Effective Engineering "Teaching" in Practice
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Lecture – 03
Better learning (Bloom's Taxonomy)

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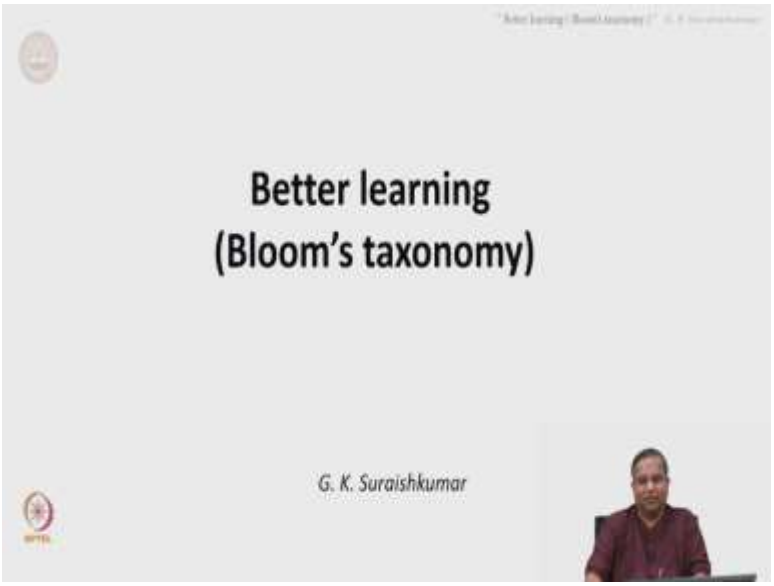

Welcome to this lecture, in the course effective engineering teaching in practice. In the previous lecture, we saw how to go from an inexperienced teacher's position, to a position where the learning of students could be improved. We had seen the various aspects of a lecture, the various forms that a lecturer could take to be effective for the learning and students. The traditional idea of a lecture is I talk you listen, that is a very primitive view of a lecture; where as we saw in the last class, in the last lecture, that it can be used in widely different ways to improve the learning of students.

In this lecture, let us see what better learning is all about. We have been saying for the better learning of students, better learning of the participants and so on so forth. What does better learning actually mean is what we are going to see in this lecture. To do that let us take the help of something called Bloom's taxonomy, which is a very well-known thing, very popular thing right now. We will make use of that and try to understand better learning from the Bloom's taxonomy point of view. It is a very preliminary way of understanding, a primitive way of understanding or rather very old way of

understanding, but that is very effective and probably that would be a good place to start for people who are trying to get into a mode to improve learning by students.

So, what is better learning?

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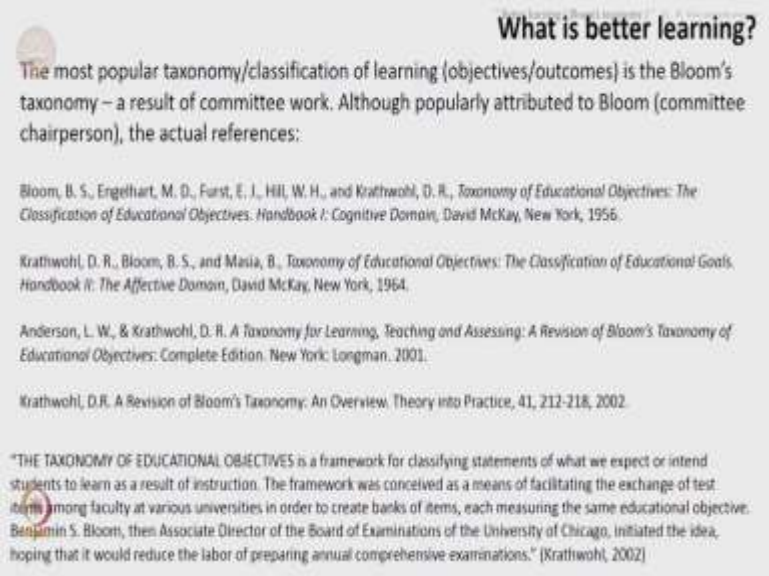

The most popular taxonomy, the Bloom's taxonomy is a taxonomy, which essentially is a classification of learning, typically objectives and outcomes. And this was a result of the work by a committee of people, which was headed by Professor Benjamin Bloom way back in the 1950s in the US in Chicago. The committee had people from all over the US, it was Professor Benjamin Bloom who was in Chicago. It was actually done for school children, the high school children.

But it has been done in such a level that we use it even today with great ease. It has gone through minor modifications, we use it even today with great ease and it is very relevant even today. As I mentioned earlier, the work is popularly attributed to the chairperson of the committee, for a good reason because he had taken a lot of effort to put this committee together, to arrange meetings, to make sure that it goes in a proper direction and so on so forth. Whereas, if you are interested in the actual contributors to this work, the members of the committee who later made major contributions, these are the actual references Bloom and many other people, this is the original reference way back in 1956, the taxonomy of educational objectives, the classification of educational objectives handbook one cognitive domain ok.

And then you have this by Krathwohl and others in 1964, and then much later ,when there was a need to revise the cognitive aspects of the Bloom's taxonomy in the cognitive domain, Anderson Krathwohl published some work in 2001, and the next paper Krathwohl himself, the paper by him or an overview by him in 2002. All these are very important references which give an idea, which give the actual aspects of the work itself.

Now, let us see what it is. The taxonomy of educational objectives is a framework for classifying statements, of what we expect or intend students to learn as a result of our instruction. The framework was conceived as a means of facilitating the exchange of test items among faculty at various universities, in order to create banks of items each measuring the same educational objective. Benjamin S Bloom, then associate director, he also had held an administrative position, a responsibility position, then associate director of the board of examinations of the University of Chicago, initiated the idea hoping that it would reduce the labor of preparing annual comprehensive examinations. This is actually from the paper by Krathwohl 2002, this gives a very good idea of a; what it was and Kathwohl was one of the initial members himself.

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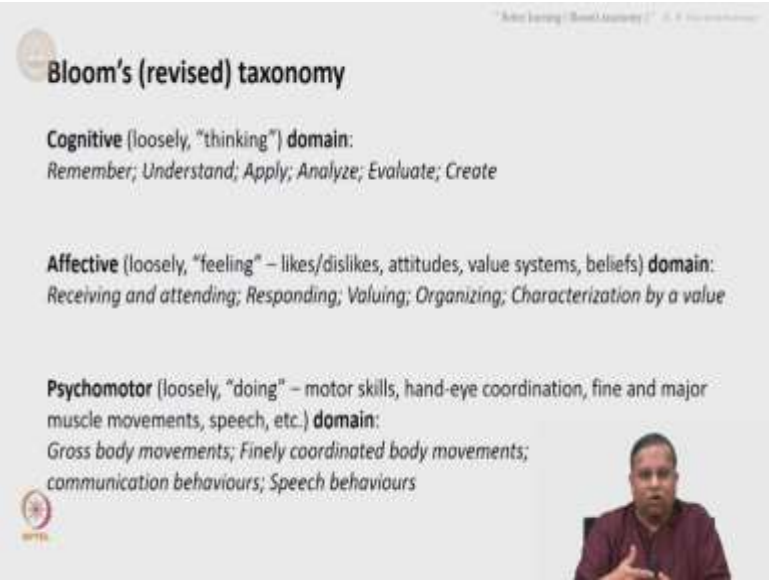

So, let us look at the Bloom's revised taxonomy. There has been a minor change from the earlier thing, there is a reason for the change and so on so forth. If you are interested you can go back and read the original papers and read the revisions especially the last 2

papers 2001-2002 Anderson and Krathwohl and Krathwohl himself, that will give you a very good idea of the history of this process and the needs for this revision. For the purposes of this course, this lecture, we will just look at the best available now which is the Bloom's revised taxonomy.

This revised taxonomy is in 3 major domains. The first domain is called the cognitive domain. Loosely, cognitive domain means anything related to the thinking process; such as remember, understand, apply, analyze, evaluate and create are these six levels of learning in the cognitive domain; remember, understand, apply, analyze, evaluate and create ok.

As you go from left to right, the depth of appreciation at the cognitive level increases. Then, the second domain is called the affective domain, loosely speaking it is the 'feeling', it is not the emotions, but it is a 'feeling', aspects that go along with it, such as likes and dislikes, attitudes, value systems beliefs that go with a person. That determines the learning by the person. For example, receiving and attending some information, how do you respond to that information or how a student responds to that information, organizing, valuing, organizing and characterization by a value finally, all these are the various levels of learning in the affective domain. We look at some details a little later.

The psychomotor domain is the third domain. Loosely speaking it is the doing domain hands on kind of thing. For example, motor skills, hand eye coordination, fine and major muscle movements, speech and many other related aspects are in this domain. Characterized by or if you want to provide the specific details to the taxonomy here, the gross body movements, finely coordinated body movements, non verbal communication behaviors and speech behaviors are the various levels in the psychomotor domain ok.

And you could see that all these are very relevant to say that somebody has learnt. The cognitive aspect is only one aspect of it. Affective - how the persons' attitudes are towards learning is very important to which determine how the person learns. Similarly for, especially for engineering and so on so forth somebody must be able to work with their hands. Of course, you appreciate it at a much higher level and so on so forth, but at some level you must be good in working with your hands, and especially when you get on to experimental research and so on and so forth, even at a high level you need to be very good with your hands, hand eye coordination and so on and so forth.

So, all these are very essential for engineering education.

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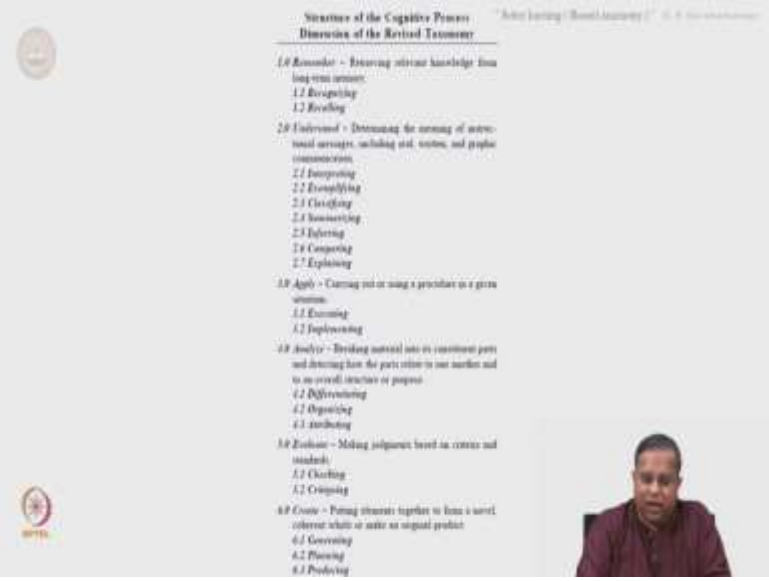

So, this is the table from Krathwohl 2002 paper, the structure of the cognitive process it is slightly small you might have to pause it and look at it if you want to look at it. The first one as I say, this is in the cognitive domain itself or only the cognitive domain the various aspects. The first one was remember which essentially means retrieving relevant knowledge from long term memory such as recognizing and recalling.

The second level is the understand level, it is determining the meaning of instructional messages including oral, written and graphic communications. For example, interpreting, exemplifying, classifying, summarizing, inferring, comparing explaining all fall under this domain of understand, this aspect in the cognitive domain of understand. The third level is the apply level, which means carrying out or using a procedure in a given situation. Some of the things that describe this level are executing, implementing. The fourth level is the analyze level which means breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose. To give you specifics, this could involve differentiating between various things, organizing things to this gather attributing something to a certain aspect and so on.

The fifth aspect level is evaluate - making judgments based on criteria and standards; such as checking critiquing fall under this level. And the highest level is or the deepest level, whichever way you want to look at it, is the create level, putting elements together

to form a novel coherent whole or make an original product. So, the activities here are generating, planning, producing and so on ok.

So, this gives you an idea of the kind of learning, the depth to which learning can happen even in a class, and it all depends on the facilitator of learning to take students to the highest level. Most courses are pretty much at the remember and understand level . Maybe remember, sometimes remember -understand and maybe remember, understand and apply to is where most courses in engineering reach. But there are possibilities of reaching the highest levels or the highest depths of learning by designing your course appropriately, we will see how to do that a little later in this course.

Now, let me give you examples to understand whatever we have been talking about.

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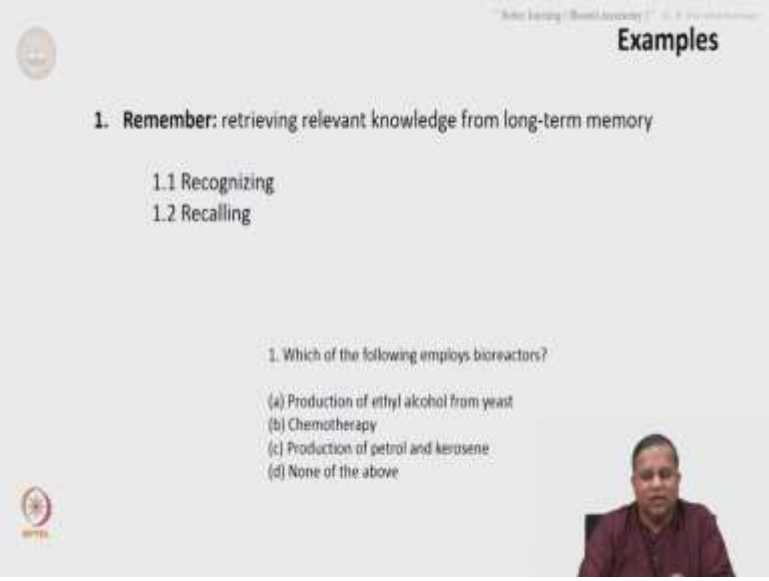

First level – remember. As I mentioned earlier, retrieving relevant knowledge from the long term memory recognizing recalling. For example, the question here, which of the following employees bioreactors? This is a question from my bioreactor course maybe. Which of the following employees bioreactors? The choices are production of ethyl alcohol from yeast, (b) chemotherapy, (c) production of petrol and kerosene, (d) none of the above.

So, the person must be able to recall or remember this factual information to be able to answer that question. Therefore, this question tests the student learning at the remember

level. By the way the answer is (a) production of ethyl alcohol from yeast, which is irrelevant here. I'm giving you this as an example. Even if you have not done the course, it does not matter or even if you do not know the information, does not matter to be able to appreciate the kind of questions that we are looking at or the kind of testing that we are looking at.

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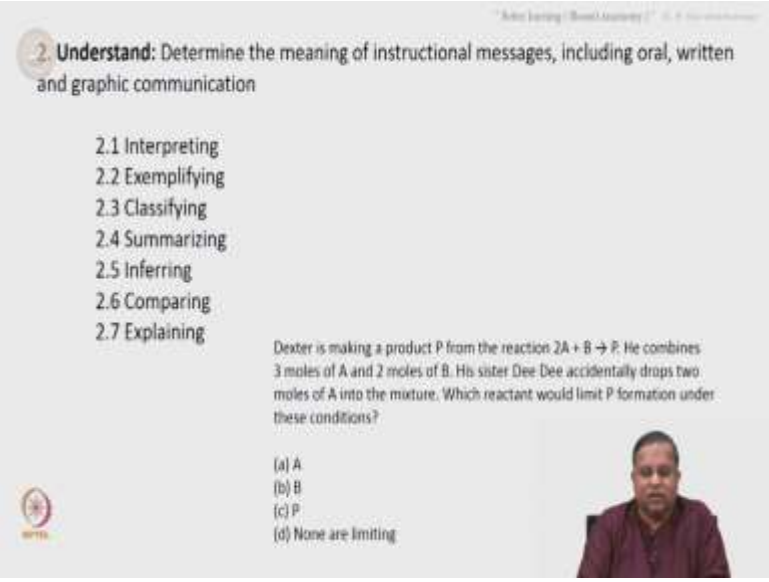

Second- understand. Determine the meaning of instructional messages including oral, written and graphic communications was mentioned earlier. Interpreting, exemplifying, classifying, summarizing, inferring, comparing and explaining. As an example, it could be something like this. This was a problem that was made up by my TA Steffi Jose while making up the assignment problems for our earlier NOC mooc on bioreactors. Dexter is making a product P from the reaction

$2A + B \rightarrow P$

He combines 3 moles of A and 2 moles of B. His sister Dee Dee accidentally drops 2 moles of A into the mixture. Which reactant would limit P formation under these conditions?

This would require understanding the concept of a limiting reactant and then applying it to this particular case where 2A + B giving you the product. It has 3 moles of A and 2 moles of B and you are asked to find the limiting reactant here. And which one of these

either A, B or P? Which one is the limiting reactant is the question or none of the above, none are limiting is the other choice ok.

These kind of questions which need the student to first recall the information and then also understand the information, to be able to get a meaningful answer is at the understand level.

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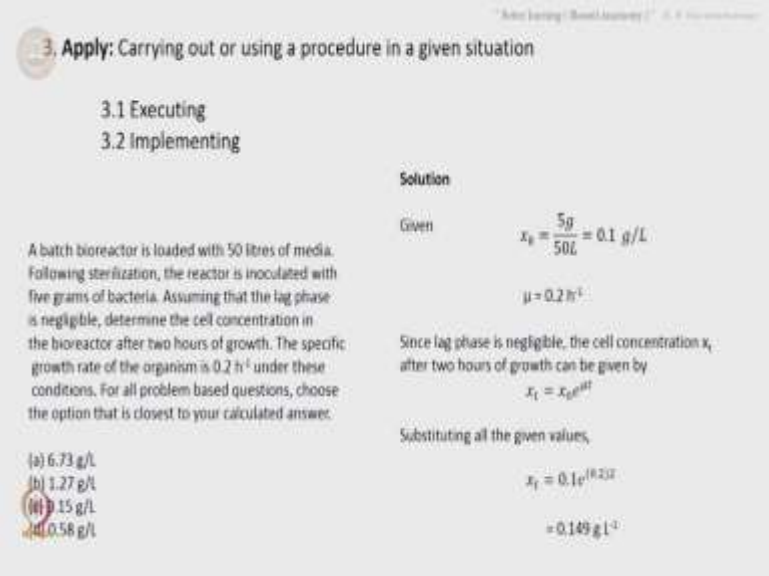

Third level – apply. Carrying out or using a procedure in a given situation, executing/ implementing. Example could be a problem something like this. A batch bioreactor is loaded with 50 liters of media. Following sterilization, the reactor is inoculated with 5 grams of bacteria. Assuming that the lag phase is negligible, determine the cell concentration in the bioreactor after 2 hours of growth.

The specific growth rate is given 0.2 h^{-1}. For all problem based questions, choose the option that is closest to your calculated answer. In this way, we avoid difficulties with them making some round of changes and so on so forth. The various answers are given there. To answer this, somebody must be able to recognize, recall the appropriate information, then must have understood the information how to apply it, and then actually apply it to the situation. I will tell you the solution in detail. I am sure you must be able to follow it. It is a first order, differential equation. You must be able to follow it. The solution is something like this. What is given is that the initial cell concentration is 5 grams in 50 liters. So, the concentration turns out to be 0.1 gram per liter. The specific

growth rate is given as 0.2 per hour. These are the two given pieces of information. Also given that the lag phase is negligible and therefore, the cell concentration x after 2 hours of growth, need not take into account the lag phase at all. You do not have to know the details. If you listen to me, that is good enough to get the point here.

And therefore, if you know the basal equation is that

$$\frac{dx}{dt} = \mu x$$

If you solve that you get

$$x_t = x_0 e^{\mu t}$$

And therefore, if you substitute the values, the x_t that we are needed to find is

$$x_t = 0.1e^{(0.2)(2)}$$

and all the units are consistent and it turns out to be a 0.149 gram per liter therefore, the answer is (c) ok.

So, these kind of questions require somebody to apply. The fourth level is analysis level, which is taking much further than the applied level.

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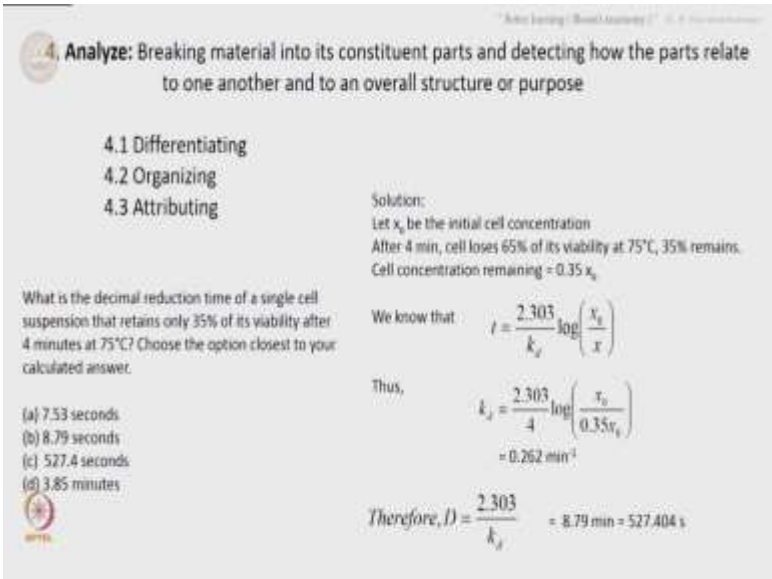

Apply is just use that. Here you need to look at various aspects. Analyze is breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose, differentiating, organizing, attributing. An example is - what is the decimal reduction time of a single cell suspension that retains only 35 percent of its viability after 4 minutes at 75 degrees C. Choose the option closest to your calculated answered. 4 answers are given. To do this one, this is the solution. Let me just read out the solution so that you will understand what aspects of the analysis come in here.

Let x naught be the initial cell concentration right and after 4 minutes it is given that the cell loses 65 percent of its viability. At 75 degrees c, that is the condition, 35 percent remains and therefore, the cell concentration remaining is 0.35 of x_0. You will get t in terms of something called a death constant kd as

$$t = \frac{2.303}{k_d} log \frac{x_0}{x}$$

Therefore, kd turns out to be 0.262,

And therefore, the decimal reduction time which is defined as 2.303/ kd, you can work this out. It is the time needed for a tenfold reduction in the cell concentration. So, that tenfold reduction means $log \frac{x_0}{x}$ will turn out to be log 10. So log 10 to the base 10 is 1 therefore, D = 2.303/ k_d.

So, that will turn out to be 8.79 minutes or 527.4 seconds and therefore, c is the answer. So, this calls for remembering, understanding, applying, analyzing and then apply that is what it means here.

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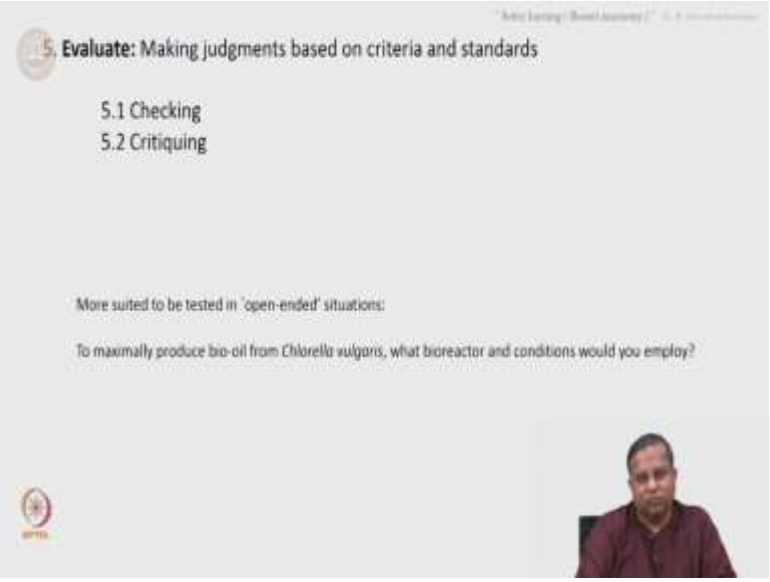

The evaluate level - making judgments based on the criteria and standards, checking and critiquing. It is a little difficult to give you an example here. Let me very briefly give you a statement. These are all, the evaluate aspects can be done best by open ended questions. It could be, an example could be - to maximally produce bio oil from *Chlorella vulgaris*, what bioreactor and conditions would you employ ok.

So, this calls for evaluating, knowing, understanding the various bioreactors available, their advantages and disadvantages, then deciding what would be appropriate for use with *Chlorella. Chlorella* is a photosynthetic organism. Therefore, it needs light. Therefore, you need a photo bioreactor and what conditions depending on the optimal conditions, that are needed for that particular purpose. All that needs to be employed. Therefore, this is an example of evaluate. And finally, create. Let me go back, yes, create. Putting various elements together to form a novel coherent whole or make an original product ok.

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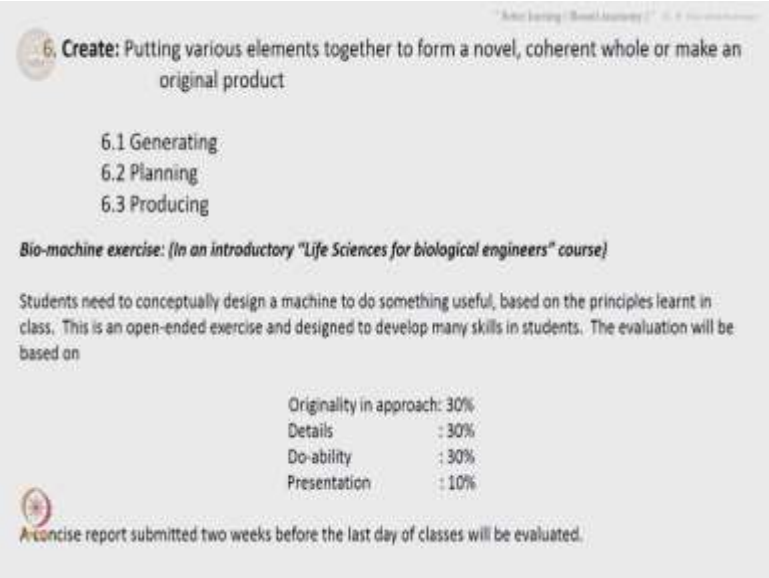

The specifics are generating, planning and producing. And an example could be something like this. This is an exercise that I give to all my core course classes. In this particular case, it is the bio machine exercise. This kind of an exercise I give to all my core courses. This is for the introductory life sciences for biological engineers course. This is our own students. The biotech students take this in their first semester. This is not for all other engineers. They do not, the other engineers may not the need this amount of depth, but our students do. Students need to conceptually design a machine to do something useful based on the principles learnt in class. This is an open ended exercise and designed to develop many skills in students. The evaluation will be based on originality and approach thirty percent, details 30 percent, doability 30 percent, presentation 10 percent.

And a concise report submitted 2 weeks before the last day of classes will be evaluated. If there are models that they make, they would be evaluated at the same time by the entire class and so on. So, this is an example of the create exercise. So, as you can see in the cognitive domain, you can go from the very superficial level of learning which is remembering, all the way up to create which is the highest level of learning or the deepest level of learning.

This is another exercise that I just mentioned, the earlier exercise was for that particular course - the CFA exercise. CFAs stands for choose focus analyze.

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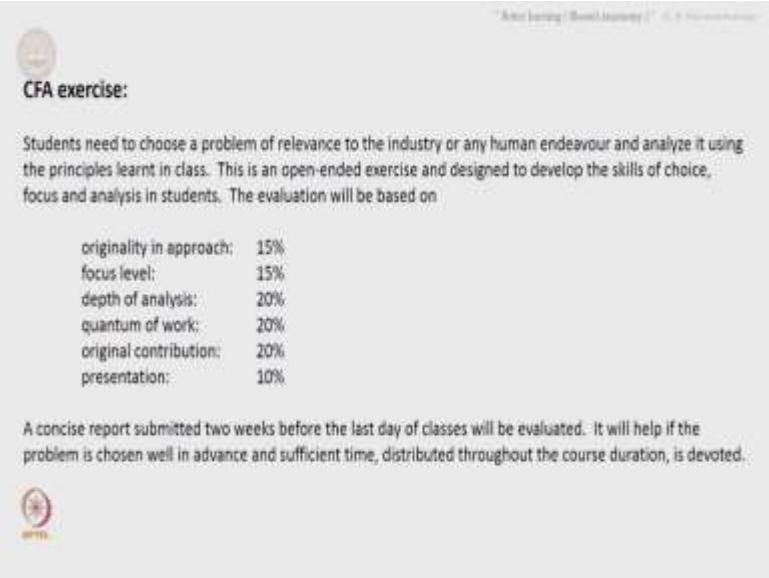

This is an exercise. It is an exercise that is very helpful to the students. Students appreciate this a lot after doing the exercise, and they remember it for a long time. We will talk more about this later in the course, but for now as an example of a creative exercise, students need to choose a problem of relevance through the industry or any human endeavor and analyze it using the principles learnt in class. This is an open ended exercise and designed to develop the skills of choice, focus and analysis in students.

The evaluation will be based on originality in approach 15 percent, focus level 15 percent, depth of analysis 20 percent, quantum of work 20 percent, original contribution 20 percent and presentation 10 percent. A concise report submitted 2 weeks before the last day of classes will be evaluated. It will help if the problem is chosen well in advance and sufficient time distributed throughout the course duration is devoted. This is the other example of a create level exercise. If you are interested you could watch these videos that are given there. These are nice videos which would explain the, or which will help you appreciate the application of Bloom's taxonomy a little better.

Next is the affective domain. Remember there are 3 domains; cognitive, affective and psychomotor. This is development in the affective domain. We will very briefly look at this. We will not spend too much time. Somehow engineers have not given much importance to this. It is a very important aspect. I think all 3 domains are equally important, but because of the history, because of the place where we are you know, you

also need to know where we are and then probably you can take these forward. I need to reflect that in this particular course and therefore, we will not spend too much time in these 2 domains.

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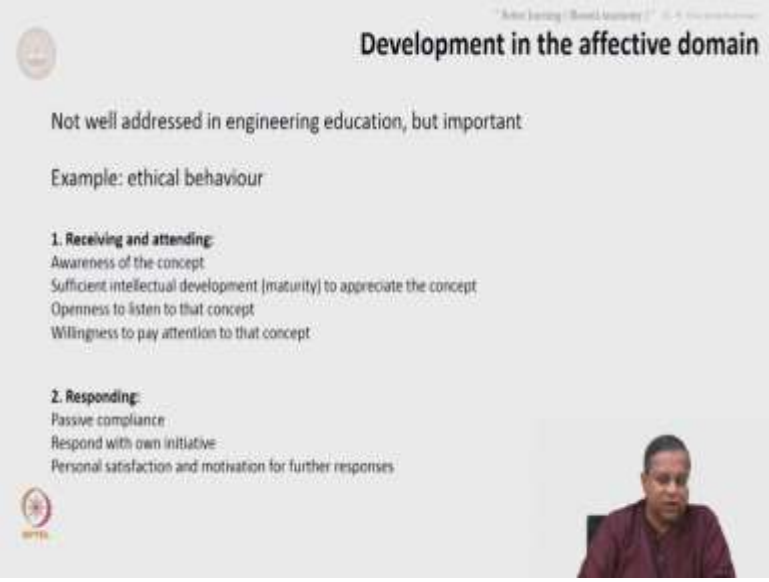

Although they are very important, my personal opinion is that they are very important.

Just mentioned not well addressed in engineering education, but important. For example, ethical behavior right. That directly falls under this domain. We know how important it is, but we never address it in the cognitive domain. Receiving and attending which includes awareness of the concept being presented, in awareness, the way you receive it. Sufficient intellectual development or maturity to appreciate the concept, openness to listen to that concept - even that needs to be there otherwise it would not get across which we may not have appreciated so far.

Willingness to pay attention to that concept. That is also an important aspect, and the second level is responding which includes passive compliance first, then responding with own initiative, personal satisfaction and motivation for further responses and that is pretty much it for the second level.

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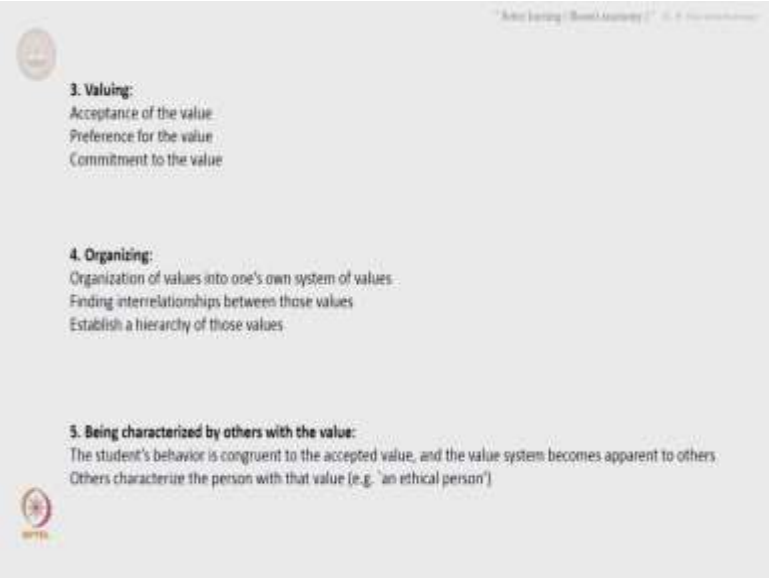

Now the third level is valuing. A person needs to value it to be able to accept it. Acceptance of the value first, that person must consider that as an important thing for himself or herself. Must develop a preference for that value above everything else, must commit to that value - commitment to the value and these 3 are important aspects of the valuing level.

Then comes the organizing level; organization of values into one's own system of values, finding interrelationships between those values, establishing a hierarchy of those values and finally, being known for those values. The person finally, gets known for those values. Very honest person - that kind of a thing. So, being characterized by others with that value, the self being characterized by others with that value. The student behavior is congruent to the accepted value and the value system becomes apparent to the others, they say that person is an honest person. Others characterized that person with that value, that is what I just said. An ethical person is the example given here.

And as you can see, if you go back, there is a certain theme here, its good to appreciate this. First the person is receiving and attending to it, even that is an important aspect to worry about. Then the person is responding to it and then the person is creating a value for it in his or her own system and commits to it. Then the person is organizing those values into the person's own system of values and then finding interrelationships and a

hierarchy for those values, and then ultimately becomes known by the others for that value. This is the organization of the various levels in that domain.

Then finally, the psychomotor domain in very brief aspect of the psychomotor domain, but very important especially if you do, even if you know you are not going to work in the shop floor, if you work in the shop floor it becomes absolutely important. Even if you do not, you know to be able to appreciate an engineering drawing done by somebody, you need to have these skills.

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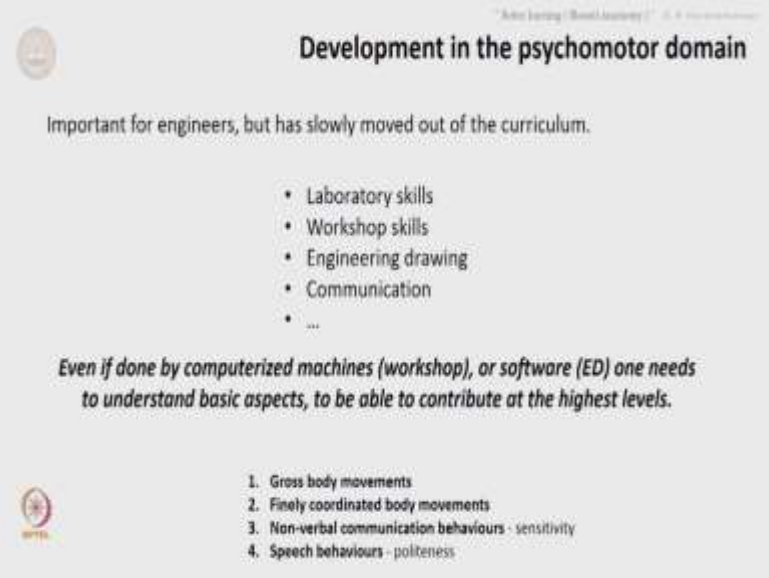

You need to have those visualization skills, must be able to work with hands and so on and so forth. In our days we used to have heavy workshop as activities and engineering drawing activities, which contributed to these. I think they are important. As I said, they have slowly moved out of the curriculum.

Laboratory skills are still important which are still there. They are very important for engineering workshop skills, yes engineering drawing as I mentioned. Communication falls under this category right and there are many other things, many other aspects. So, even if done by computerized machines such as workshop exercises or software such as in engineering design ED, one needs to understand the basic aspects to be able to contribute to the highest levels. If the person is a civil engineer and cannot draw a rectangle cleanly, then there is a problem right. Similarly for any engineering, you can

relate this aspect to. If an electrical engineer is not able to change a fuse, you know what kind of impression the person creates in the public.

The various levels here are the gross body movements, whole body movements, finely coordinated body movements, non verbal communication behaviors such as sensitivity to what others feel, say and so on so forth. Sometimes if a person is completely, especially engineering students are in the world of their own, they shut out everybody else and so on and so forth. That is not very appropriate. And speech behaviors - the person needs to be polite in speaking to the others, to be able to communicate with others and get things done ok.

So, that is in short the psychomotor domain here and previously the affective domain. We spent quite a bit of time in the cognitive domain. What we try to do here is, we said that we need to move towards better learning in students. What actually is better learning? At least our view on tha,t our taxonomy on that is what we have seen. This is the most popular and very useful taxonomy, there are other taxonomies also which are not very popular. I think that is pretty much what I have for this particular lecture. Let us meet next and take things forward. When we meet next, we are going to see how to extend the basal lecture you know. You need to be highly skilled to be an excellent lecturer, not everybody is. And therefore, you have some based lecture, how can you extend it consciously and improve the learning by others.

That is pretty much what we are going to see in most of the remaining aspects of this course, apart from the other relevant things. Let us meet next and take things forward.