GEQ1000 Asking Questions
Engineering Segment

Lecture 1.2
An Overview of Problem Solving
How do Engineers Approach a Problem?

So far, we've said quite a fair bit about the engineering mode of problem-solving. But what is a problem? To us engineers, a problem is basically anything that is not at its desired state and needs improvement. In many ways, we are very optimistic people: we believe that once we have identified a problem, we can find a good solution to it. That's why we pride ourselves as "problem-solvers."

Let me introduce you to the five-step problem-solving heuristic used by many engineers. It has its origins at McMaster University, Canada:

1. Define the Problem
2. Generate Solutions
3. Decide a Course of Action
4. Implement the Solution
5. Evaluate the Solution

This seems quite straightforward. Yet, the path to solving problems, especially complex problems, is never that straightforward.

In any problem-solving situation, it is important to define the problem correctly. Problems may be defined badly due to a variety of reasons. It could be due to ignorance, a lack of understanding of the situation. Problems may also be poorly defined due to biases. If we have a strong unjustified belief about what the problem may be, we may unconsciously ignore contrary evidence and instead search for evidence that supports our belief. That is known as ***confirmation bias***. Or we might have examined a skewed sample that is not representative of the system we are working on. This is known as ***sampling bias***.

Ignorance and biases are the key culprits to poorly defined problems. We, engineers, refer to them as ***perceived problems***. A perfect solution to a wrongly defined problem – perceived problem – is worthless compared to an approximate solution to a correctly defined problem.

When engineers are tasked to solve a problem, we are often given a perceived problem. It is up to us to ask questions to ferret out the ***real problem*** from the perceived one.

Imagine that you are a waste treatment engineer working in a manufacturing plant. One day, your boss comes into the office and says: "We need to design a new waste treatment plant to reduce the toxic waste stream flowing into the river by a factor of 10."

This project will cost about $5 million. What's odd about this is that the concentration of toxic chemicals are significantly below governmental regulations. There is no need for a new waste treatment plant. It seems that we are dealing with a perceived problem. We'll need to probe and check if the problem is correctly defined.

Here I'd like to introduce you to six classes of questions that engineers ask to gain clarity and insight, so as to derive the real problem from the perceived problem.

(1) First are questions about the problem statement. The purpose is to find out why the problem came up, who brought it up, and why it needs to be solved.

In our scenario, you could ask: "How did the problem arise?"

Your boss responds: "This came from senior management in response to bad publicity in the newspapers. There was an article about dead fish in the river and it is being attributed to toxic chemical release from our company."

Now we know how the problem came about, we can proceed to the next class of questions.

(2) Second, questions for Clarification. The purpose is to find out missing or unclear information in the problem statement.

Here, you could ask: "Can you explain how management arrived at the problem statement?"

Your boss answers: "An ongoing drought has reduced the water levels, thereby increasing the concentration of toxic chemicals in the river. This makes the water too toxic for fish to live."

This sounds reasonable. In fact, the empirical data appears to match the explanation.

But there are many possible explanations – hypotheses – to explain the phenomenon of dead fish. The same data can be used to confirm many other hypotheses. We'll need to ask a different class of questions to be sure that our manufacturing plant is actually causing the problem.

(3) Third, questions that probe assumptions. The purpose is to uncover hidden, misleading, or false assumptions.

Different assumptions can lead to very different interpretations of the same phenomenon. Here, we have been assuming that the fish were not affected by other external factors.

Would someone with a biology background approach the same phenomenon with a different set of assumptions? If so, the interpretation of what happened will be quite different. This will give us a different hypothesis to challenge the only one that we have.

According to a biologist, it turns out that low water levels and higher water temperatures tend to make fish more susceptible to disease, typically due to fungus.

Here we have another competing hypothesis for the same phenomenon. Which is the right one? The next class of questions can clarify!

(4) Fourth, questions that probe reasons and evidence. Through these questions, we can explore whether facts and observations support an assertion or conclusion.

Now that we have an alternative hypothesis, let's question the evidence itself, i.e. the dead fish! It's a lot easier and cheaper to test for fungi or bacterial infections in fish, than it is to test for toxin poisoning.

As it turns out, scientists have been collecting the dead fish and noticed fungal infections in many of them.

While this new piece of evidence certainly confirms our alternative hypothesis, it still doesn't rule out that our manufacturing plant was in no way involved. More questioning is needed.

(5) Fifth, questions that probe viewpoints and perspectives. The purpose of these questions is to learn how things are viewed or assessed, and to help look at the problem not only from a relative perspective but also from a system-wide perspective.

Are there dead fish elsewhere that are not linked to the manufacturing plant?

In our scenario, it turns out that there have been significant fish deaths upstream of the river. Toxins from the treatment plant are released further downstream and could not have reached this part of the river. This confirms that our plant is not the cause of fish death!

We can now conclude that the earlier defined problem of fish dying due to toxic discharge was a perceived problem. Building a new waste treatment plant would not fix anything, since the real problem is that the ongoing drought is causing a fungi infection, and that is killing a lot of fish.

This leads us to our last class of questions:

(6) Sixth, questions that probe implications and consequences. This class of questions will help us understand the end result if the inferred action is carried out.

What will happen if we don't do anything about this?

If the ongoing drought persists, the fungi infection will continue to spread, and this might possibly wipe out all the fish in the water bodies of the region. This is the real problem.

Knowing this, we can now define the problem statement: what can we do to protect the remaining fish in the lake as part of a community-wide initiative?

Now that we have the problem statement, what's next? Well, we'll need to generate solutions. We do this through a process of brainstorming to generate as many ideas as possible. Here, we employ various techniques to stimulate different patterns of thought and to overcome mental barriers.

Here, I'd like to discuss some brainstorming techniques unique to engineering. ***Futuring*** is a systematic process of removing potential technical blocks by planning scenarios about the future. Often, we'll employ variants of the same scenario, e.g. things will remain the same, things will get better, things will get worse, etc. These scenarios help to clarify our thinking about issues, so that we can make better decisions.

Engineers often utilize unique knowledge and skill sets of individuals and groups with different backgrounds to facilitate ***cross-fertilization*** of ideas. For instance, a group of scientists were working on finding an alternative to the chemical DDT in fighting mosquitoes. Then, a rocket scientist who worked on guided missiles came up with a solution of fighting mosquitos: With lasers!

As an alternative to cross-fertilization, ***analogies*** are used to find solutions to similar problems in other disciplines. A technique called ***TRIZ*** (Russian for TIPS – Theory for Inventive Problem Solving) is frequently employed to generate solutions for problems.

I won't go into detail here, but one of its central principles is to resolve contradictory elements in a problem as well as to use any current defects in the system to solve problems.

Here's a really interesting example: A company that manufactures and ships soaps received multiple complaints from customers that some of the boxes did not contain soaps. Through brainstorming, engineers identified three solutions:

1. Manual verification of boxes before shipping
2. Deploy an X-ray machine to scan for the presence of soaps and have a robotic arm remove the empty boxes from the packaging line
3. Use a fan and blow the empty boxes right off the production line

As you can see, Idea #3 made use of a weakness within the system to solve the problem. Only $20 was spent to install a fan that effectively solved the empty box problem. There's no need for manual labour or high-cost technology!

Brain-storming and other techniques mentioned above are important creative processes that can help us discover new and interesting solutions.

From here, engineers can proceed to decide on a course of action, implement the solution, and evaluate it. We will discuss these three steps in detail, in the next few lecture videos.