GEQ1000 Asking Questions
Engineering Segment

Lecture 1.1
Introduction to Engineering
Engineering as Problem Solving

Hello students, I am Prof. Seah Kar Heng from the Department of Mechanical Engineering.

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In this segment, we shall focus on how we, engineers, think. In particular, we shall examine how engineers ask questions as they go about solving the problems of humanity.

When a student is studying engineering, he says he is studying “engine” for short, or else he says he is from the Engine Faculty. This often creates a misconception that engineering is the study of engines. Actually, the word “Engineer” comes from the word “Ingenious” and not “Engine”. It is a very general term used to refer to someone who uses his or her ingenuity to solve everyday problems with whatever resources that are available.

In many universities, the Faculty of Engineering is referred to as the Faculty of Applied Science, which is a very accurate term to use. Whenever a scientist makes a new discovery, there will always be a plethora of alternative uses for that particular discovery. And engineers are the ones who will find ingenious applications of those new scientific discoveries.

In other words, engineers are like practical scientists, who put into reality what the pure scientist or mathematician conceives and formulates.

For example, Sir Isaac Newton discovered the laws of motion. Each law that Newton discovered has endless engineering applications. Many engineers have since applied these laws of motion by designing and constructing moving objects like vehicles, ships, aeroplanes, space craft, etc. The laws of motion are even applicable in the nano sciences, governing the movement of tiny objects like electrons. It requires a questioning mind to figure out whether certain desired gadgets and machines are possible, given the present state of resources.

These applications are never static. They are ever-evolving as we come to learn more and more about our physical world.

At the heart of it all, engineering is a problem-solving discipline. If you come to an engineer with a problem, he will try to design and create a solution for you. No problem is too big or too small – or microscopic even – for us to solve.

Now, let us pause here for a bit. In general, all human beings are problem solvers. We solve problems all the time, whether or not we are engineers. Figuring out how to get from Point A to Point B is a problem we solve regularly. And we don't need to go through four years in the Faculty of Engineering to solve it.

If that's the case, what's so special, what's so unique about the engineering mode of problem solving?

Let us first focus on the kinds of problems engineers deal with. Engineers are typically engaged to solve multi-faceted problems. What seems to be a single problem may in fact turn out to be a problem that requires satisfying several different criteria at the same time.

The creation of a Mass Rapid Transport system in Singapore may seem like a single problem. But if we look at it closely, it is a multi-faceted problem. The limited land available in Singapore means that engineers have to find alternatives for placing the tracks and stations. They have to solve problems related to the construction of underground tunnels: how to dig tunnels underground without causing damage to the structures above, and without disrupting traffic and the livelihoods of people in the vicinity. Other than that, the engineers have to solve other problems like how to deliver electricity to trains in an efficient and safe manner, and how to build stations that aren't just safe, but also convenient for passengers to access.

To further complicate matters, the engineer works in an imperfect environment filled with a variety of constraints, uncertainties, and risks. Something as simple as a passenger or bag could prevent the train door from closing properly, thereby causing delays in our MRT system. Or a thunderstorm could cause an electrical short circuit. In torrential rain, water could easily flood the MRT tunnels since they are underground. Cracks and corrosion could cause leaks in the waterproofing. The engineer must find a solution that caters to all these requirements.

There are also many sources of constraints, the most obvious being a finite amount of time, money, and material resources allocated to solve the problem. The engineer will need to minimize waste while fully utilizing the limited resources at hand. The engineer is also limited by the laws of nature as well as the laws and regulations of the state. Every potential solution will present both a set of benefits and costs. The engineer must also solve the problem in a way that caters to the desires of the client.

It is often the case that these multi-faceted problems are also multi-disciplinary in nature. The creation of better infrastructure, reliable transportation, secure and fast communications, affordable medical treatments, etc., are not just technical problems. They profoundly shape the way we live.

No doubt it was a scientist who discovered how electricity flows, but it took an engineer like Thomas Edison to invent a lightbulb and to find a way to efficiently mass produce it for everyone to use. We may take the lightbulb for granted today.

But back in Edison's day, the introduction of the lightbulb to homes and streets meant that many people could continue working and playing longer in the night, even in places where daylight was scarce. This allowed millions of humans to be more productive for longer hours. The lightbulb paved the way for new forms of social interactions where people could meet and engage with one another in new and meaningful ways.

The engineering mode of problem-solving stretches beyond the domain of engineering itself. As engineers, we have to access the entire body of human understanding and wisdom: mathematics, the natural sciences, the social sciences, computing, design, and the humanities, in order to solve real-world problems. The engineer employs the concepts and tools from these various fields and brings them together in a synthesis that enriches our human experience.

Here's another example. Decades ago, engineers were looking to solve the energy problem: how do we provide more energy at a time when our demand for energy has grown tremendously? Today, it is obvious that they made use of scientific analyses on how the sun can convert mass into huge amounts of energy through Einstein's famous equation ($E = mc^2$). But before the engineers thought of utilizing such scientific discoveries, they turned to literature, or more precisely, to science fiction. Numerous scientific discoveries, like the discovery of radioactivity, fueled the imagination of so many science fiction authors who envisioned a future where humanity could harness energy from atoms. It was this seemingly unlikely source that gave engineers the creative inspiration to attempt such a novel solution of designing and inventing a nuclear power plant.

However, the problem with living in an imperfect world is that things don't always go the way we plan. According to Murphy's Law, "Anything that can go wrong will go wrong." The engineer must devise a solution that pre-empts all the possible ways that things can go wrong, either with the environment, the people or systems involved, or with the solution itself.

But there is a limit to what we engineers can do in this regard. We are limited by our experiences and understanding of the world, and can only do our best to pre-empt all the known possibilities for failure as well as all the unknown possibilities.

But we must remember that the engineer is constrained by the finite amount of time, money, and resources available to him. There is only so much that can be done. Thus, every potential solution that comes to the engineer's mind must be carefully considered against the numerous constraints.

The engineer requires a great deal of creativity to "think out of the box" in order to discover a brilliant solution that overcomes those numerous constraints.

For this reason, in engineering, there is no single "right" answer or perfect solution to any problem. The engineering mode of problem solving seeks to find the best possible solution, or the optimal solution that will fit the needs of a multi-faceted problem constrained by numerous factors.

This is an ever-advancing process. So long as there are engineers who are bold enough to ask questions on how we can “do things better,” there will always be new engineering inventions. That’s why it is important for engineers to always be creative, to challenge the status quo, and to ask questions. There is no final perfect answer as we live in an imperfect and ever-evolving world. But as engineers continue to solve the many problems of humanity, we will slowly and steadily improve the things around us to enhance our human experience.