NBA Accreditation and
Teaching – Learning in Engineering
(NATE)
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Lecture 14
Categories of Knowledge-2

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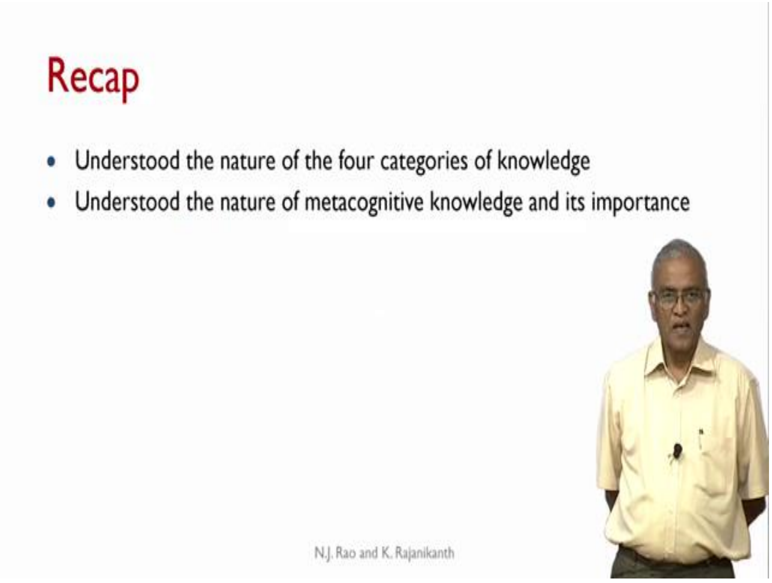

Greetings and welcome to module 1, unit 13 of course NATE, NBA Accreditation Teaching and Learning in Engineering. The unit is related to categories of engineering knowledge. In the last unit, we understood the nature of 4 categories of knowledge which are applicable to all disciplines. And especially, we noted the nature of metacognitive knowledge and its importance.

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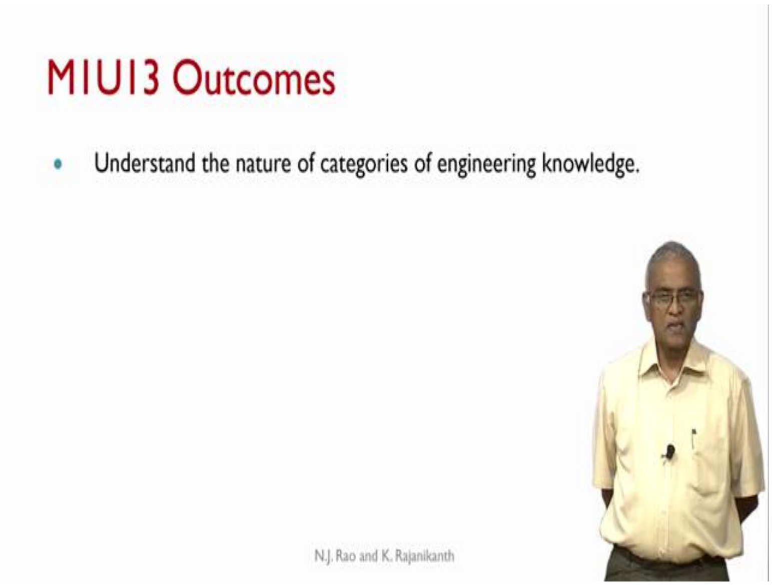

And in the current unit, we will try to understand the nature of categories of engineering knowledge. That means, we already making a claim, there are some categories of knowledge specific to engineering outside the general 4 categories that is a claim and people have been investigating at least there is some amount of understanding that there are categories of engineering knowledge.

If they are not addressed in your engineering programs, then you are really missing something about engineering itself. That is a claim.

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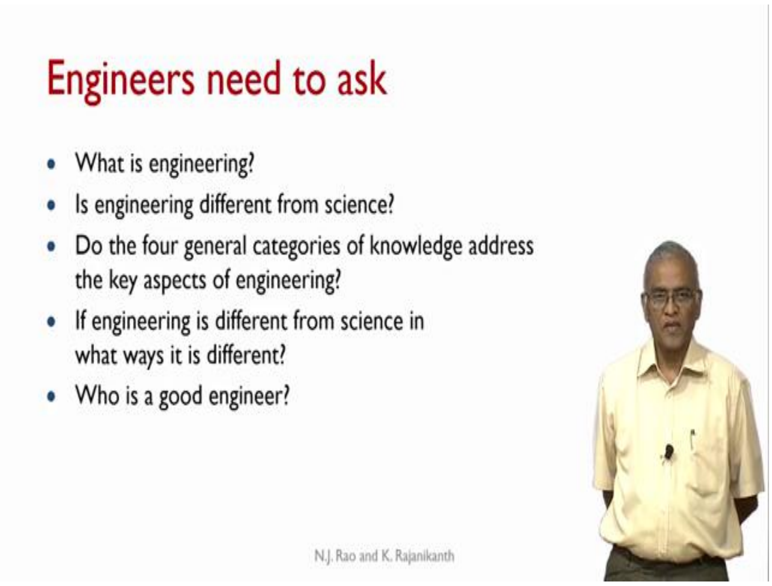

Now, so we try to address these questions for example, different people have different views of that. And it always comes out when you ask a large number of teachers in engineering, what is engineering in their view, just formally defining engineering. When you ask that question in survey, different people seem to have very different views of what engineering is, which is somewhat unfortunate.

Because we need to have clarity about our own profession of engineering teaching, so, we look at all for example, all engineers need to ask, what is engineering, is engineering different from science? Do the four general categories of knowledge address the key aspects of engineering? If engineering is different from science, in what ways it is different and who is a good engineer? We looked at some of these aspects in the earlier unit.

Now, again, whatever I am going to present, you may or may not agree with what it is, but you must consider these issues and have your own opinion.

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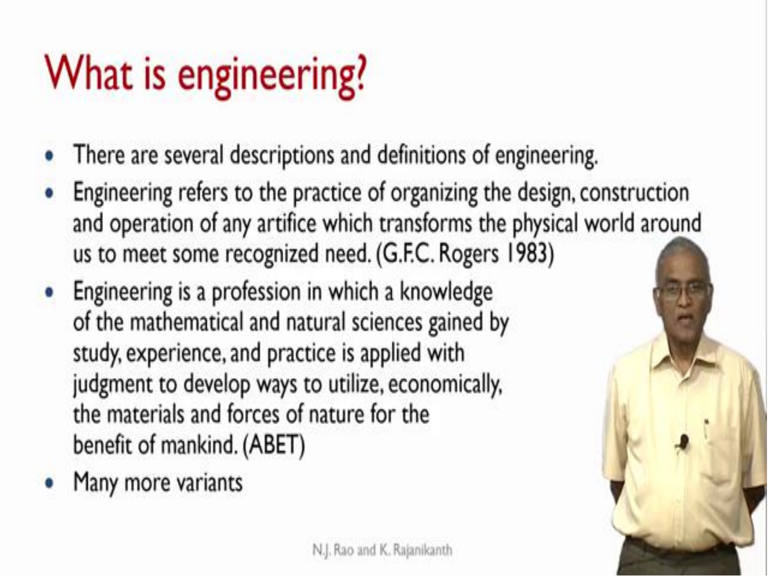

There are first of all to formally define what engineering is. there are any number of definitions of what engineering is, I am giving two of them here. Engineering refers to the practice of organizing the design, construction and operation of any artifice which transforms the physical world around us to meet some recognized need.

When you look at all elements of this, like organizing the design, construction and operation, often artifice and what is this artifice? Which transforms the physical world around us, in what way? To meet some recognized need, a whole bunch of issues will come out of that which you have to address.

This was a definition given by G.F.C. Rogers back in 83. Now, ABET that is Accreditation Board for Engineering and Technology of United States of America defines engineering like this. Engineering is a profession, in which knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgment to develop ways to utilize economically, the materials and forces of nature for the benefit of mankind.

Once again, I feel sad, the focus is on because that is the first part of the sentence, applying knowledge from mathematical and natural sciences gained by the study all that, but what is the goal actually develop ways to utilize economically the materials and forces of nature for the benefit of mankind. So, the engineers role is to utilize economically the materials and forces of nature for the benefit of mankind. But not in a arbitrary way with the knowledge of mathematical and natural sciences gain by study, experience and practice.

So, this is the definition and there are any number of variants for this. One can write, ones own definition. Actually, if you put multiple definitions, they are not at variants but they may be emphasizing according to themselves, what is the most important aspect of engineering activity.

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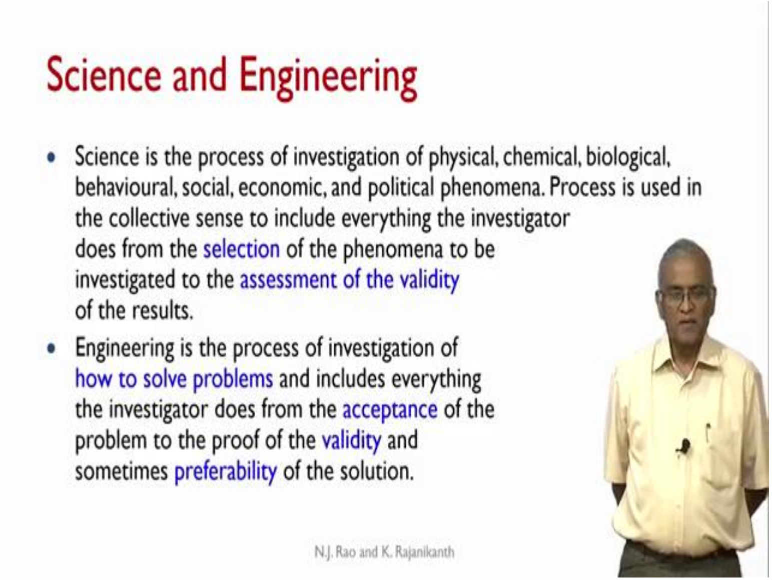

Now, let us look at two definitions of science and engineering which come very close to each other. Here science is a process of investigation of physical, chemical, biological, behavioral, social, economic and political phenomena is a process of investigation that is a science is a process of investigation period. Now, process is used in the collective sense that means, it is not done by one person but a large group, the entire community to include everything. The investigator does from the selection of the phenomena to be investigated to the assessment of the validity of the results.

So, the purpose of science is to investigate phenomena and also the assessment or the validity of the reasons when do I call my conclusions are valid. Whereas engineering is a process of investigation of how to solve problems, say how to solve problems is the focus of engineering and includes everything the investigator does from the acceptance of the problem to the proof of the validity and sometimes the prefer ability of the solution. Because why prefer ability comes into picture?

There can be many valid solutions to a given engineering problem and out of that, I may prefer one okay. So, the prefer ability of the solution is also accepted is necessary to be, is also part of engineering activity.

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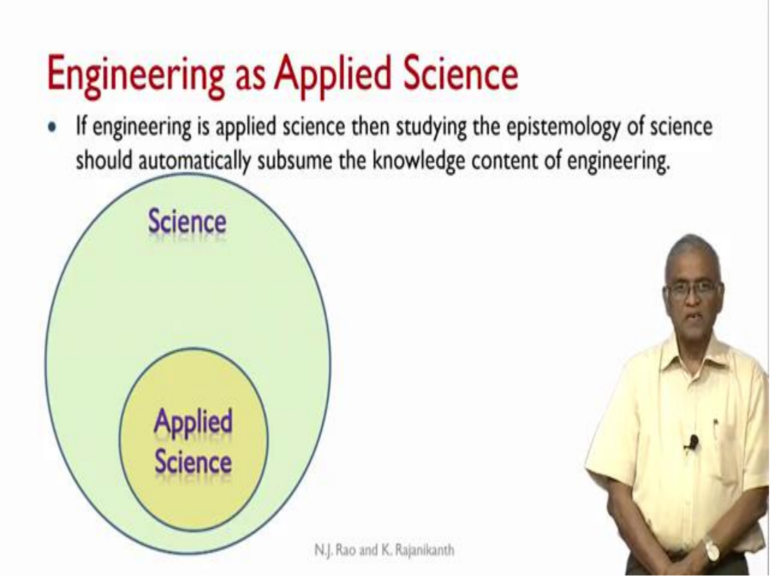

Now, one of the most common I would consider misconception though many people use it and swear by it, is engineering is applied science. If engineering is applied science, then studying the epistemology of science should automatically subsumes the knowledge content to engineering. Look at this picture, science is a big circle and if you have added applied, you added an adjective right. So, it is a subset of that, then engineering is a subset of science that people do not agree. But still they use the word engineering is nothing but applied science.

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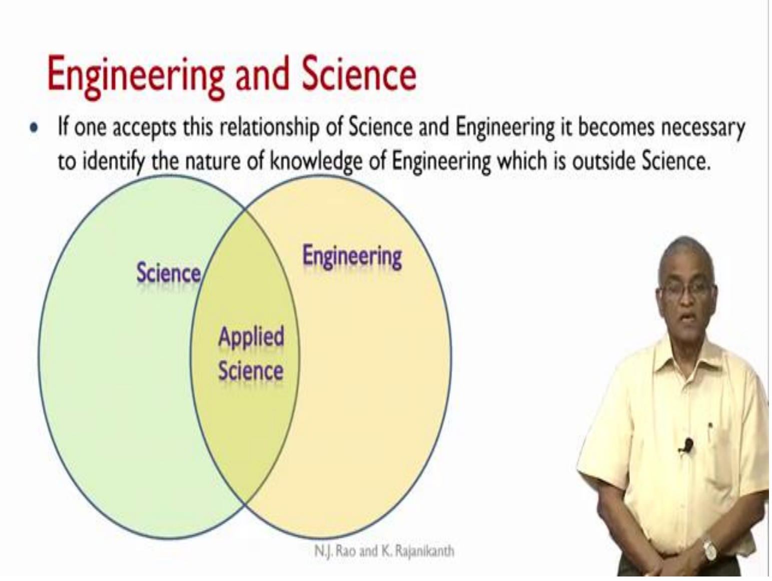

If it is not if you, what is the relationship between engineering and science if you ask, so if sciences one circle and engineering is another circle, there is a lot of an intersection between them. That size of the intersection is your wish, how big or how small you want to make. But even if when there is some intersection, there is something outside that intersection in engineering.

Then you have to say, what is that outside engineering? In the sense, what is outside here? I need to capture that. If I do not capture this, then I am only not I am not addressing all of engineering. Then I am constraining myself to be what we may generally call engineering science, which is the intersection between the two science and engineering.

But if you talk about engineering, there is something outside let me say I take this particular position, engineering is not applied science is more than applied science. And there are many aspects of engineering which are which fall outside the purview of science. And that is the reason why one needs to look at are there some categories of knowledge that outside these 4 general categories we talked about.

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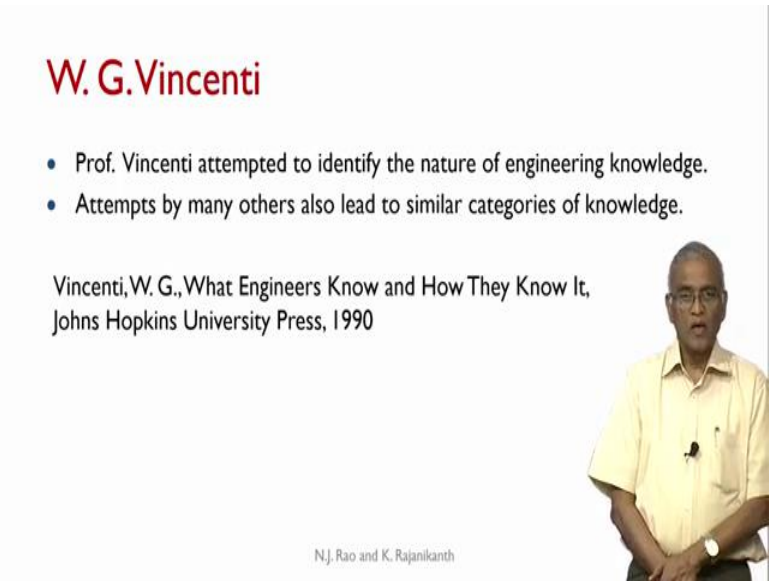

Now, one of the prominent persons who looked at the nature of engineering knowledge is professor Vincenti of Stanford University, incidentally is more than 101 years old right now. And many others also have investigated and talk somewhat slightly different from Vincenti, but they all lead to similar categories of knowledge. And these are presented in this 1990 book of professor Vincenti, what engineers know and how they know it.

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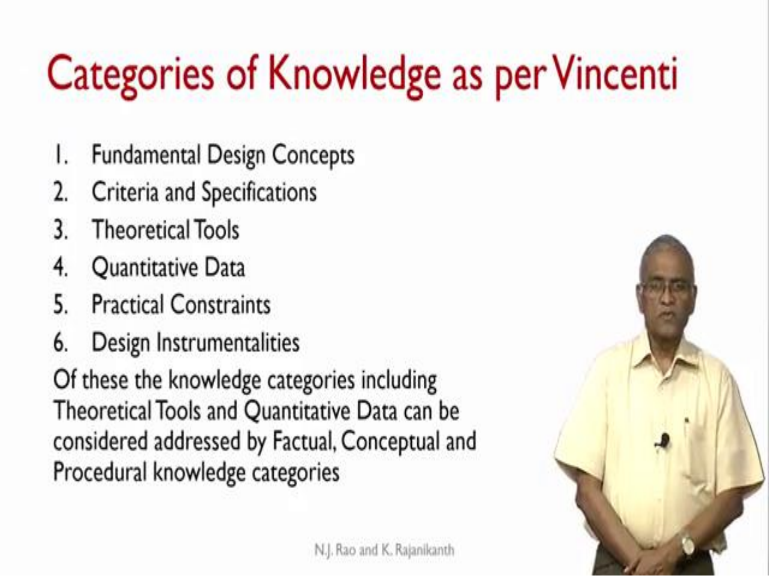

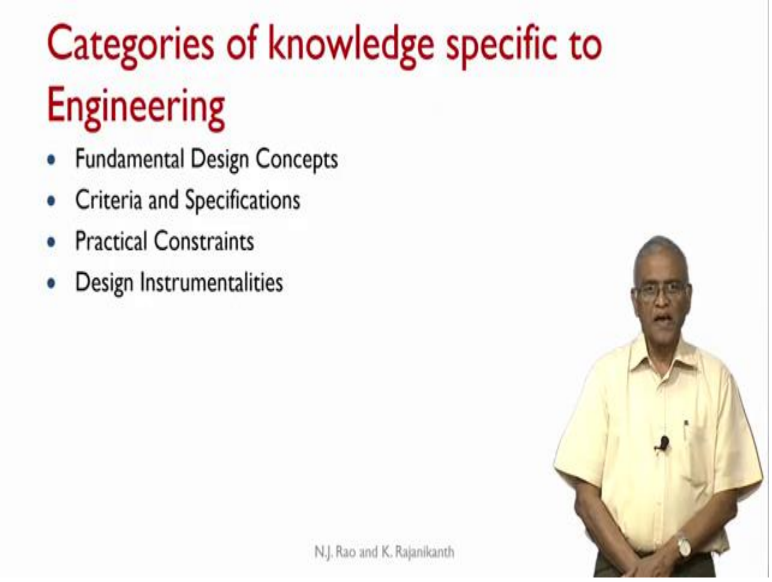

Which of the categories of knowledge as per Vincenti, there are he presented 6 categories, fundamental design concepts, criteria and specifications, theoretical tools, quantitative data practical constraints, design instrumentalities. He did not worry about science, he just looked at engineering and said these are the 6 categories of knowledge that he can look at.

Now, if you look at the 6 categories, the categories including theoretical tools and quantitative data, if you take these 2 can be considered their address by factual, conceptual and procedural knowledge okay. So, you do not have to again (re) that is, this is a different label actually theoretical tool is a different label. Quantitative data is a different label for factual knowledge.

So, if I subtract these 2 categories, then I have these 4 categories of knowledge specific to engineering, which are not addressed by the general categories. Fundamental design concepts, criteria and specifications, practical constraints and design instrumentality, let us look at what these are.

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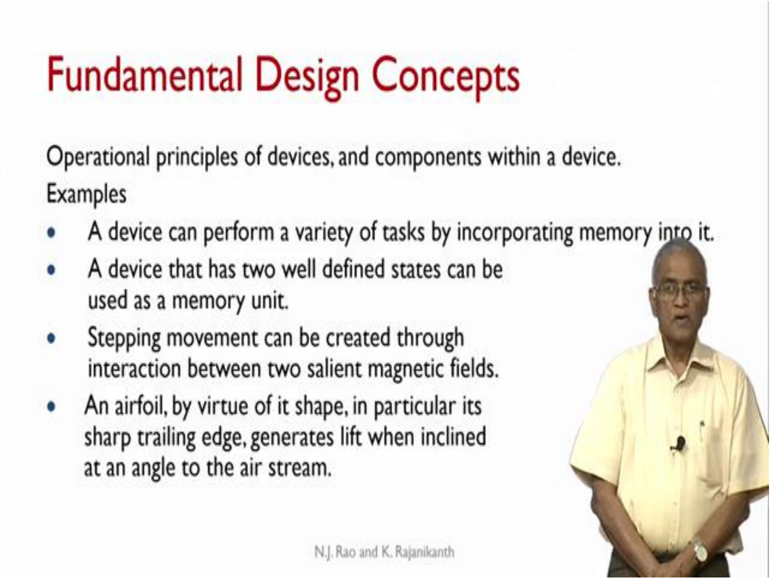

These are fundamental design concepts are operational principles of devices and components within a device. For example, this principle operational design concept does not automatically emerge from the knowledge underlying or the knowledge of the physics or chemistry or biology of the phenomena that you are investigating. The design principle operational principle will have to come out of that it is not against any of the, what you call, underlying knowledge, but it does not automatically come as a logical consequence of that.

For example, if you take a device can perform a variety of tasks by incorporating memory into that. And this principle has come after the principle has come into or it is acknowledged by people or it is presented none other than one (())(13:30), the so called the concept of computer has come into existence. Once that comes, it looks like you can take this principle for granted. But it took, it was only an initiated sometime in 50s or I think around in the 50s.

Similarly, a device that has two well defined states can be used as a memory unit. And this is a basis for designing all types of memories. Another one, stepping moment can be created through interaction between two salient magnetic fields. So, you have whole bunch of stepping motors that come into action and there are any number of appliances based on stepping movement.

For example, the most important one, an airfoil by virtue of its shape in particular, its sharp trailing edge generates lift when inclined at an angle to the air stream. This was realized after centuries of struggle to try to find out how to fly by Wright Brothers, they have created an airfoil like this, which created the required lift and then you got the first airplane flown by them.

But the underlying physics was not known at that time. So, they have come out with this particular design concept and the underlying aerodynamics all the science of that has come much-much later there is around Second World War. And now, once you understand the underlying aerodynamics, you can keep improving the performance of the airfoil that what it. So, but the fundamental design concept will have to be separately acknowledged. So, each one should know what are those design concepts in the, that particular branch of engineering.

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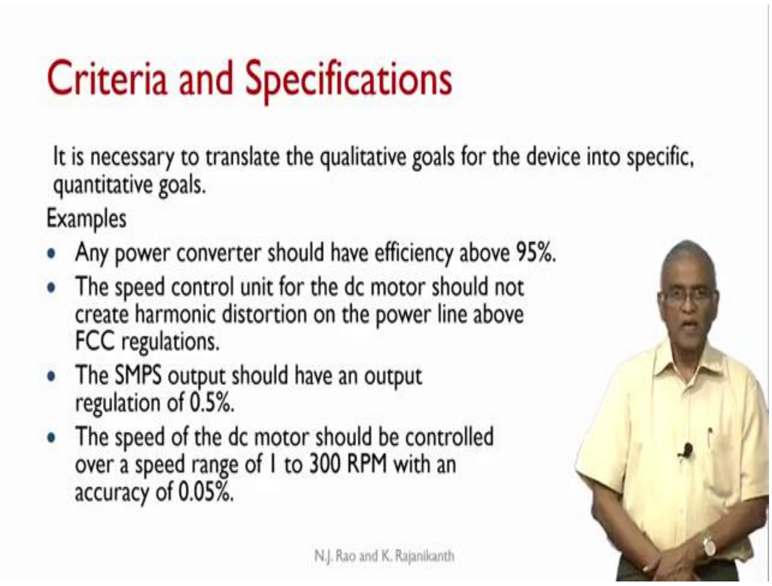

Now, this is the most important one, unfortunately most neglected in practically all undergraduate programs. There is nothing done in engineering which is not done as per some criteria and specifications, you do not. You cannot make any device or any object, any artifact without starting from specifications. And the specifications have immense effect on how much time it takes, whether you can do it or not or how much it costs. Everything is dependent on the set of specifications. So, a student should certainly understand the role of criteria and specifications.

If he does not understand, I would practically say he does not know anything about engineering. Nobody is going to give you just end of the chapter problems for you to solve and that makes you an engineer. So, it is necessary to translate the qualitative goals for the device into specific quantitative goals. For example, you take any power converter should have efficiency about some 95 percent. Yes, for example, if I want to design a power converter at 90 at let us say 99 percent efficiency, is it viable with the current available technologies and devices and if I want to do that is it in at a acceptable level of cost?

So, the specifications determine practically everything. Or you take another example, the speed control unit for the DC motor should not create harmonic distortion on the power lines above the FCC regulations. That is actually one of the basic requirements whenever you design a any speed control unit for the DC motor or for that matter induction motor anything that you design, a power, a converter or a power regulating device if you design that it should not create harmonic distortion on the power line and how much distortion, that is specified by the FCC.

Similarly, another example the SMPS that is switch mode power supply output should have an output regulation of 0.5 percent, something that has 2 percent regulation or 0.1 percent regulation is an SMPS with 10, let us say 5 percent regulation and 0.1 percent regulation will be vastly different in its complexity, cost and the amount of time required to design.

The speed of DC motor should be controlled over speed range of 1 to 300 RPM with an accuracy 0.05 percent, 0.05 percent is a very tall order. You require so many special components and so much of circuitry to achieve that kind of range as well as accuracy. So, in engineering specifications or everything and the student should have the feel for the specifications for the artifacts that come out of his discipline.

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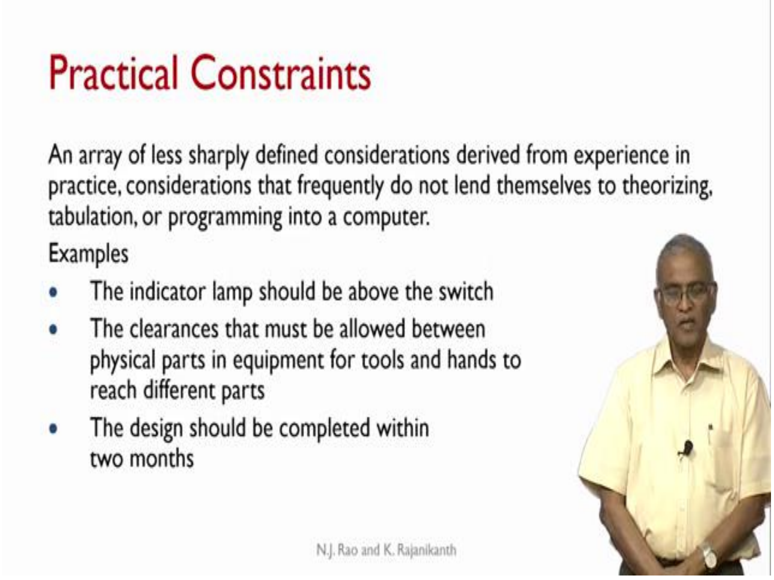

Now, there is another one you an engineer always works under practical constraints that every engineer should be aware of, because there you cannot get either the data or the resources that you want to solve a problem. They are not infinite resources that are available or all the information that you want is not available. So, you have an array of less sharply defined considerations derived from experience in practice, consideration that frequently do not lend themselves to theorizing, tabulation or programming into a computer.

So, what happens when you do not have the data, that is one of the constraints and you still have to solve the problem like you can say more or less this is a very important aspect of engineering. Some people define engineering is decision making with under constraints or under practical constraints. For example, one simple data, the indicator lamp should be above the switch.

Let us say there is a switch and there is an indicator lamp and should the switch can be should be on the side or above or below. If you want to answer that question, here the answer is indicator lamp should be above the switch. Why? Simply when you are switching on, your hand should not kind of obstruct the lamp. Now, what kind of knowledge is this? So, it is not as structured like your F equal to m a.

So, but one should be aware of all the practical constraints and one should not treat them with say that oh anyone can do, these are all hand waving and this is not a what you call proper knowledge and so on. This knowledge is very important for practice of engineering. The clearances that must be allowed between physical parts and the equipment for tools and hands to reach different parts, there are some rules let us say, how do, when I want to repair equipment, I must be able to reach that with my tool.

Now, you have to create space for that or you must design the equipment in such a way that I must be able to open it out and when I open it out, all parts are accessible to my tools. That tool will have to be built in right in the beginning, when you are trying to design an artifact. Another practical constraints, the design should be completed within 2 months. So, what, how do you react to that? You will go and say I require this much resources if you want to do it in 2 months.

And if the required resources are not available, it is not possible to achieve this, but this 2 months kind of thing will is a practical constraint or when you are responding to a natural disaster, you have to solve some problems within a very-very short limited time with the under the constraints that you have on the spot.

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Now, another one category of knowledge, design instrumentalities, it is again not as well structured as that. But it is a procedural knowledge including the procedures way of thinking and judgmental skills by which it is done. Some examples, top-down approach to design of a product, many times when you are designing a large product or system or let us say even a software product, people say you do top-down approach. So, that is one design instrumentality or you phase the development of a product.

Some activities can be done parallely, some can be have to be done serially, how do you arrange the serial parallel activity is that that tells you the phasing and how do you allocate human resources or as well as financial resources for that, is all depends on how you phase the development of a product.

Structuring of an electronic product, example design walkthrough is a very common practice in software development. It is also a practice in developing an electronic product. Identify all members of the team early on and include every member in the group communication from the outset. Let us say this is a room, this is a piece of knowledge that you use.

If you compare this with, let us say, a procedural knowledge or a conceptual knowledge, it does not look in the same category. But it is as important as any other when you are talking about an engineering activity especially done by a group.

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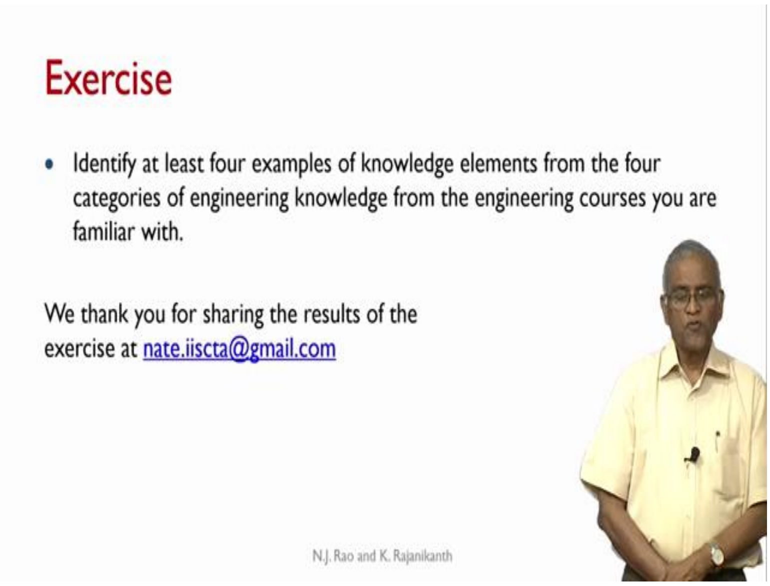

These 4 categories of engineering knowledge are important and the extent to the extent to which you incorporate these dimensions into your instruction, it decides to what kind of good engineer that you will be able to train. So, our appeal to you is to the engineering faculty is that first convince yourself the importance of these 4 categories of engineering knowledge. And then make effort in how to incorporate that into your instruction or when the students do the project and make them sensitive to these issues.

Now, as an exercise, we request you to identify at least 4 examples of knowledge elements from the 4 categories of engineering knowledge from the engineering courses that you are familiar with. You may not be able to find these in a pure let us say pure engineering science course are just science course. But from all engineering courses, you should be able to find out examples of this knowledge elements. We would appreciate if you can share the results of your exercise at this mail.

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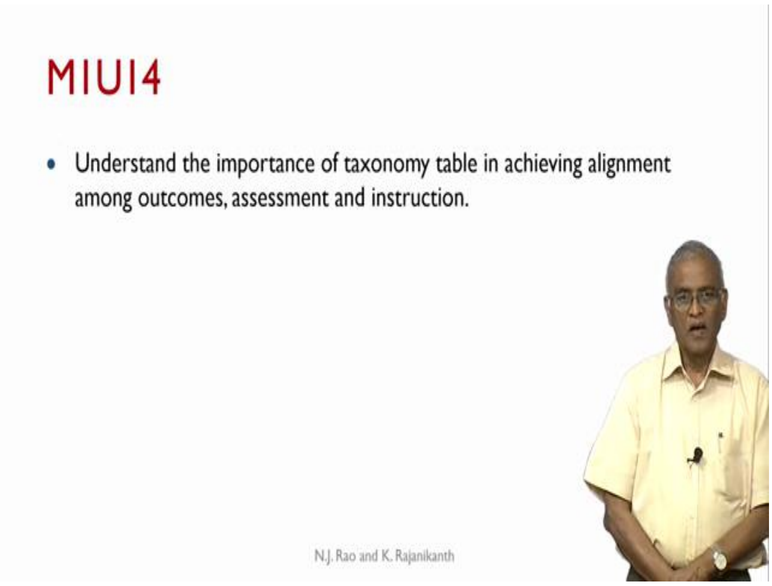

And in the next unit, we will try to understand the importance of taxonomy table in achieving alignment among outcomes, assessment and instruction. What follows is this, you have already looked at the cognitive levels and we looked at the 8 categories of knowledge of engineering. And then they can all be put together in the form of a table. And the table itself can serve as a very good tool for attaining what we call alignment. And thank you very much for your attention.