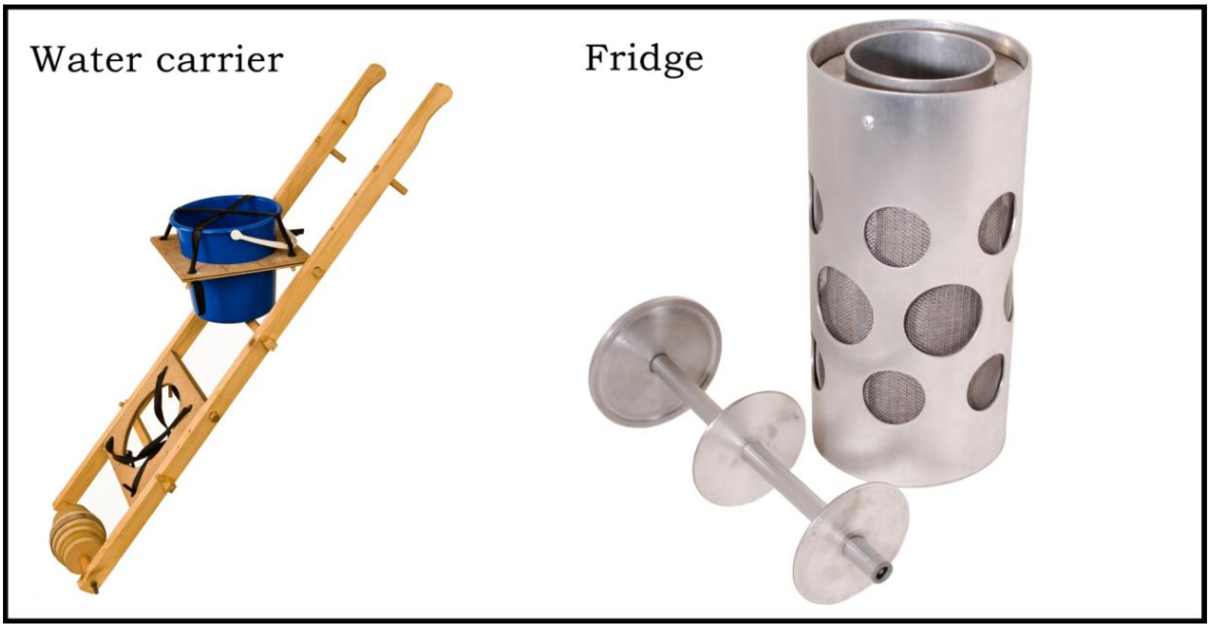
As I got older, I learnt about the properties of different materials and became more experienced in using a range of tools. At secondary school I began to win awards for my design projects, beginning with a toothpaste dispenser for arthritis sufferers - such as my other granddad, who found it difficult to squeeze tubes. The design incorporated levers that changed the required *squeezing* action into a *pushing* one: this simple innovation meant that not only could my granddad use it when cleaning his teeth, but that *anyone* struggling to squeeze pretty much *any* tube could benefit. A device that began life as a toothpaste dispenser for my arthritic granddad became multi-functional and useful to a diverse range of people.

On the back of this project my school, South Craven School in West Yorkshire, put me forward for a national engineering competition, where I was lucky to be one of the winners. Unfortunately, however, I didn't acquire a patent on my product and so lost all rights to it.

Although that was massively disappointing, I still got great satisfaction both from seeing my granddad using the dispenser as originally intended and from knowing that other people would use it in contexts I had never imagined. I decided around this time that I wanted to build more products to help people.

My second invention helped to make the journey for African women and children, who often walk many miles a day to collect water using only one or two jerry cans, safer and more efficient. I designed a carrier that allows a single person to transport up to five containers of water. (The same carrier can also be adapted to carry firewood or other heavy loads.) Carrying water on your head, or even using a yoke, causes long-term back problems: once this starts to happen, women start to struggle to carry the water they need, their children start to take their place instead, and a vicious cycle continues. My carrier eradicates this issue, and furthermore is *designed* to be manufactured in Africa itself - thereby creating jobs, allowing more children to attend school, and improving the quality of people's lives.

With this product, I was nominated for the national Sustainable Design Award and was lucky enough to be announced amongst the winners. At the ceremony, I was inspired by one of the speakers, sustainability expert Ed Gillespie, who spoke about climate change and explained how humanity continues to consume far too many of our scarce natural resources.



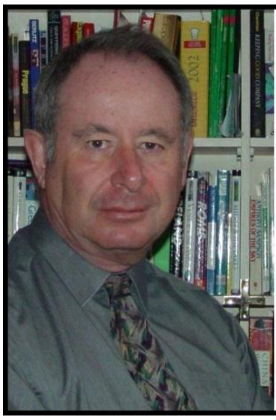
For my final year project at school, I decided that I wanted to create a sustainable refrigerator that could be powered by renewable energy. Built using barrels, spare car parts and ordinary household materials, requiring no electricity, and intended to be powered by "dirty" water, my design was not suitable for the UK market. But it was ideal for use in the developing world. The fridge consists of two cylinders, one inside the other. In between these a locally-sourced material (such as sand or wool) is packed tightly before being soaked with water. When the fridge is placed in a warm environment the sun's energy causes the outer part of the fridge to "sweat." As the water evaporates, heat energy is transferred away from the inner cylinder, which therefore becomes cooler.

The sustainable fridge is an improvement upon the usual "pot in pot" cooler, where the products that are stored come into contact with the water used for cooling. Due to the risks of contamination, only clean drinking water - a very scarce commodity in parts of the developing worlds - can be used in these coolers. Furthermore, only fruit, vegetables and items stored in non-porous containers can be kept safely. As well as saving precious drinking water, my fridge is also hygienic and dry - allowing a wider variety of things, such as meat and medicine, to be stored when they couldn't before.

I refined my fridge during my time at University and, because I wanted as many people as possible to build their own fridges, gave away the design plans to townships across southern Africa. Women in these townships now produce fridges from scrap materials, not only providing refrigeration in areas where it hasn't previously been available but empowering women to support themselves and their families and, again, creating jobs.

Some people question why I decided to "open-source" my designs - giving away the plans for free. It's simple: to me it feels like the right thing to do. I'm motivated by human need as well as sustainability principles, and my products would *never* have made the difference they have made today if I had taken the selfish route and decided to make as much money as possible. As an inventor, my dream is to see people benefitting from my products. I feel that I have started to achieve what I set out to do.

Ethics and Employability (John Turnbull)



John Turnbull is a Chemical Engineer who worked internationally for BP in R&D, Production and Business Management. He has served as Chairman of the IChemE Technical Policy Board and is a Fellow of the Royal Academy of Engineering.

Is an appreciation of ethics good for one’s employment prospects?

This struck me at first as a rhetorical question. The answer seemed so obvious; as it should be! But then I reflected on the happenings we hear about on an almost daily basis in the media. There are expenses scandals, child abuse scandals, accusations of banks illegally manipulating markets; the list goes on. So of course it is not completely unreasonable to ask whether “unethical behaviour” is becoming the new norm.

After I graduated in 1961 I joined the research and development (R&D) department of a major oil and petrochemical company. I worked on process development and design, and later the production of mathematical models of refinery processes. I soon learnt that while the company and my bosses placed great value on imagination and creativity, their number one requirement was reliability. The need to be able to trust the results and conclusions of my work was paramount. Falsifying, or misrepresenting results could put a whole project in jeopardy.

Later, as my career progressed, I became responsible for a range of petrochemical businesses. This included commercial as well as technical aspects. Secrecy and confidentiality must often surround commercial issues. Individuals must respect this. But one also becomes aware that commercial confidentiality can sometimes be used as an excuse to cover things up.

At one stage in my career, I was the director responsible for a number of petrochemical plants. One evening, I received a phone call and was informed that there had been a major explosion at one of those plants. I immediately set off for the plant to see for myself what had happened and to ensure that the aftermath was being dealt with properly. The scene at the plant was a total shock. It was devastated. In fact the explosion had been sufficiently severe that windows were blown out in buildings outside of the plant's perimeter. Fortunately there were no injuries to personnel inside or outside the plant. The major reason for this was that the designers of the plant understood perfectly well the hazardous nature of the materials being processed. The layout had been carefully thought through and the control room was housed in a blast proof building.

An explosion at this plant was potentially an event that we wanted to keep quiet. It could have damaged not only our business standing, but also our wider reputation. But then, after more thought, we decided that this was an event with possible industry-wide safety implications. After a thorough investigation of the circumstances and causes we invited all the operators of similar technologies to a seminar to hear what we thought had happened. It was a revelation. Other operators, some direct competitors, had had various similar, related incidents, albeit none of them quite so serious. While we had heard rumours about such events, up until the seminar we had no hard facts to rely on. Our openness and willingness to describe our experience and investigations created an atmosphere in which all of the participants felt able to share their experience in respect of process safety. We all learnt a great deal and the industry became a much safer and more reliable place. Our initial fear that the incident would damage our reputation was completely misplaced. On the contrary, by organising the seminar, which focused on common safety issues, in such an open way, our standing was enhanced.

We engineers are involved in a very complex and wide ranging discipline. Our particular skill set and experience are necessarily limited. We must be aware of this at all times. We have an ethical responsibility to only operate within our specific level of competence.

One operation which demands the highest levels of competence from an engineer is the modification of an existing design. We must not only see the merit of the modification, but also understand why the original designer did not incorporate this new proposal in the first place. In the 1970's I was responsible for planning the commissioning of a new major petrochemical complex. The team in charge of a major plant at the centre of the complex were concerned and even irritated by the length of time required to go step by step through the proposed commissioning sequence. An engineer in the Technical Department believed that he could see a way to short circuit the sequence by means of a simple modification. However, he was not able to see the full implications of his proposal and went ahead without reference to other more experienced and cautious colleagues. In effect the modification compromised the integrity of a key system. The result was a disastrous explosion and fire, which thankfully did not result in any loss of life or limb. But it was extremely expensive in terms of money and lost time.

At the heart of any ethical code is a requirement to place honesty and integrity as top priorities. In the wider community we all know that, without this, things soon degenerate into a jungle like society in which might overrules right. For the engineering community the need goes even deeper. We design, build and operate processes and machines involving huge amounts of potential power and impact. Passengers on a high speed train or an airplane place enormous trust in the skill and integrity of the engineers, and others, responsible. We cannot allow ourselves for whatever reason to lower our standards.

One of the most challenging roles that comes later in a career is the choice and assessment of potential employees. Fortunately in the case of professional engineers, universities and colleges do a good technical job with the support of the appropriate institutions. Looking at engineer’s qualifications and role within the appropriate institution gives an excellent insight into skills, and this combined with experience enables judgement to be made of competence. It is much more difficult to assess character. The key question is “Can I trust this person?” But there are many related ones. How will he or she react to pressure? Will they be able to resist the temptation to take shortcuts when under time pressure? Will they attempt to cover up mistakes or failures? In my experience, however strong a candidate’s technical qualifications, without the required character and personality they should not be offered a job.

There are some employers who do not share the lofty ethical aims of our profession. I have met in my time situations where I considered that improper influence was being brought to bear in a decision to award a contract. Where I felt that I could handle it, and ignore the pressure, decision making was simplified. If the pressure seemed too great for me I had no hesitation in referring the matter to my superiors. And if I did not have the confidence in their ability to handle the situation with integrity then I would have started to look at the job adverts in the press. If one cannot trust one’s employer in dealing with technology, customers or suppliers, then one cannot trust them to deal properly with their employees.

Professionalism (Rob Lawlor)

Rob Lawlor is a lecturer at the Inter-Disciplinary Ethics Applied centre, University of Leeds. He has been teaching engineering ethics since 2005 and was one of the authors of the RAEng's *Engineering Ethics in Practice: A Guide for Engineers.*

When lecturing first year engineering students, I start by asking the students whether or not they think that engineering is a profession, in the way that medicine and law are professions.

Having now asked this question to hundreds – probably thousands – of engineering students, the number of students who have answered "no" still hasn't reached double figures. It seems, therefore, that the vast majority of engineering students consider engineering to be a profession.

What is the significance of this?

When teaching engineering ethics, one of the most common responses that I get from students is this: "I can see that this is an ethical issue, but it isn't my job to make the decision. I am just an employee. I have a duty to do what my boss says."

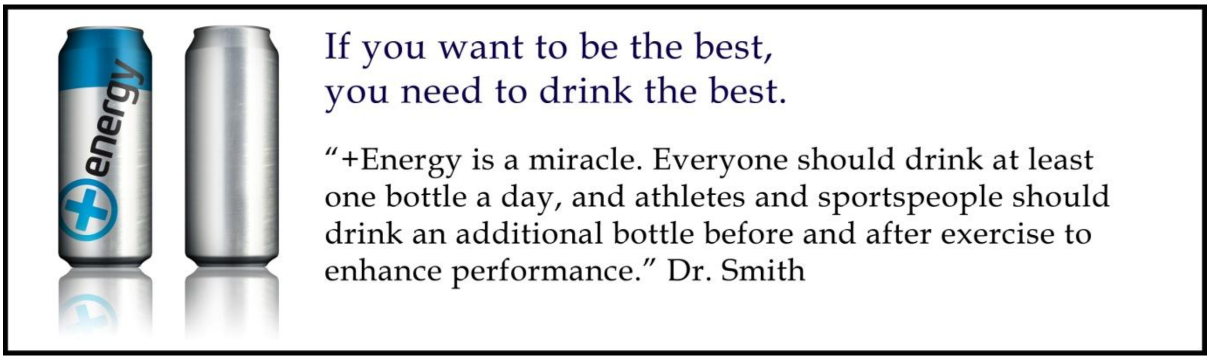
What does this response have to do with the question of whether or not engineering is a profession?

To answer this, we need to think about what it means to say engineering is a profession, or what it means for an individual to be a professional. There is actually a lot written about what a profession is, and there is also a reasonable amount of disagreement and controversy. However, without going into those details, it is common to appeal to features like having specialist skills, a lengthy education, and professional qualifications. In addition to these features, however, it is also common to talk about a role of providing a service to the public, being in a position of trust, being part of a professional body and having a code of ethics.

For example, F.A.R. Brennion claims that a defining characteristic of a profession is an "outlook which is essentially objective and disinterested, where the motive of making money is subordinated to serving the client in a manner not inconsistent with the public good." (*Professional Ethics: the consultant professions and their code*, C. Knight, 1969, p. 15.)

This doesn't mean that it is wrong to be motivated by money: if you chose to study engineering because it pays well, that is fine. And it doesn't mean that engineers cannot aim to make a profit. It does, however, mean that there are some things that an engineer cannot do to make money.

Consider this in relation to the medical profession. If anything is a profession, medicine is. Imagine that I invent a new drink, and want to market it and compete with other drinks. It tastes nice, but it is very unhealthy. It is full of sugar and fat and caffeine. This is a problem, because people are becoming more health conscious, so I don't think people will buy it unless they think it is good for them. So I approach a doctor to ask her to endorse it. I want her to film an advert. Her credentials will appear at the bottom of the screen, while she tries to persuade the viewers to buy the new drink, explaining how healthy the drink is. I also plan to use the doctor's endorsement on billboards.



What should the doctor do? Does it matter if I offer her £1,000,000?

The offer may be very tempting, but it is clear what she should do. She should refuse. If she did anything else, she would be acting unprofessionally, going against her code of ethics, and she would be struck off.

This isn't because she shouldn't be motivated by money. It isn't because she can't make decisions based on making a profit. It is because, as a professional, she has particular responsibilities that come with the profession. The profession is meant to serve the public. A professional can aim to make money, and to make a profit, but only to the extent to which this is consistent with their professional responsibilities. The medical profession is meant to serve the public, in relation to health and the treatment of illness.

Now consider, again, the student who says, "It isn't my responsibility to make that decision. I am just an employee, so I have a duty to do what my boss asks me to do." This is a mistake. If you consider engineering to be a profession, this has implications. Your first responsibility is to the public, rather than to your boss. If your boss asks you to do something that is inconsistent with your professional responsibilities, you should refuse.

What are an engineer's professional responsibilities? See the next chapter.

Statement of Ethical Principles

ROYAL ACADEMY OF ENGINEERING

Engineering Council

The Royal Academy of Engineering and the Engineering Council have identified four fundamental principles that they believe “should guide an engineer in achieving the high ideals of professional life”, and which “express the beliefs and values of the profession”. These are:

Accuracy and Rigour

Professional Engineers have a duty to ensure that they acquire and use wisely and faithfully the knowledge that is relevant to the engineering skills needed in their work in the service of others. They should:

- always act with care and competence

- perform services only in areas of current competence.

- keep their knowledge and skills up to date and assist the development of engineering knowledge and skills in others.

- not knowingly mislead or allow others to be misled about engineering matters.

- present and review engineering evidence, theory and interpretation honestly, accurately and without bias.

- identify and evaluate and, where possible, quantify risks.

Honesty and Integrity

Professional Engineers should adopt the highest standards of professional conduct, openness, fairness and honesty. They should:

- be alert to the ways in which their work might affect others and duly respect the rights and reputations of other parties.

- avoid deceptive acts, take steps to prevent corrupt practices or professional misconduct, and declare conflicts of interest.

- reject bribery or improper influence.

- act for each employer or client in a reliable and trustworthy manner.

Respect for Life, Law and the Public Good

Professional Engineers should give due weight to all relevant law, facts and published guidance, and the wider public interest. They should:

- ensure that all work is lawful and justified.

- minimise and justify any adverse effect on society or on the natural environment for their own and succeeding generations.

- take due account of the limited availability of natural and human resources.

- hold paramount the health and safety of others.

- act honourably, responsibly and lawfully and uphold the reputation, standing and dignity of the profession.

Responsible Leadership: Listening and Informing

Professional Engineers should aspire to high standards of leadership in the exploitation and management of technology. They hold a privileged and trusted position in society, and are expected to demonstrate that they are seeking to serve wider society and to be sensitive to public concerns. They should:

- be aware of the issues that engineering and technology raise for society, and listen to the aspirations and concerns of others.

- actively promote public awareness and understanding of the impact and benefits of engineering achievements.

- be objective and truthful in any statement made in their professional capacity.

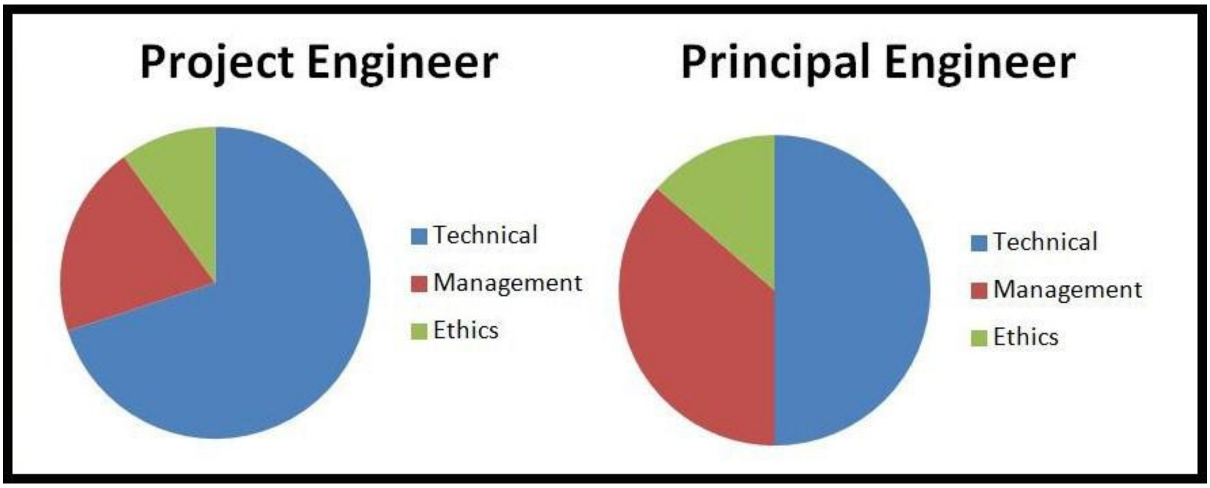
The Roles of an Engineer (Martin Haigh)

Dr. Martin Haigh, owner of training and development company, Lattitude7, is a Chartered Engineer, a Fellow of The Institution of Mechanical Engineers, and holds a PhD from the University of Leeds. Martin teaches ethics to undergraduates and professionals at the University of Leeds.

When I graduated with a degree in Mechanical Engineering I had no idea of the direction my career would take. Engineers can have varied roles throughout their careers from highly technical roles to ones of management and leadership. Technical roles, as you might expect, include being immersed in the use of mathematics, physics and science but other engineering positions will lead you to focus on communications, report writing, finance, negotiations and people development.

I had two job offers when I left University; one with Rolls-Royce as an Aerodynamicist – my final year project was on turbine blade vibrations - and the other job was as a **Project Engineer** with an automotive parts supplier. I took the latter job and started in the R&D Laboratory soon after graduating. The job was really exciting and meant I was involved in many projects. The role involved setting up experiments, writing software, running tests, analyzing results and writing reports. The engineering content of this job was high but also involved administrative duties. I did not manage anyone and had very little ethical judgements to make. However, even in an entry-level graduate position there is an element of responsibility and I had to act with honesty and integrity, and had to ensure that my report recommendations reflected the actual test results as senior engineers would make business decisions based on my findings.

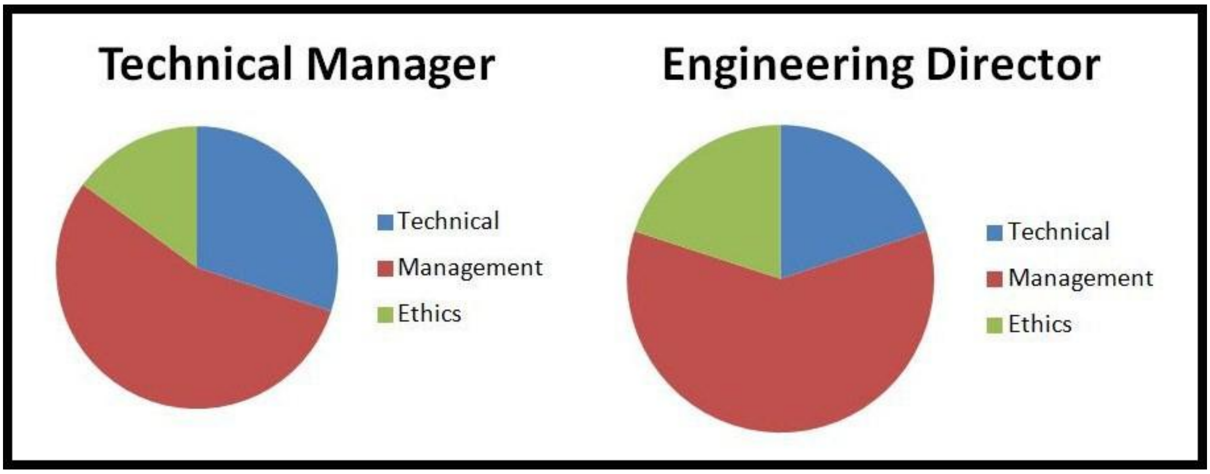
The charts below show the types of responsibility that I had in this job, and in later jobs.



A few years later I became **Principal Engineer** and two things happened; I was responsible for two other engineers and I had a lot of customer contact. Therefore, people management became a new skill I had to learn and I also had to wear a commercial hat. Arriving at work in the morning I did not just have to think about my own activities, I had to ensure that there was interesting work for my two engineers. I was also responsible for helping them to understand the importance of operating with integrity in the fast-moving manufacturing arena.

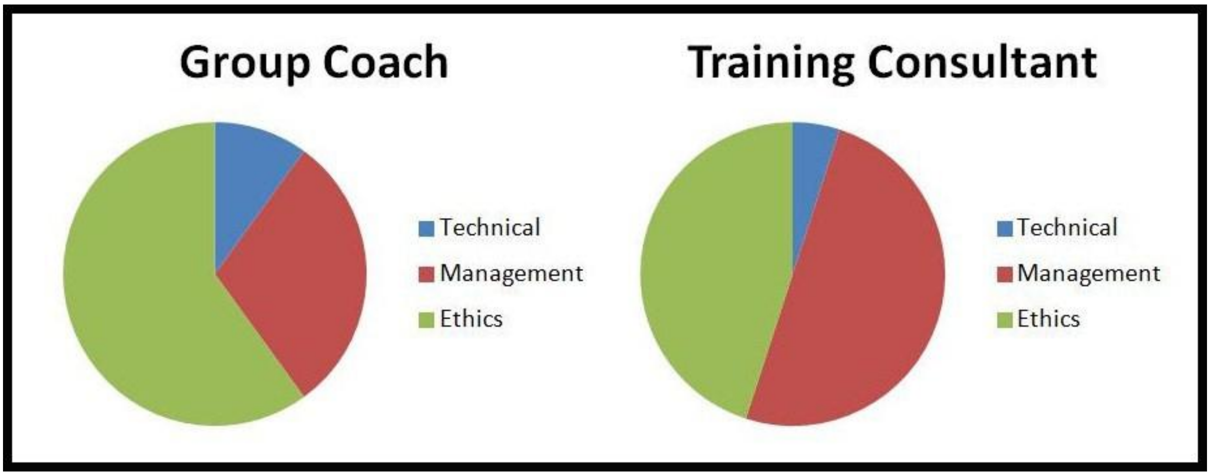
When interfacing with the customer I sometimes had to make decisions on how much to tell the client without lying, considering the interests of my company but also considering the interests of the client, and my duty to be honest and to act with integrity. Fortunately, the type of customer we had also had a vested interest in the projects succeeding. This is one advantage of being in a professional supply chain; if projects were slipping our customers would support us in identifying the issue and providing solutions.

When I was promoted to **Technical Manager** the job became one of managing a team of professional engineers and support staff. I would look after their welfare and ensure projects were on time and within budget. In this post I had to learn even more about people management but also had a major responsibility for a sizeable engineering budget. I also had to consider, in much greater detail, the health and safety for my staff and the department. My main ethical judgements were around the fair allocation of resources and staff development.



I then took a position as **Engineering Director** of a manufacturing-led business, the job was one of leadership rather than hands-on engineering. This role was also focused on politics; fighting the corner for the engineering department but also ensuring that the engineering department was represented in the best possible light both within the company and to the outside world. Ethics and integrity were very high on the agenda at this company. Therefore, I had to ensure that every one of my employees demonstrated the highest standards in this regard. To support our ethical and moral compass, the company provided code of conduct training for all professionals.

When I became a **Group Coach** and Talent Leader for global engineering, people skills became dominant as I was charged with building a "mobile" talent pool. Ethical decisions and considerations centred on confidentiality, identifying the most appropriate roles and ensuring that engineers were provided with the best possible training and development opportunities.



Now, operating as a **Training Consultant** and working with high-profile engineering companies I find that ethics and integrity are high on their agenda. I am often asked, when running personal development programmes, to include segments on ethics and code of conduct. Some organisations embrace this but others still have to move integrity higher up their corporate agenda. In respect of my own ethical position I need to ensure that I treat client information with a high degree of confidentiality and that I demonstrate a high level of integrity on a day to day basis.

In summary, Engineering is a fantastic and very rewarding profession and you can use your skills to pursue many other directions in your career. The writer André Gide said "You can never discover new oceans unless you have the confidence to lose sight of the shore". Never be frightened to change your career but make sure that you maintain your integrity. For a professional engineer, life is full of rich opportunities. Therefore, always be fair with people (one day your employee might become your boss), and make sure you operate with integrity. People notice and respect integrity and you will be in demand, as much for this as for your engineering talent.

Sometimes when we face difficult engineering judgements we have to find creative and innovative ways to overcome problems. As you go through your engineering profession it is always useful to keep assessing your values and making sure that your personal responsibilities are clear and adhered to. Your responsibilities should then extend to your workplace and, if there is an external element to your job, marketplace responsibilities are critical. Increasingly, organisations are crossing national boundaries so do not be surprised if you are asked to take on global responsibilities. Your organisation is likely to have a code of conduct and, with some ethics and integrity awareness training, you will be well placed, not only to comply with this, but also to lead change in your organisation.

Engineering Responsibility (Natasha McCarthy)

Natasha McCarthy is Head of Policy at The Royal Academy of Engineering. She authored the book *Engineering: A Beginner's Guide*, which explores the impact of engineering on society and culture and the nature of engineering knowledge and practice.

Engineering is one of the key influences that shape our world – physically, digitally, socially and economically. The inventions and innovations of engineering have created new ways of living and working, and as they have shaped our lives they have become crucial to supporting and maintaining our quality of life. From the supply of essential services such as power and water to life support machines in hospitals, the products of engineering are threaded through peoples' lives both individually and collectively. This means that engineers have a responsibility, but also a great opportunity, to ensure that they have a positive influence on society.

The influence of engineering and technology on society is not a one-way relationship. Engineering offers an array of technological possibilities, and society makes a choice between them. The choice might be made through consumer decision, for example through the battle of formats recently seen between Blu-ray versus HD DVD. Economic considerations also lead to one technology being favoured over another. When Henry Ford was developing the Model T, he experimented with cars running on ethanol (which is now understood to be a far better fuel in terms of pollution and emissions), but the low price of oil at the time led him to focus his attention on cars that would run on gasoline. Political debate can make a technology unpopular, either through the kinds of direct social action that affected the uptake of GM foods; or through laws and regulations that may control a technology or prevent it being used at all, as some countries have controlled the use of certain websites or social media tools.

But while society shapes the way that technologies are developed and taken up, the options that society may take up or reject are made possible by engineers. This means that engineers are in a position of responsibility, with the opportunity to create technologies that can have a positive influence on society and that can help to solve the problems and concerns of society.

One aspect of engineers' responsibility is to limit the harms that the products and systems that they produce have on communities or broader society. Major infrastructure projects such as new roads or rail systems can bring huge benefits to a community, through extra connectively and the change of urban regeneration. But they can also have negative effects on local landscape and peoples' homes and livelihoods. Engineers have a responsibility to reduce those negative impacts as far as possible, as well as engaging with the community affected to keep them informed and listen to their concerns. Engineers can also design those infrastructure systems so that they provide benefits to the communities they affect, using the opportunity to regenerate the local community by building homes or shops. Consideration could also be paid to using the construction project to deliver additional, beneficial services. For example, could new superfast broadband connectivity be introduced when the train line is built?

Engineers also have to manage the risks posed by the technologies they develop. Part of this is understanding the immediate safety implications of its development and use, but unforeseen or long term risks are also of importance to the engineer. For example, emerging technologies such as synthetic biology, nanotechnologies and autonomous systems all offer potential benefits and opportunities. But they all pose potential dangers, from the release into the environment of substances whose behaviour is not fully understood, to the use of autonomous vehicles where the issues of responsibility and accountability in the case of an accident are not yet agreed or understood. And for all such emerging technologies, members of the public may have fears or objections about their use that engineers need to take seriously.

But engineers do not only have these sorts of "negative" responsibilities. Engineers also have the opportunity to engage in projects that make a positive contribution and that help to solve problems faced by society. Engineers have a major role to play in developing energy efficient technologies and low carbon energy generation, which will be essential to limiting climate change.

They will also have a crucial role in adapting our infrastructure to the effects of a changing climate, making roads, railways, energy and communications systems resilient to severe storms. In this way they can help to protect our quality of life as the risk of major flood and other extreme weather increases.

Engineers globally can contribute to the development of affordable and appropriate infrastructure for developing countries, to help deliver clean water, sanitation, power and communications to poor communities. Engineers have a central role in developing healthcare systems, and again providing such systems in developing countries at an affordable price is a challenge that engineers can play a central role in.

A lot of our leisure time is spent using technologies from 3D film and TV to social networks. Engineering is behind those technologies and it shows that engineering can improve our quality of life way beyond providing essential services such as energy and healthcare. Engineering offers new ways to work, with remote connections to workplaces and ever more effective virtual meetings, enabling people to get more out of their work and free time. In these ways and more, engineering supports the economy, creating jobs and prosperity, helping nations to grow economically.

Because engineers are such a central part of society, it is important that engineers engage with the wider public. We all have responsibility to limit our energy use and the pollution we create. We all have concerns about the health and wellbeing of people in countries that are less wealthy. But we all know there is limited money to solve all of society's concerns. If engineers can work with the public to explain how engineering can help address their concerns, and to help us decide which are the most effective and affordable ways to address these concerns, we can make great progress. The final principle in the Royal Academy of Engineering and Engineering Council's Statement of Ethical Principles is "responsible leadership: listening and informing". Engineers have a major role to play in listening to society, informing them of what engineering can achieve, and focusing their efforts to ensure that engineering meets the needs of people.

Engineers Without Borders (Alistair Cook)

Alistair Cook is currently the Head of Learning for EWB-UK. While working in Bolivia, he developed an innovative funding model for solar stoves. He has also been involved in the International Development Design Summit.

Engineers Without Borders UK (EWB-UK) is an organisation that creates massive small change by empowering thousands of new engineers to remove barriers to development. As part of a global movement of young engineers who recognise their role within social, economic and technological justice, we believe that, through empowering our members, raising awareness in their peers and working with our partners, we can help create a world where everyone has the engineering they need for a life free of poverty.

We are part of a global social movement of young engineers and designers who want to utilise their skills to participate in solving some of the largest global challenges and this appetite for change drives the organisation. In 2001 a group of students at the University of Cambridge heard about a similar organisation in Canada and inspired, started the first branch of the UK charity. Since then we've grown to over thirty student branches and fifteen regional professional networks alongside a supportive academic community.

We understand that engineers are good at doing things and solving problems but engineers need to be good at understanding people too. By taking the time to understand context, by embracing complexity and by acting as mediators between people and technology, engineers will be able to better understand technology's impact and its influence.

Most of our seven thousand members are, or have been, involved in their university branch. These student societies organise their own events, training and member-led international partnerships, supported by the EWB-UK network and are active in education work, both within the UK and increasingly with our international partners.

In the majority of branches, this education work starts with our Outreach programme, where students and professionals from one of our thirty-plus student branches, or fifteen professional groups, come together to deliver fun, hands-on, practical workshops to school children. For example, the workshop “Water for the World” includes fun and messy activities, like building a water filter out of plastic bottles and sand, but it also raises awareness of the 884 million people who lack access to clean water and the 2.6 billion who lack basic sanitation.

During their time at university, students are supported to undertake final year research projects partnering with non-government organisations around the world. EWB-UK is now offering support for further development and implementation of technological solutions designed in this process through the Innovation Hub. The support comprises connecting the inventors with mentors, funding and other support in order to create tangible change from final year undergraduate and graduate projects. Through our academic community we now have opportunities for EWB-UK to become increasingly involved in the undergraduate curriculum (such as the many universities engaged each year in the EWB Challenge, which is our first and second year design challenge, focusing on design problems defined by one of our partner communities).

Outside of the curricular routes, EWB-UK also runs a national training programme, ranging from half day introduction courses to summer schools of various durations taking place on location with our long-term international partners in developing countries. Learning is supported further by opportunities for engineering students and young engineers to take up EWB-UK placements with our international and UK partners or by working on member-led programmes of work involving international partners.

We want:

Engineers with a deep passion for defeating poverty
Engineers with humble, holistic and systems thinking
Engineers with a broad understanding of the human experience
Engineers with deep listening, learning and communication skills
Engineers with the ability to create, innovate and invent
Engineers with the ability to manage and to lead
Engineers with the technical skills to solve complex problems
Engineers with a global perspective
Engineers with inspiration

We want… Engineers Without Borders.

We believe that, thanks to the hard work of thousands of our volunteers, we can transform the engineering profession and create massive small change to catalyse sustainable development through engineering. You are invited to join us on the learning journey to address global challenges with your engineering skills. To find out more or get involved please visit www.ewb-uk.org.

About the photos:

Construction Collaboration - by Jo Ashbridge

Simple Action for the Environment (SAFE), founded in 2009, is a small non-government organisation (NGO) based in the Dinajpur District of northwest Bangladesh. Every year SAFE collaborates with various local NGOs and Housing & Hazards, to host international participants during a two-week workshop. The event offers an insight into the challenges of a hand-to-mouth existence and is an opportunity to experiment with building technologies aimed at giving millions of people durable, hazard-resistant homes. In the year this photo was taken, 19 participants (predominantly with an engineering background) worked with local builders, craftsmen and homeowners to construct a double-storey bamboo house for a family of four in Jorgen Babur Mart slum, Dinajpur.

Transporting a Hydroelectric Power Station Transformer in Need of Maintenance, Arnakot Deurali, Western Nepal – by Daniel Narayanan

This transformer formed part of the HV distribution from a 90kW hydroelectric power plant, constructed using donations and volunteered engineering services, and serving some 1,200 people. Daniel was conducting a study into demands on the system when it failed, and provided valuable assistance to identify the cause – overloading and poor system design further downstream. It could not be repaired on-site, so the villagers committed to carrying over 400kg of transformer on bamboo poles more than 1km up the track pictured to the nearest road. Despite the scheme's overall success, this highlighted the difficulties of providing maintenance services within this environment.

Further reading

Engineering

Natasha McCarthy, *Engineering: A Beginner's Guide*

Engineering Ethics and Professional Ethics

Engineering Ethics in Practice: a Guide for Engineers, Inter-Disciplinary Ethics Applied and The Royal Academy of Engineering

Michael Davis "Thinking like an Engineer", *Philosophy and Public Affairs*, 1991

Mike Martin and Roland Schinzinger, *Ethics in Engineering* (or their shorter, but largely similar, *Introduction to Engineering Ethics*) – especially the chapter "Engineering as Social Experimentation"

Charles Fleddermann, *Engineering Ethics*

Richard Bowen, *Engineering Ethics: Outline of an Aspirational Approach*

Real Integrity, Jim Baxter, James Dempsey, Chris Megone and Jongseok Lee

Environmental Ethics

James Garvey, *The Ethics of Climate Change: Right and Wrong in a Warming World*

John Benson, *Environmental Ethics: an Introduction with Readings*

Philosophical Ethics (and, in particular, is ethics just opinion?)

Piers Benn, *Ethics*, especially chapters 1 and 2, and also chapter 3.

Bernard Williams, *Morality*, especially "Interlude: Relativism" and "Utilitarianism"

Stephen Law, *The Philosophy Files*, file 6 (and also 1).
(Don't be put off by the fact that this is aimed at children. Stephen Law is an academic philosopher and this is a very good introduction to philosophy, and files 1 and 6 focus on ethics. The first of these focuses on the ethics of eating animals, but is useful for looking at how he argues, but also because the treatment of animals will be relevant in many areas of engineering, as part of impact on the environment for example.)

Rob Lawlor, *The Trial of Socrates*
(Again, to an extent this is aimed at a younger audience, but nevertheless key arguments about whether ethics is just opinion, or whether ethics has to come from religion, are covered here.)

Biographies

Sarah Bell

Sarah Bell teaches environmental engineering at University College London (UCL). She began her career as a process and environmental engineer on an aluminium smelter in Australia. Her research now focuses on how engineers can contribute to improving the sustainability of urban water systems.

Kevin Macnish

Kevin Macnish is a teaching fellow in applied ethics at the Inter-Disciplinary Ethics Applied Centre, University of Leeds, and has been teaching engineering ethics since 2009. He has MAs in philosophy, theology and international relations, and is completing his PhD on the ethics of surveillance. His interests are in ethics as applied to surveillance, security, technology and the military.

Emily Cummins

Emily Cummins is an award-winning inventor with a passion for sustainable designs that change lives. Her latest innovation is a sustainable fridge which is "powered" by dirty water but keeps the contents dry, hygienic and cool. Emily refined her fridge in African townships before giving away the plans to benefit local people. As a result of her work, Emily was named as One of the Top Ten Outstanding Young People in the World 2010.

John Turnbull

John Turnbull is a Chemical Engineer who worked internationally for BP in research and development (R&D), Production and Business Management. After retirement he worked as a consultant in the USA, Europe and the Far East. He has served as Chairman of the IChemE Technical Policy Board. He is a Fellow of the Royal Academy of Engineering and has been involved in projects concerning Risk Management, Ethics and the Philosophy of Engineering.

Rob Lawlor

Rob Lawlor is a lecturer in applied ethics at the Inter-Disciplinary Ethics Applied Centre, University of Leeds. He has been teaching engineering ethics since 2005, and was one of the contributing authors of the Royal Academy of Engineering's *Engineering Ethics in Practice: A Guide for Engineers*. His research interests include exploitation, responsibility for climate change, and moral theories. He is the author of *Shades of Goodness: Gradability, Demandingness, and the Structure of Moral Theories* and the illustrated ebook *The Trial of Socrates*.

Martin Haigh

Dr. Martin Haigh, owner of award-winning training and development company, Lattitude7, is a Chartered Engineer and Fellow of The Institution of Mechanical Engineers and holds a PhD from the University of Leeds. He was formerly the Ethics Advisor for the product development community, in Europe and MEA, in a global corporation. As a member of the steering group of the Royal Academy, Ingenious initiative, he helped design the Professional Ethics for Professional Engineers (PEPE) training programme. Martin has delivered a number of these PEPE programmes on both an open corporate and in-house basis and teaches Engineering Ethics to undergraduates at the University of Leeds.

Natasha McCarthy

Natasha McCarthy is Head of Policy at The Royal Academy of Engineering. She leads a team engaging with policy issues across the whole spectrum of engineering research and practice, from energy systems to medical implants. Natasha has particular interest in engineering ethics, professional responsibilities and technologies at the interface with society – from surveillance technologies to critical infrastructure. Natasha's background is in philosophy and history of science and technology and she previously lectured at the University of St Andrews. She authored the book *Engineering: a Beginner's Guide*, which explores the impact of engineering on society and culture and the nature of engineering knowledge and practice.

Alistair Cook

Alistair Cook is currently the Head of Learning for EWB-UK having first become involved with EWB-UK through the Glasgow University branch and, after volunteering as national publicity co-ordinator, undertook a placement in South Africa, working with a local partner in helping provide water wells to local communities. While working in Bolivia, he developed an innovative funding model for solar stoves, and he has also been involved in the International Development Design Summit having participated in Boston, Ghana and helped organise the Brasil 2012 summit.

Acknowledgements

I am grateful to the Teaching Engineering Ethics Group (TEEG), the Royal Academy of Engineering (RAEng) and an anonymous charitable organisation for making the project possible, and to the Engineering Council, Engineers Without Borders UK (EWB-UK), Health and Safety Laboratory (HSL), Institution of Chemical Engineers (IChemE), the Institution of Civil Engineers (ICE), the Institution of Engineering and Technology (IET), the Institution for Materials, Minerals and Mining (IoM^3), the Institution of Mechanical Engineers (IMechE) and the University of Leeds, for their support.

I am grateful to Kevin Macnish and Kathryn Blythe for their assistance in putting the ebook together, to Nicola Stacey (HSL) and Liz Melsom for proof-reading, and to Matt Clark for his assistance with the cover page and the institutional logos.