

Lecture 1.7

Engineering as an Iterative Process

How does Questioning Lead to Technological Progress?

Let us take stock of what we have learnt.

Engineers are essentially problem-solvers. We use scientific knowledge and apply it to make life better for humanity through our problem-solving skills.

There are two activities that engineers constantly engage in: modelling and monitoring. These are important to the engineering mode of problem solving.

Modelling helps us to develop an understanding of a system, and it is an indispensable tool for helping us discover solutions to a problem. Monitoring keeps engineers firmly grounded to reality, as it provides a check and balance to evaluate both our models and our solutions.

Many engineering problems demand engineers to exercise creativity. This often requires us to tap into the vast expanse of human knowledge and wisdom, in order to design a solution. Some problems require the design of a **product**. Others require engineers to design a **process**.

This is easier said than done. Engineering design is more complex than it seems because the engineer lives in the real world – in an imperfect and uncertain world, with many constraints, such as the laws of nature, the availability of resources, and the laws and regulations of a state.

Engineers need to rise above and beyond these constraints to develop the best solution possible, while at the same time anticipating a range of uncertainties that may lead to catastrophic failure.

When failure occurs, the engineer needs to accurately pin-point its main cause. This is often done through the process of elimination, achieved by testing and confirmation.

Through all these stages, the engineer asks a myriad questions, some of which generate even more questions in a never-ending cycle. You may think that this spiral of questioning leads nowhere. But that's not true! The spiral of questioning brings us to higher and higher levels of sophistication in our daily lives, so much so that we now live in an era full of wonderful facilities and connectivity that our ancestors could never have dreamed of.

Let us consider some ingenious inventions made by engineers which we all take for granted today. What were the questions that they asked, which propelled them to come up with these inventions that we can't do without today?

Just two centuries ago, only live music was available. In order to enjoy music, one had to personally attend a concert, or gather musicians to one's house or courtyard. For this reason, it was mainly royalty and the wealthy who could enjoy listening to musical performances. Today, we have recordings and online streaming, such that music is brought into the comfort of one's home. Everyone can enjoy music any time, any day.

How is this possible? It all started when someone asked whether a live performance could somehow be “bottled” and brought to the masses in their homes.

The engineer Thomas Edison tried out many possible avenues to achieve this and finally invented the phonograph or gramophone, that inscribed music into Phenolic and Vinyl records. These records captured or “bottled” the sounds, so they could be reproduced at will. It was a technological breakthrough.

However, gramophone records were very bulky and heavy. They scratch easily if not handled with care, and they would warp under heat, thereby distorting the reproduction of sound.

This prompted engineers to ask: can music be bottled in a “weightless” fashion?

This led to the invention of wired and wireless broadcasts, and the public was able to enjoy music right in the comfort of their homes. And of course, if we can “bottle” music, can we also “bottle” images? Questions like this drove engineers to invent the cathode ray tube and the television.

One serious drawback of course was that once the music was broadcast or telecast, it could not be repeatedly enjoyed at will by the consumer. The engineers were then compelled to ask: how do we store music so that we can enjoy music again and again in a convenient way?

Enter the magnetic tape, which could record these sounds and reproduce them any time at will. It was not long after, that consumers discovered that these tapes gradually stretched over time and the frequencies of the sounds fluctuated and marred the music. This led engineers to yet another round of problem-solving before solutions were found.

To cut a long story short, we can now enjoy near-flawless reproductions as well as live-streaming of musical performances, thanks to the ingenious inventions of engineers such as fibre optics, digital formats, and solid-state storage, things that we take for granted whenever we listen to music wherever we may be.

Here’s another example. Leonardo da Vinci was a veritable renaissance man who was a great questioner. He was a curious man and he questioned everything he could about science, engineering, medicine, art – in fact a plethora of diverse fields of study. One of his questions was “How does blood flow within the human body?” With dissections, glass models and superior observation, he theorized how vortices in the aorta work to close the aortic valve. This would only be confirmed in recent times. But through his curiosity, he managed to draw countless anatomical drawings, showing various parts of the human body, including an unborn baby.

Fast forward a few hundred years. The same curiosity exists in mankind. However, with the advancement in science, engineers have been able to come up with various devices to look into the internals of the human body. When Wilhelm Rontgen discovered X-rays, it averted the need to cut up a person’s body in order to see what’s inside. Now, taking an X-ray is a standard procedure whenever a doctor wants to verify if a patient has a broken bone, an impacted tooth, an infected lung, or cancer.

Later on, X-ray machines were complemented by MRI (Magnetic Resonance Imaging) machines and CT scan machines, the latter also known as CAT (computerized axial tomography) machines. These are the products of scientists and engineers who continually search for better ways to study the internals of the human body.

With these modern medical engineering marvels, researchers were finally able to confirm some of Leonardo's conjectures. Using MRI, medical staff can now see what has always been hidden from view – vortices in the aortic root do have a role in closing the aortic valves, which is an important medical discovery. Sometimes, questions have to undergo a slow burn. A simple question like "how does blood flow?" needed numerous other scientific and engineering questions to be asked and answered before we discovered the answer. It does not matter that the questions asked today cannot be answered just yet, as there is always hope that in the future, answers will be found.

Engineering is anything but static. Engineers are never satisfied with the present situation and will ask if things can be improved. This involves refining solutions with as many iterations as there is time and resources for. If time permits, the iterations will go on forever.

Truly, we have benefitted hugely from the questioning minds of engineers through the ages. So long as engineers continue to question and challenge the status quo, who knows what other wonders are in store for us in the coming years?