Teaching and Learning in Engineering (TALE)
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Lecture - 11
General Categories of Knowledge

Greetings and welcome to the unit on Knowledge Categories as a part of Taxonomy of Learning.

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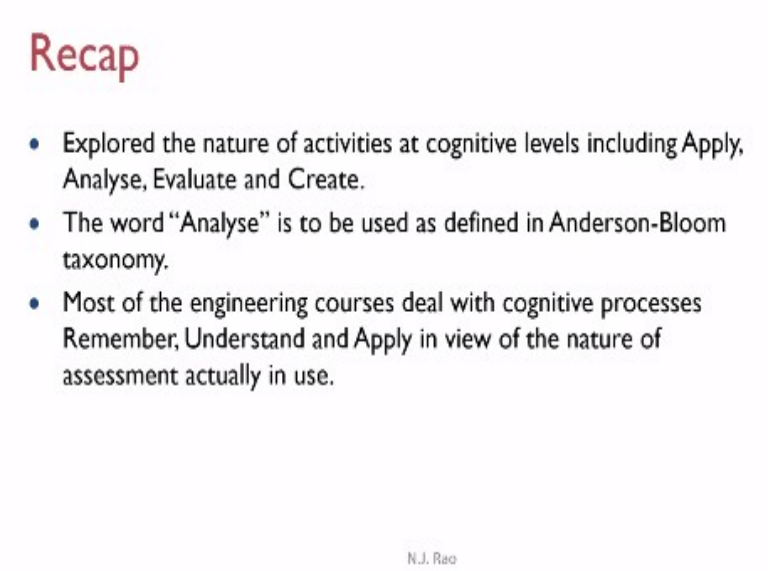

In the last unit on the taxonomy, we explored the nature of activities at cognitive levels, Apply, Analyze, Evaluate and Create. And we also realized the word Analyze is going to provide rather give some difficulty to the teachers as well as the students because the word Analyze is used in a very loose or commonsensical way by majority of the faculty. But whereas Anderson-Bloom Taxonomy gives a very specific meaning to Analyze.

So if you are following this taxonomy or as well as this kind of pedagogical training, then Analyze means/ has a very much narrower meaning in the context of Anderson and Bloom. And once you look at all these, all the six categories of cognitive levels the way presently the engineering courses are organized the cognitive processes Remember, Understand and Apply are the only one that are addressed through courses.

If you want higher cognitive levels, the present assessment mechanism or the present examination system does not allow. By merely putting action verbs that come from these higher cognitive levels does not mean that actually the questions belong to higher cognitive levels. So right now it is Remember, Understand and Apply and what one should do the percentage of questions or the activity that you do should be dominantly in Understand and Apply rather than in Remember. So that is what it reflects the present situation.

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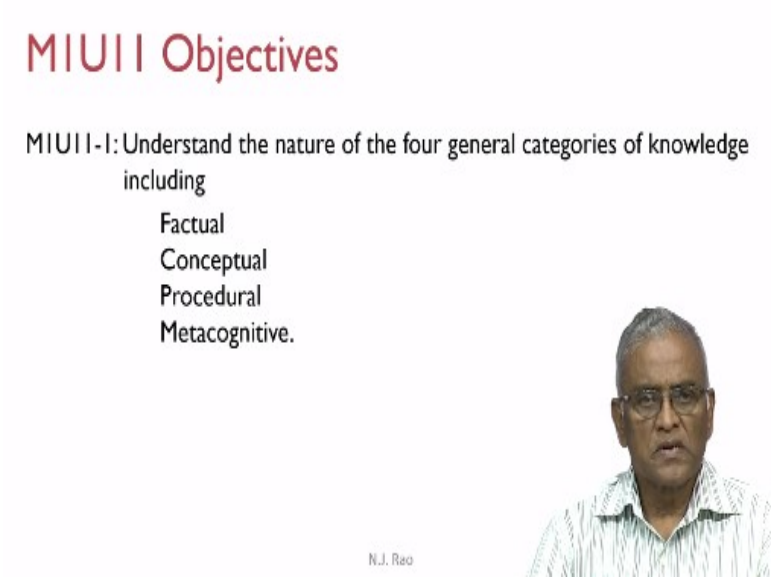

Now, in present unit M1U11 we are trying to understand the nature of four general categories of knowledge. These are Factual, Conceptual, Procedural, and Metacognitive. That is the understanding the nature of these four general categories is our objective.

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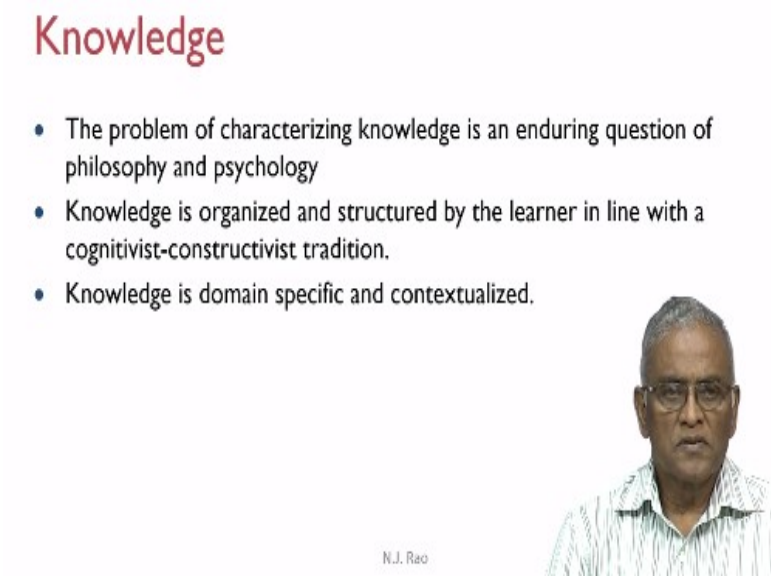

Now, the moment you come to the word knowledge it is a word that is used by everyone quite comfortably. May be many times it is valid use of the word but the problem comes when you try to define what constitutes knowledge and this is not an easy question to answer because that is the concern of the philosophy for the last 2000 years and yet there has been no agreement on (what exactly constitute) what is knowledge.

So, the problem of characterizing knowledge is still an enduring question of philosophy and psychology. So we will not even attempt to kind of make a try to come to some kind of a conclusion going through that. We are going to give an operational definition. That means for our course, this is the way we are going to design what is knowledge. Now just again as a label, knowledge is organized and structured by the learner in line with what you call cognitivist-constructivist tradition.

Let us not elaborate on cognitivist and constructivist tradition. That we may do in another module. But that is the framework in which you are using the word knowledge. And we also recognize knowledge is domain specific and contextualized. This is also a philosophical view that knowledge is contextualized not absolute, okay? So that is the prelude to what we are operationally going to look to at this.

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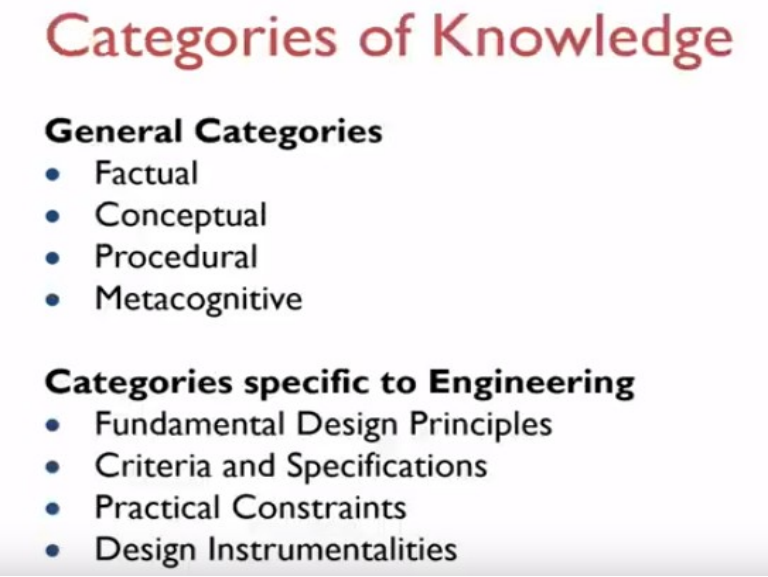

Now, there are four general categories of knowledge which we have mentioned. Factual, Conceptual, Procedural, and Metacognitive. There are also while these four categories apply to all subjects whether it is humanities, social sciences, sciences, engineering call it the other professional subjects like medicine, chartered accountancy anything that you talk about, all these four categories are universally applicable.

But there are some specific categories of knowledge with respect to engineering, specific to engineering. If these are ignored, something about engineering is you are removing. So these four categories specific to engineering are Fundamental Design Principles, Criteria and Specifications, Practical Constraints, Design Instrumentalities. We will look at these four categories specific to engineering in one of the units later. But right now, we will look at the four general categories.

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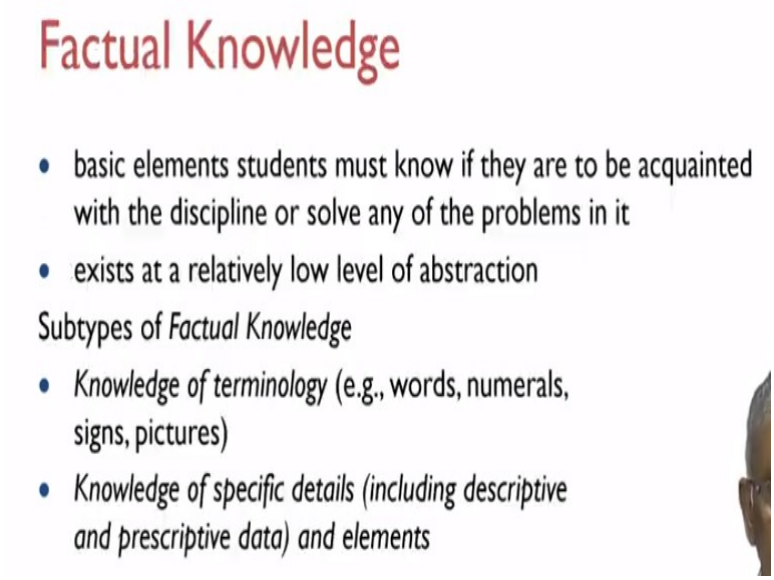

This is fairly simple to understand. Factual Knowledge - Basic elements students must know if they are to be acquainted with the discipline or solve any problems in it. It exists at relatively low level of abstraction. First of all every subject has its own language. There are terms that are defined specifically and you have to use those terms only in that context. That means specific to that subject.

And there are some symbols that we associate with some device or some function whatever it is you have some terminology and some kind of symbols, they are all factual knowledge. Now subtypes of factual knowledge include knowledge of terminology; words, numerals, signs, and pictures. And knowledge of specific details including descriptive and prescriptive data. For example the density of iron is so much or the weight of something is so much.

You are talking of very specific details like that. One is descriptive. Descriptive means you are giving factual specific details of what already exist in nature. Prescriptive data means we want something to be such and such. We will say the weight of this chair should not exceed something. That is also prescriptive; that is prescriptive data. So an engineer or anyone should be familiar with both descriptive and prescriptive data. So these are the subcategories of factual knowledge.

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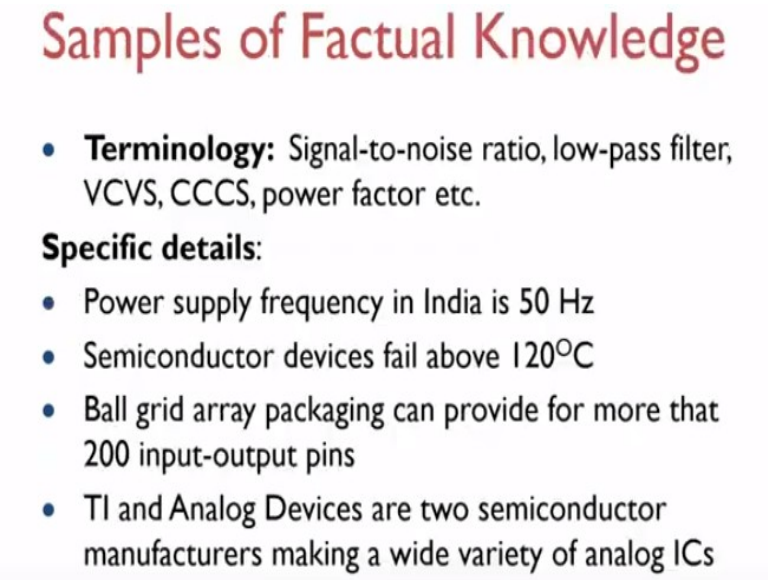

Terminology will mean again I am giving a bit more of electrical engineering example. Signal-to-noise ratio, low-pass filter, some terms like VCVS, CCCS, power factor etc., these words mean only something specific to people who are working in the area of Electrical Engineering or Electronics Communication Engineering. And maybe peripherally some people from Mechanical and Civil also maybe familiar with these words.

But this terminology is dominantly with respect to Electrical Engineering. Some specific details like power supply frequency in India is 50 Hz or it is supposed to be 50 Hz. Semiconductor devices fail above 120 degrees. Ball grid array packaging can provide for more than 200 input-output pins. Example Texas Instruments, Analog Devices are two semiconductor manufacturers making a wide variety of analog ICs. As you can see these are all facts and figures.

But it is some of these facts and figures have to be internalized. Every time I cannot go and keep consulting some book, textbook. These days of course Wikipedia or Google you will be totally ineffective if some of the numbers are not thoroughly internalized. It has to be part of your, so to that extent factual knowledge is important but we cannot afford to remain only there.

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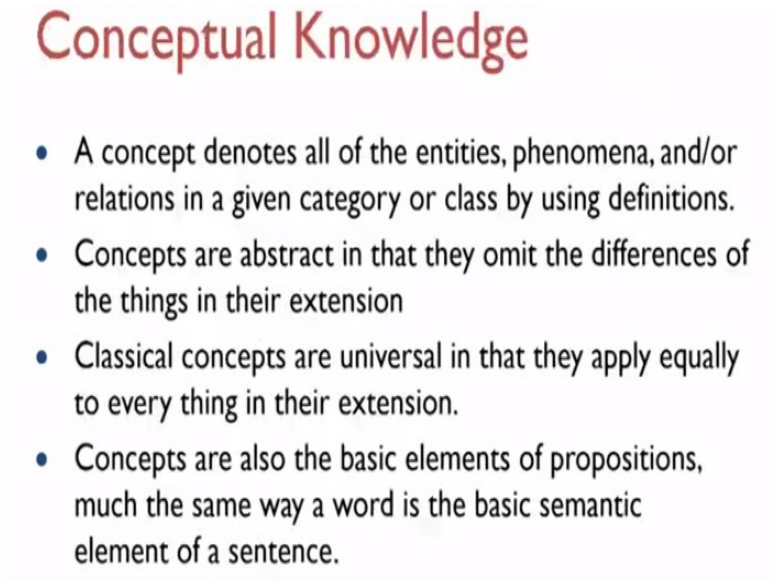

Coming to the Conceptual Knowledge while everyone every engineering teacher considers what concepts are very important and our experience shows that when you start defining what a concept is everyone has an issue or a problem. It could not be stated very clearly only replaced words like concept with idea, more fundamental things and so on like that. But a formal definition if you want, a concept denotes all the entities, phenomena and or relations in a given category or class of using definitions.

That means you collect a like take something like chairs. There are number of/ any varieties of chairs in the world today. But the moment you look at something you know whether it is a chair or not. So the chair is really can be considered as a concept. When I call something as a chair, I am willing to ignore the differences between two objects whom we are calling as chair, right? So that is what the definition is.

Denotes all of the entities and phenomena and or relations in a given category or class of using definitions. Concepts are abstracts in that they omit the differences of the things in their extension. For example if you call something as a metal, I call something as a metal. When I use the word metal, I am willing to ignore differences between two or three different metals. Just an object is a metal. Or like a tree, tree is a concept.

I am willing to ignore the differences between mango tree and a coconut tree. But both are trees, okay? So the concepts are abstracts in that they omit the differences of things in their extension. Classical concepts are universal in that they apply equally to everything in their extension. That means their extension is much larger for classical concepts. And also what happens is concepts are like elements of propositions much the same way a word is a basic semantic element of a sentence.

How do you make a sentence? Using several words. Similarly, a proposition can be made with multiple concepts put together. That means if I combine two or three concepts and create a relationship that is also conceptual knowledge. Generally, we call that as a principle.

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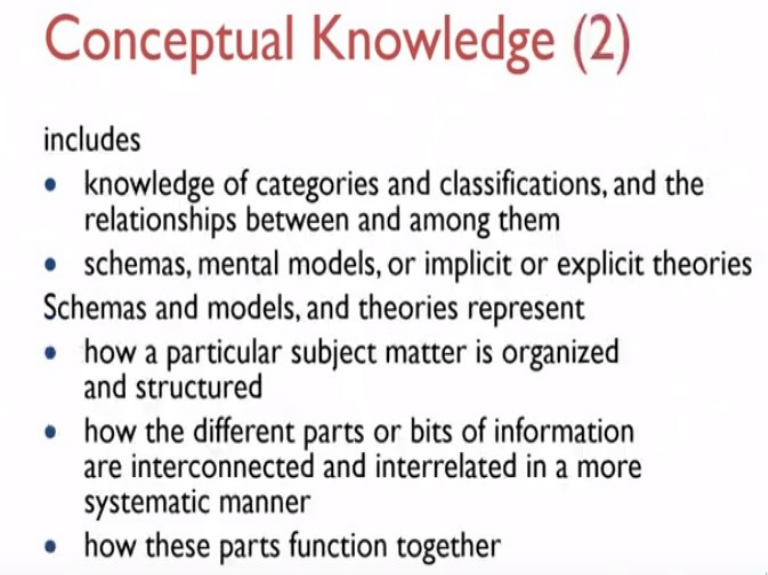

So here conceptual knowledge will include categories and classifications like we said metals and the relationship between and among them. That is what we/ that also is considered conceptual knowledge. On top of that conceptual knowledge includes schemas, mental models, or implicit and explicit theories. All theories are also considered as conceptual knowledge. What are conceptual schemas and models in theories? How a particular subject matter is organized and structured.

If you try to solve or look at a problem in Electrical Engineering from the framework of Mechanical Engineering you can have some difficulty because the words do not mean the same

thing and some of the accepted procedures are not the same in each branch and so on. So schemas represent how a particular subject matter is organized and structured. How the different parts or bits of information are interconnected and interrelated in a more systematic manner, how these parts function together. The classical example is let us look at this.

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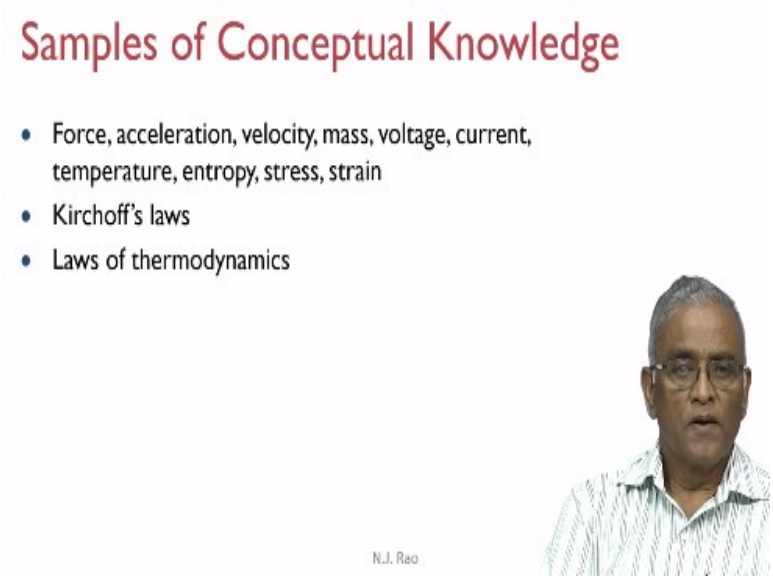

For example samples of conceptual knowledge - Force, acceleration, velocity, mass, voltage, current, temperature, entropy, stress, strain. Each one of those words represents a concept. For example F is force, mass is m and acceleration is a. So if you call it F = ma all the three are concepts but I am creating a relationship among them and that is also conceptual knowledge. Only thing we now call it a principle.

So a principle or a law if you talk about, a law is nothing but represents interrelationship between two or more concepts. That is what we can say. Similarly, other examples are Kirchoff's laws or laws of thermodynamics. They are all samples of conceptual knowledge.

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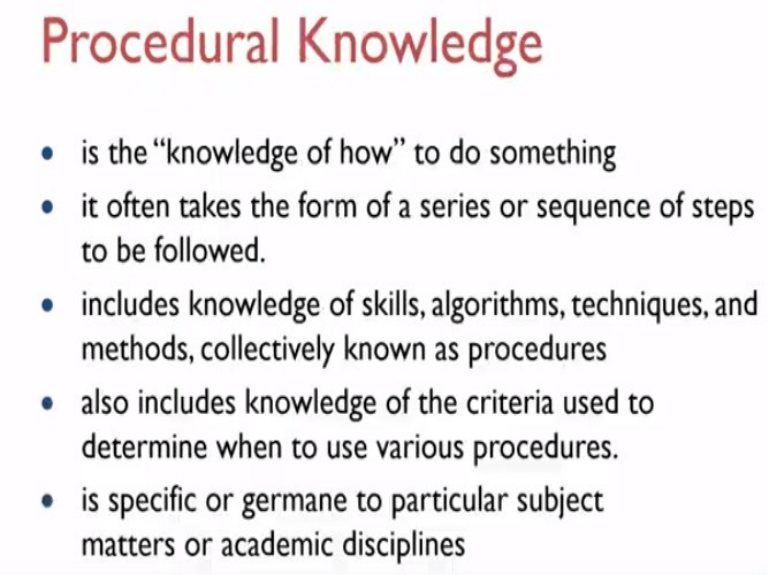

Now come to Procedural Knowledge. Is the knowledge of how to do something. This is fairly simple to understand. In every subject or every branch you have to go from one point to the other. I follow a sequence of steps to arrive at a result. So it often takes the form of a series or sequence of steps to be followed. But I should have the ability to follow the, or perform those steps, sequence of steps.

It includes the knowledge of skills, algorithms, techniques, and methods collectively known as procedures. A easy to understand thing is an algorithm is a procedure. Technique is to measure something you have to follow certain sequence of steps to measure the density of let us say of a given material. It also includes besides following a procedure like I have to solve a second order differential equation, I am given a procedure.

Or I have to find a Laplace transform of a given differential equation. So there is a procedure to be followed and that is procedural knowledge. But it also includes the knowledge of criteria used to determine when to use various procedures. For example if something is nonlinear you cannot apply Laplace transform, okay? So while you know how to create what do you call find a Laplace transform, you should also know when to apply or in what situation that procedure can be applied.

That is also part of procedural knowledge. And many times, these procedural knowledge is specific or germane to particular subject matters or academic disciplines. They are not necessarily universal.

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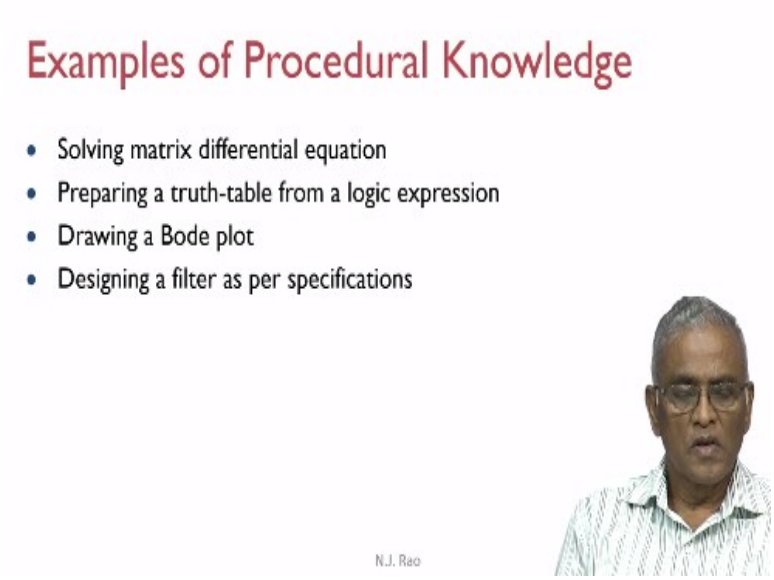

Some examples of Procedural Knowledge. Solving matrix differential equation. Preparing a truth-table from logic expression. Drawing a Bode plot. Designing a filter as per specifications. These are all procedural knowledge.

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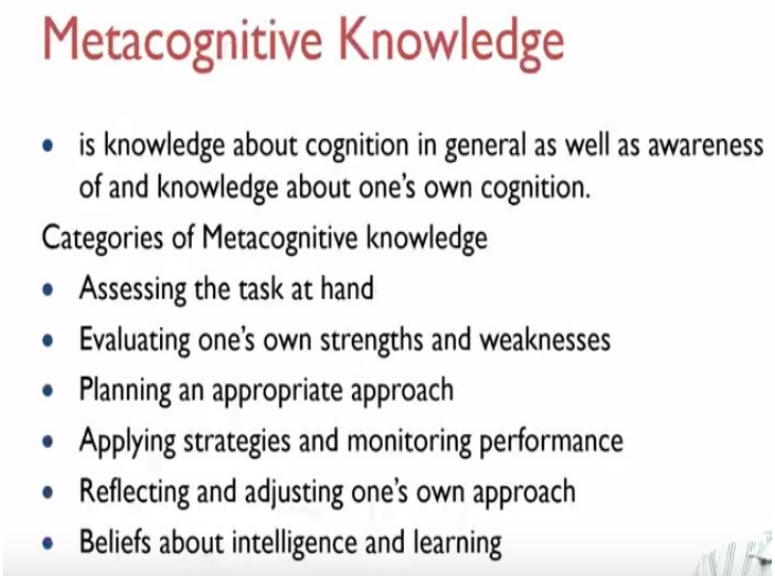

Now come something not very commonly known is Metacognitive Knowledge. We will have a complete unit on this particular thing. I consider it is very important for the teacher to know

about it. But let us see. It is not easy to handle either. Metacognitive knowledge by the very word meta-cognitive is a knowledge about cognition in general as well as the awareness of and knowledge about one's own cognition.

For example most common thing is many times we think we know about something. But possibly we do not know until we realize when you have to solve a problem you start getting any number of doubts. That means what we thought we knew, we did not know. So the most fundamental thing is do I know what I know? If a student mistakenly thinks that he already knows then we move forward with our subject taking a person along with you who did not know the earlier ones.

So what happens is all the things that he is learning will either be inadequate or will be half baked. Now some of the categories of metacognitive knowledge. Given a task, assess the task at hand. That is how much effort is needed? What kind of background knowledge that you need to have? And how much time it is likely to take? So assessing the task at hand, if somebody says, oh I can solve something in half an hour, it maybe right and may not be right.

If his metacognitive knowledge is poor it will turn out to be wrong. Evaluating one's own strengths and weaknesses. Everyone should have clear knowledge about one's own strengths and weaknesses. Planning an appropriate approach. Applying strategies and monitoring performance. That I should be able to monitor myself. That is I am following something and am I getting to, am I reaching the milestones as originally asked.

I should be able to monitor my own performance. Reflecting and adjusting one's own approach. I should have the ability to reflect and keep making adjustments. And my own beliefs of what intelligence and learning and I am sure when you talk to each other in a common parlance we make endless number of assumptions about our metacognitive knowledge.

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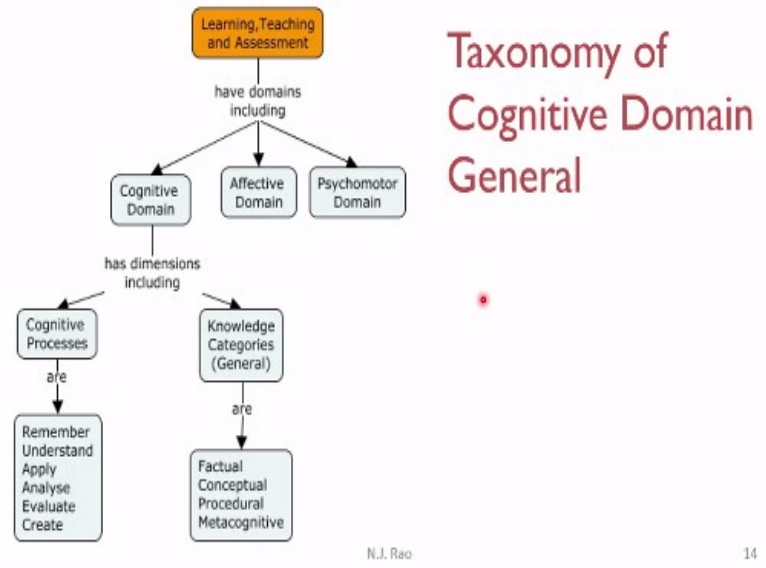

Now let us put down all these things together into a kind of a diagram. The Learning, Teaching and Assessment have domains including we have already mentioned cognitive Domain, Affective Domain, and Psychomotor Domain. We will elaborate these two domains a little more in other units and coming to Cognitive Domain. It has dimensions including Cognitive Processes and Knowledge Categories. There are two dimensions to this.

And cognitive processes are Remember, Understand, Apply, Analyze, Evaluate, and Create. And Knowledge Categories are Factual, Conceptual, Procedural, and Metacognitive. What we will try to do there are has dimension, again knowledge categories that are specific to engineering will come later. So but right now whatever we have handled till now can be graphically organized like this. So it is taxonomy of cognitive domain general.

That means this part will apply not only to engineering subjects but to any other subject as well.

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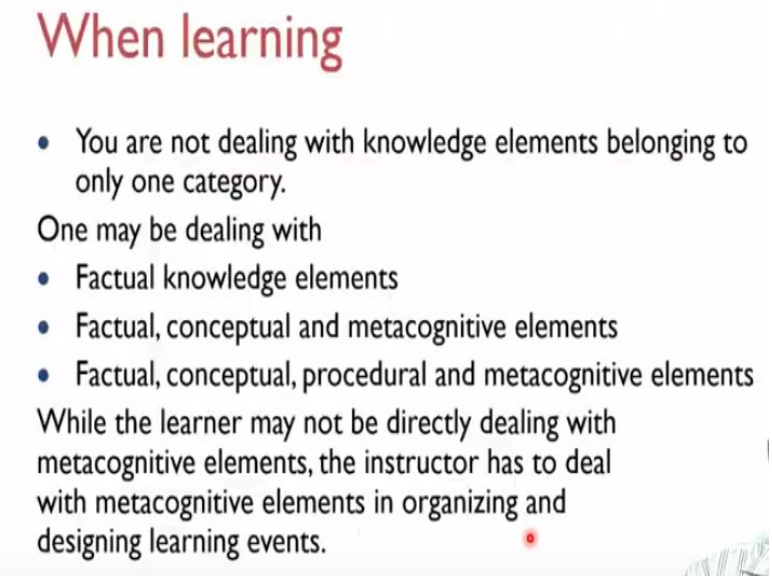

Now this is what one has to keep in mind. Generally you are not dealing with knowledge elements belonging to only one category. One may be dealing with just factual knowledge elements. That you are just keep on analyzing facts and figures in the classroom. For example I can describe a concept. I can describe a procedure. Even that is factual knowledge, okay? I am expected to factual knowledge elements. I am expected to Remember and reproduce.

Whereas it can be Factual, Conceptual, and Metacognitive in some cases. And it can be all the four; Factual, Conceptual, Procedural, and Metacognitive elements. While the learner may not be directly dealing with Metacognitive elements, the instructor has to deal with Metacognitive elements in organizing and designing learning events.

Our research shows that unless if the teacher is not aware of the metacognitive knowledge of the students, then what he is doing in the class or working in the laboratory may not be effective at all and that leads to many other problems. Anyway we are not going to look at those problems and finding out solutions but if you survey the engineering colleges across the country, it is one of the issues is the very poor state of metacognitive knowledge of the students that are coming out through the competitive exam route.

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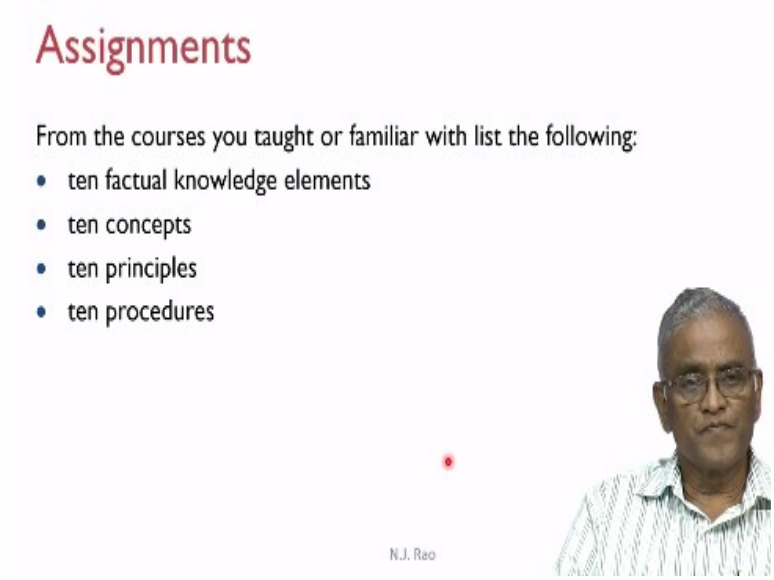

There is the assignment for this unit. From the courses you taught or familiar with list 10 Factual Knowledge Elements. Take a subject and whatever facts and figures that you are talking about it needs to be one word or two words that is all for each element but list 10 of them and similarly list what you consider concepts, 10 of them or 10 principles. Principles are nothing but concepts related to each other, two or more concepts related to each other.

Similarly, give 10 procedures from the course that you are dealing with. It is only giving examples from your course. This hopefully, the purpose of this assignment is that you start looking at the subject that you are very familiar with from a slightly different framework in terms of knowledge elements.

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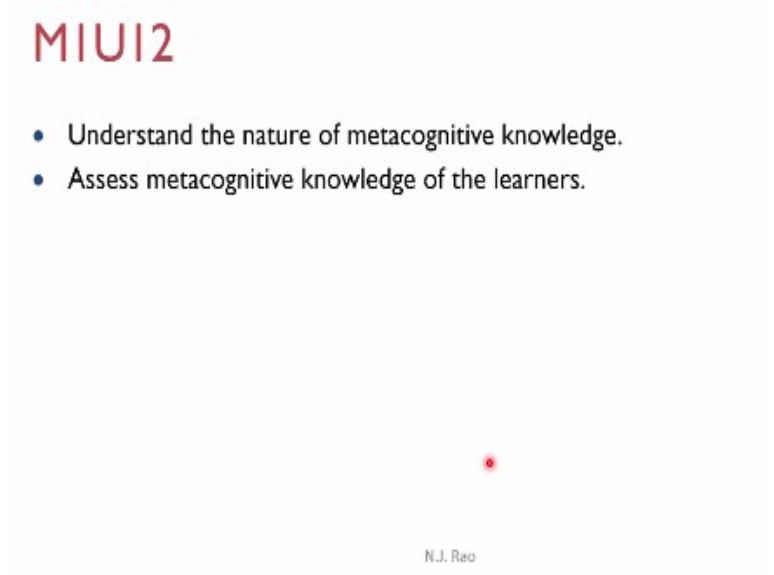

And the next unit, we will try to look at, understand the nature of metacognitive knowledge. Assess metacognitive knowledge of the learners. I felt spending, because of the importance of metacognitive knowledge it is worthwhile spending at least one unit on this. Thank you very much.