Effective Engineering "Teaching'' in Practice
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Lecture – 04b
Problem based learning (PBL) & Problem Solving (part – 2)

Welcome to this next lecture. It is in the same topic that we looked at in the previous lecture. The title is Problem based learning and Problem Solving. I thought it would be nice to take these together. The problem based learning was introduced as the simplest extension to I talk - you listen kind of a traditional lecture and what we are going to do today or begin to do today is look at problem solving. I will go back to problem based learning in a more complete sense as we go through the course. Today let us begin with problem solving.

Problem solving is very necessary for engineers. All engineers would be used to solving closed ended problems in classes, in exams and so on so forth. In real life it is very necessary and therefore, we train them to solve problems.

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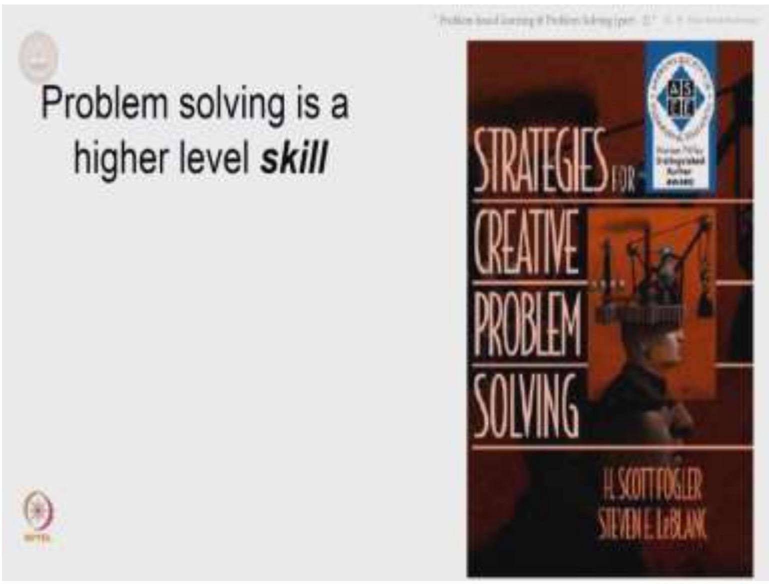

However problem solving is not easy. That is because problem solving is a higher level skill. Do you recall the Bloom's taxonomy of learning objectives? By the way I think I need to mention the taxonomy is equivalent to, you might be familiar with botanical taxonomy - the way of classifying various plants taxonomy, in life in general in terms of organisms, animals and so on so forth.

Taxonomy is putting them into certain categories so, that it becomes easier to understand them and attribute things to that category, because things are attributed to that category and therefore, we could come up with easier means of addressing any issue. That becomes one of the applications of taxonomy. Similarly Bloom's taxonomy is a taxonomy. It is a system by which you categorize things and then it becomes easier, from an understanding perspective, to address challenges. So, coming back to this - the higher level skill, if you recall a Bloom's taxonomy, it is recall, understand, apply, analyze, evaluate and create/design and so on so forth; create or design and so on right.

The problem solving is a higher level skill. You at least need the apply level skills to be able to address problems and that is why it is not easy for many students who are not used to solving unseen problems. To help us with this or to help you with this, let me introduce a reference book, this is by Scott Fogler and Steven Leblanc. The title is strategies for creative problem solving. It is a very nice book. It is available. If you want a book to follow you, could look at this book in the library or buy this book and so on - a reference book.

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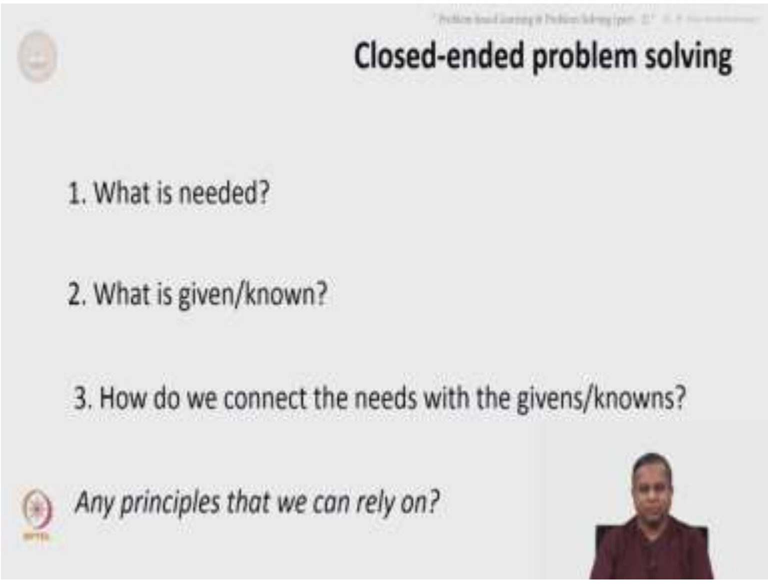

Coming back to the higher level skill. You need higher level skills to solve, it needs to be developed in students and let us see one of the ways of developing this skill for closed ended problem solving. What does closed ended problems mean? It means that everything is known, whatever is needed is known and what needs to be found is very clearly known. You need to use the things that are known to get whatever answer or a response is required. That is closed ended problem solving. These are typically used in time bound exams and so on so forth.

In the other side you have open ended problem solving, where whatever is needed may not be known. The student needs to go and find out the various things that are necessary to answer the particular question,n maybe from handbooks, maybe from other reading sources and so on, maybe from reliable sources on the internet and things like that. So, let us look at closed ended problem solving. Even these skills need to be developed in many students. Some students who come in through highly competitive exams to such programs for example, in the IITs, they may have developed these skills.

But even in IITs, there are a large number of students who do not have these skills and therefore, it needs to be developed in a formal fashion and in many engineering students this skill needs to be developed. Let me present one of a my own strategies for developing these skills. If you want to look at you know time tested formal strategies and so on so forth, you could look at the book or other literature in problem solving. Now let me present this which seems to work.

First ask the question what is needed? What is needed to be found as a part of the question, the problem? Second - be clear about what is given or known in the problem. Some things may be given explicitly, some data such as let us say avogadro number and what is the definition of a mole and so on so forth, may be required to be known as a part of a background to solve the problem. They may not be explicitly given, any of the physical constants may not be explicitly given if they are repeatedly used, for example, gas constant may not be given and so on.

But it may be necessary to solve the problem. Therefore, it is good to know what is given and known and then the last step is to look at how do we connect the needs to the givens/ knowns? Simple, straight, but very hard too. Especially for people who do not have the skills, the third step is very hard to do and it needs practice. And one of the nice things to look for when you are trying to link or connect the needs with the givens and knowns is to see whether any principles that we can rely on are available, this will become clear as we go along as I give you an example.

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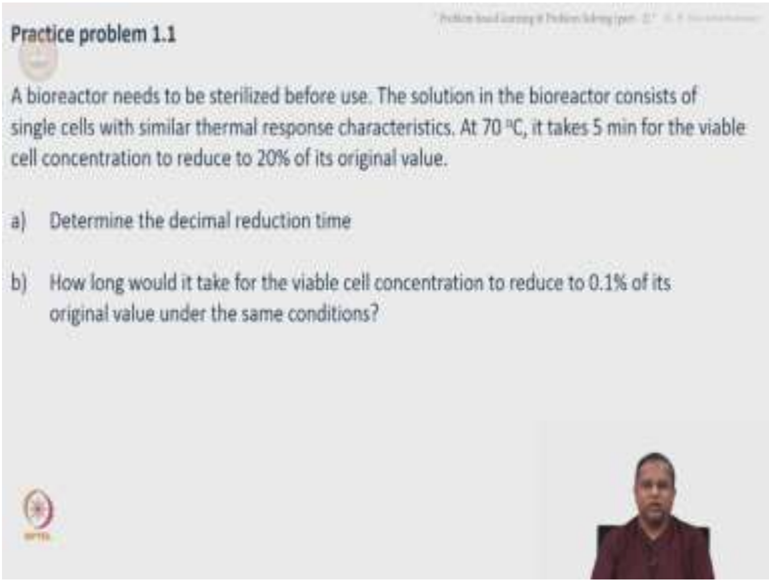

And that is what I am going to give you next. This is a practice problem in a different course. I have just repeated the same problem and I will tell you the solution from the point of view of problem solving for a closed ended problem.

The problem reads, a bioreactor needs to be sterilized before use. The solution in the bioreactor consists of single cells with similar thermal response characteristics. At 70 degree C, it takes 5 minutes for the viable cell concentration to reduce to 20 percent of its original value. Even if you are not in the field of biological engineering or related engineering, this might be easy to follow. If you do not understand a few words just leave them out, it is not very crucial to know the exact meaning of words. Here I am going to tell you what it is, but as long as you get the picture it is fine.

So, if you do not understand thermal response, do not worry about it. If you do not understand single cells, do not worry about it, although it is intuitive. A viable cell concentration – intuitive, the concentration amount per volume of cells that is actually viable. You could have viable cells and you could have dead cells. The questions are or the challenges are (a) determine the decimal reduction time, do not worry about the term now, (b) how long would it take for the viable cell concentration to reduce to 0.1 percent of its original value under the same conditions?

So, these are the 2 questions asked and we are going to solve them. So, let us apply our strategy to solve this particular problem. It is a closed ended problem. So, the first step is what is needed? The decimal reduction time. Let us take one at a time let us take (a) to begin with. The decimal reduction time, very clearly stated, quite easy to find out, but you need we need to be clear about this. So, the student needs to be clear about this. Second what is known or are given, that it is a single cell suspension, at 70 degree C it takes 5 minutes or 300 seconds.

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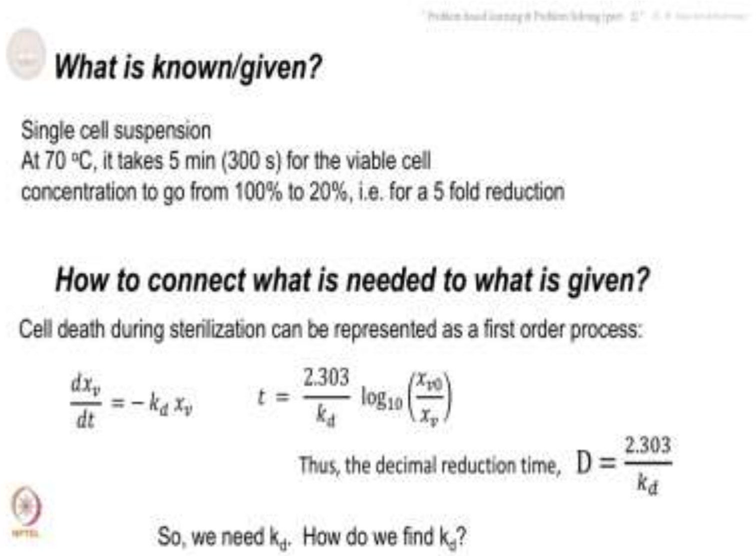

For the viable cell concentration to go from 100 percent to 20 percent, that is a fivefold reduction in cell concentration and viable cell concentration, takes 5 minutes under these conditions.

Now, how do we connect what is needed - which is the decimal reduction time, to what is given such as the thermal response characteristics, essentially those are the thermal response characteristics. So, let us see how to go about this. How do we connect? The cell death during sterilization; this is a process of sterilization, can be represented as a first order process, this would have been covered in the course already, this is an application problem or practice problem. The sterilization can be represented as a first order process is already known to the student. What is a first order process for our purposes, that the rate of change or this is a batch system therefore, the rate of change of accumulation of viable cells equals or is directly proportional to the viable cell concentration and therefore, you could represent it as:

$$\frac{dx_v}{dt} = -k_d x_v$$

Because there is a reduction, you have a minus there.

If you integrate and so on so forth you could represent the time as:

$$t = \frac{2.303}{k_d} log_{10}(\frac{x_{v0}}{x_v})$$

This is essentially what you are get. People who are used to solving a first order differential equations would immediately recognize that form, but that is essentially the solution of the equation. This is the solution of the equation that is given here, it comes in a natural log form if you convert it into a log to the base 10 you will get this form.

Therefore the decimal reduction time which is defined as the time that is needed to reduce a cell concentration by an order of magnitude, by tenfold, is nothing but this. How do you get this? You know the viable cell concentration at a time 0 is something, the viable cell concentration at time t must be one tenth and therefore, this will turn out to be 1 by 0.1 that is 10, log 10 to the base 10 is 1. Therefore, this entire thing is 1 and therefore, the decimal reduction time t for an order of magnitude reduction becomes D, capital D, decimal reduction time is $2.303/k_d$, straightforward.

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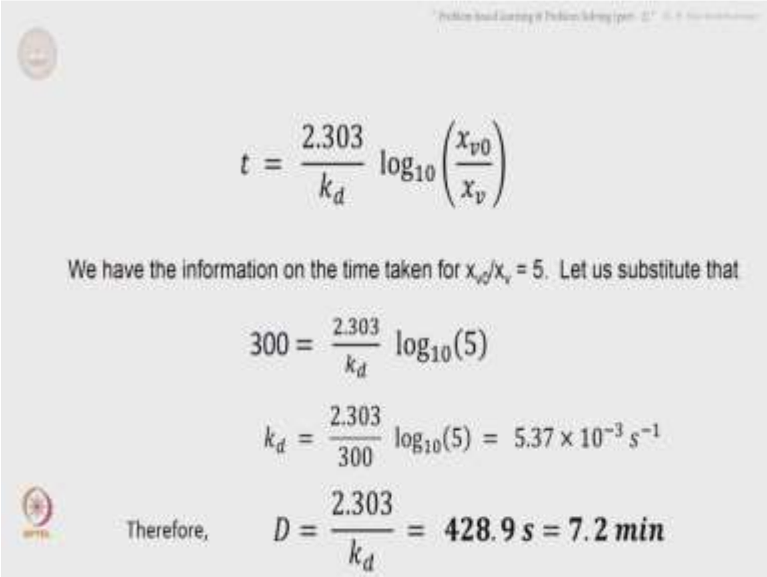

So, to solve this problem we need k_d right. Everything else is well, it is a straightforward thing, decimal reduction time is 2.303/ k_d, we need $k_{d,}$ and how do you find k_d? To find k_d we use the other data. This is the equation. We have information on the time taken for a fivefold reduction in a viable cell concentration, that is the data that is already given in the problem. Therefore, let us substitute this $\frac{x_{v0}}{x_v} = 5$ in that equation there,

it takes 5 minutes or 5 into 60, 300 seconds, we would like to work with seconds here and therefore, 300 seconds. That becomes

$$k_d = \frac{2.303}{300} log_{10}(5) = 5.37 \times 10^{-3} s^{-1}$$

Now, we have k d therefore, it is rather simple to find out the decimal reduction time 2.303/ k_d. That turns out to be

$$D = \frac{2.303}{5.37 \times 10^{-3} s^{-1}} = 428.9\ s = 7.2\ min$$

So, what is needed, what is known or given? How do we connect, what is needed to what is known and are there any principles that we can use. In this case the principle was that the knowledge, that the reduction in viable cell concentration can be represented as a first order equation or a first order process.

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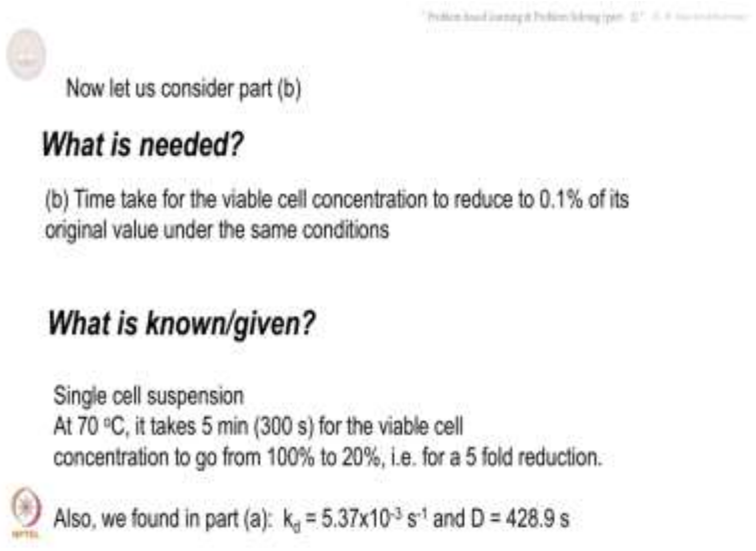

Let us move forward there is a (b) part here. Let us consider part b, what is needed? The time taken for the viable cell concentration to reduce to 0.1 percent of its original value under the same conditions. Earlier it was decimal reduction time, now it is 0.1 percent. What is known are given, the same things as earlier, the thermal response characteristics of the single cell suspension and also we found from part (a) the k_d value and the decimal reduction time.

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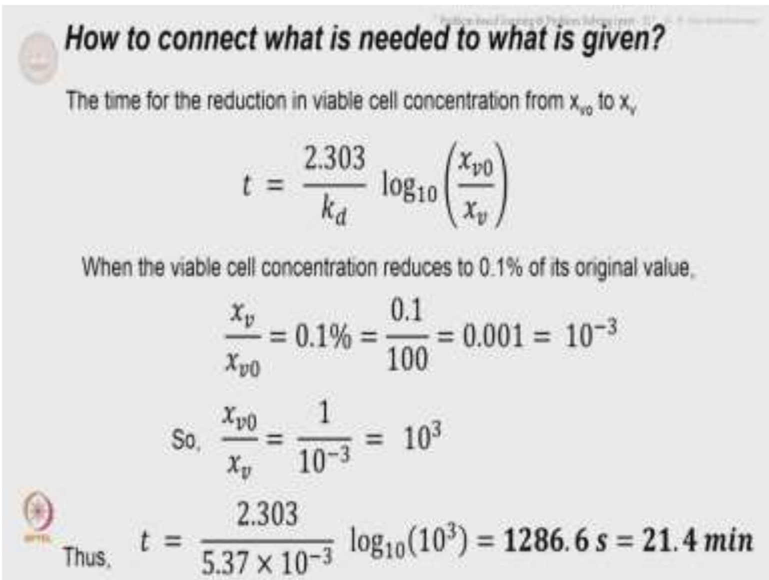

So, this is all that we know. How do we connect what is needed to what is given, the time for the reduction and viable cell concentration, we have already seen this. When the viable cell concentration reduces to 0.1 percent of it is original value, then

$$\frac{x_{v0}}{x_v} = \frac{1}{10^{-3}} = 1000$$

Therefore, the time for the cell concentration to go to 0.1 percent of its original value, the viable cell concentration that is, you substitute all the values that we found earlier, it will turn out to be 1286.6 seconds or 21.4 minutes.

So, if students who are not natural in problem solving most people are, most students are, if they follow this method of you know consciously doing what is needed, what is given, and how do we connect what is needed to what is given, then the problem solving could be a process that they that they can master with time.

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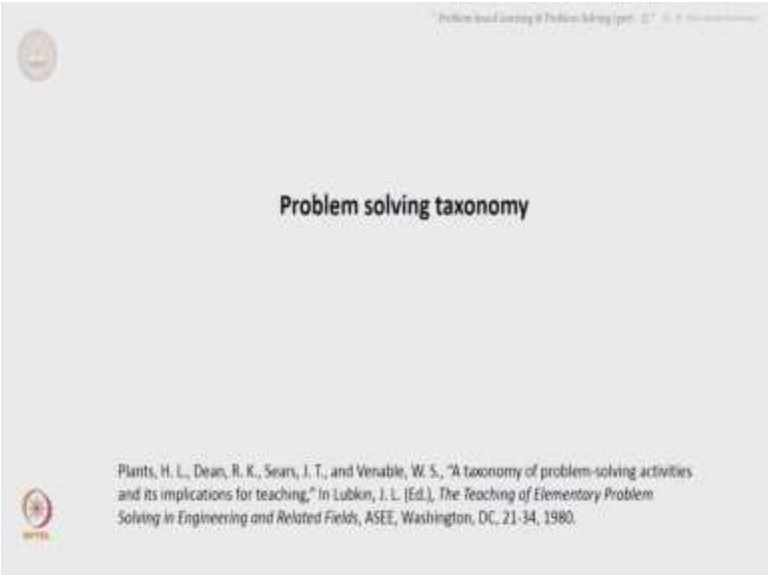

We talked about Bloom’s taxonomy, taxonomy in general, there is also a problem solving taxonomy. This was put forward by Plants *et al* in their paper - a taxonomy of problem solving activities and its implications for teaching. This was presented at a conference the ASEE Washington DC Conference in 1980.

And it is nice to know the taxonomy for better understanding. We are teachers, we understand it at a different level, therefore, we can see or understand the problems as they arise and then we can use the appropriate techniques for understood problems. Sometimes you come across a problem that may not be understood and then we will have to rely on our intuition, but if it is known and if it is very well understood that this is the way to solve this problem, why do we need to you know think about it and try things out and so on so forth. Might as well used use the tested techniques that are available in the literature. That is how this becomes useful.

But always be conscious or rather be aware of your intuition. Never let that go, that is useful for solving aspects or addressing aspects that I have not been solved as yet and so on. The problem solving taxonomy is something like this. When there are routines to be solved, this is the first level. The operation of algorithms implemented without any major decision making.

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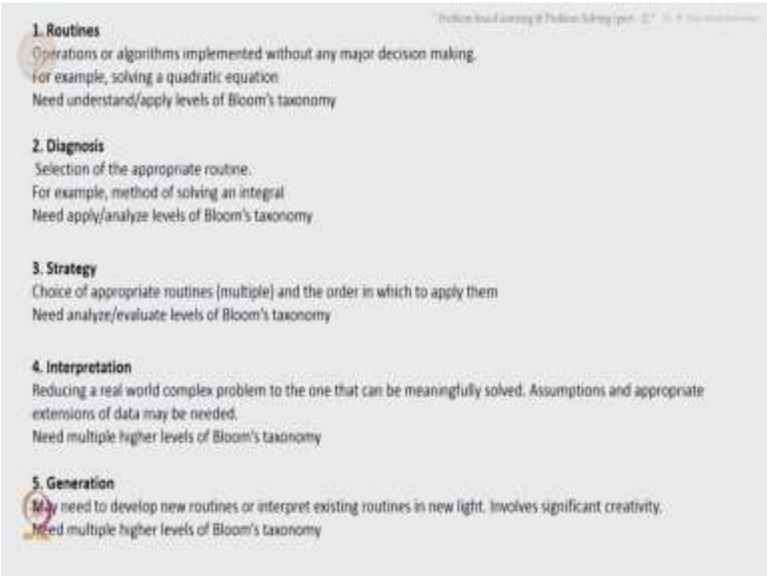

This is the surface level kind of or the first level in the taxonomy. For example, solve a quadratic equation. Students know how to solve the quadratic equation how to recognize the quadratic equation if it has an x squared term and so on so forth.

Then there are standard methods of solving the quadratic equation. The solution is of the form $\frac{-b\pm\sqrt{b^2-4ac}}{2a}$ is all known in high school and therefore, just applying that in a routine fashion falls under this category routine work. So, for routine work you need to understand and definitely apply that application apply, a skill in the Bloom's taxonomy needs to be present to be able to address routine aspects successfully.

The second level is diagnosis. Selection of the appropriate routine is diagnosis, which routine would you select? You have a suite of procedures of a let us say routines, which one is appropriate for this particular problem. Method of solving an integral could be an example. There could be various methods. Some methods would be preferable to the other methods for a given situation. How would you choose them and this of course, needs the apply and analyze level skills in the Bloom's taxonomy.

The third is the strategy level of problems, choice of appropriate routines which could be multiple. There are multiple routines that are required to solve the problem and the order in which to use them is also not known earlier. One needs to make a decision on that and that could be a strategy level problem. For example, the need to, rather there could be many examples. We will probably see some later, we have seen some already. The need here is the analyze or evaluate levels of the Bloom's taxonomy, the skills associated with them.

Fourth is the interpretation level, reducing a real world complex problem to the one that can be meaningfully solved. The assumptions and appropriate extensions of data may be needed to solve interpretation kind of problems and we need multiple higher levels of the Bloom's taxonomy to be able to solve this problem. Definitely analyze, apply, analyze, evaluate, create to be able to solve the problems and finally, generation which is the highest level in problem solving, which needs the highest level skills or problem of a learning. You may need to develop new routines or interpret existing routines in new light and it involves significant creativity, need multiple higher levels of blooms taxonomy to be able to solve this.

Therefore the taxonomy to summarize consists of 5 different levels, routines, 2 diagnosis, 3 strategy, 4 interpretation and 5 generation different levels of skills are needed to solve these different levels of problem, this is all that I have now. In this particular chapter we looked at problem based learning, initially as an extension to the regular lecture and then we looked at problem solving, our method of solving problems - closed ended problem specifically and then a taxonomy for problem solving. Let us stop here and then when we meet next, we will take up the next aspect.

I think before I come in, the next aspect would be the learning outcomes which would be handled by doctor Edamana Prasad who is the head of the teaching learning centre at IIT madras. As you know this course is handled in collaboration with the teaching learning Centre. There are 3 faculty from the teaching learning centre who will be handling the 3 topics out of the 12 topics. I will be doing the other 9. See you then. When we meet next, we will talk about something called active learning. See you.