Teaching and Learning in Engineering (TALE)
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Lecture - 07
Program Outcomes 1

Greetings and welcome to the Unit 7 of Module 1. This unit is related to the Program Outcomes as identified by National Board of Accreditation.

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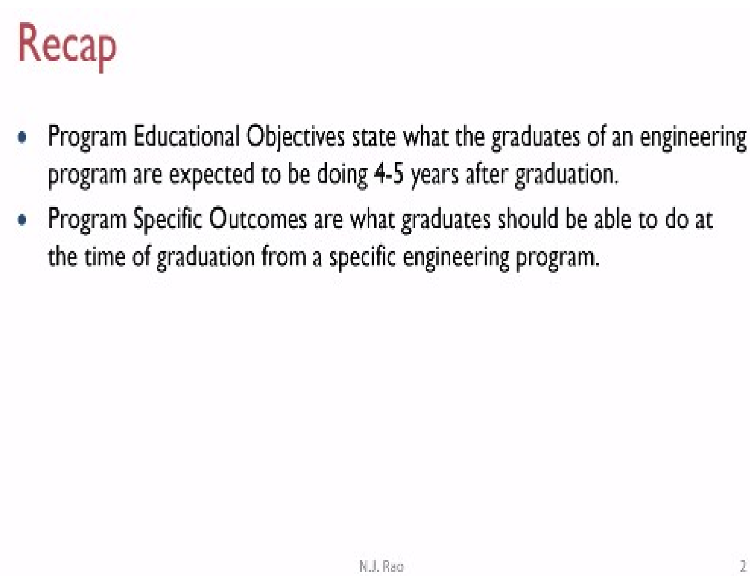

In the earlier unit we looked at Program Educational Objectives, which state that what the graduates of an engineering program are expected to be doing 4-5 years after graduation. So these Program Educational Objectives really provide a kind of a goal that needs to be attained with the activities of graduates. And then we have Program Specific Outcomes. They are what the graduate should be able to do at the time of graduation from a specific engineering program.

That means the Program Specific Outcomes are very specific to particular branch. If it is civil Engineering all the program specific outcome should be related to Civil Engineering. That is what we understood in the previous unit.

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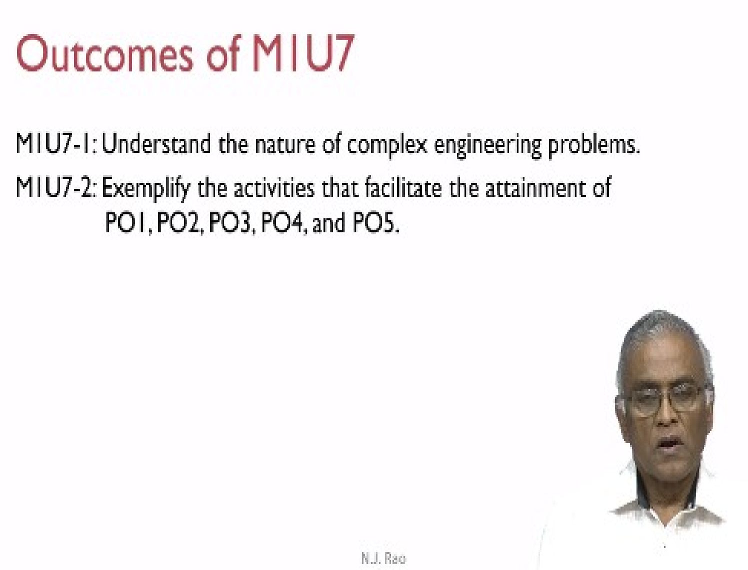

Coming to the present unit, the outcomes of this unit, we try to understand the nature of complex engineering problems and then we try to identify or exemplify the activities that facilitate the attainment of 5 of the 12 outcomes, Program Outcomes. PO1, PO2, PO3, PO4, and PO5.

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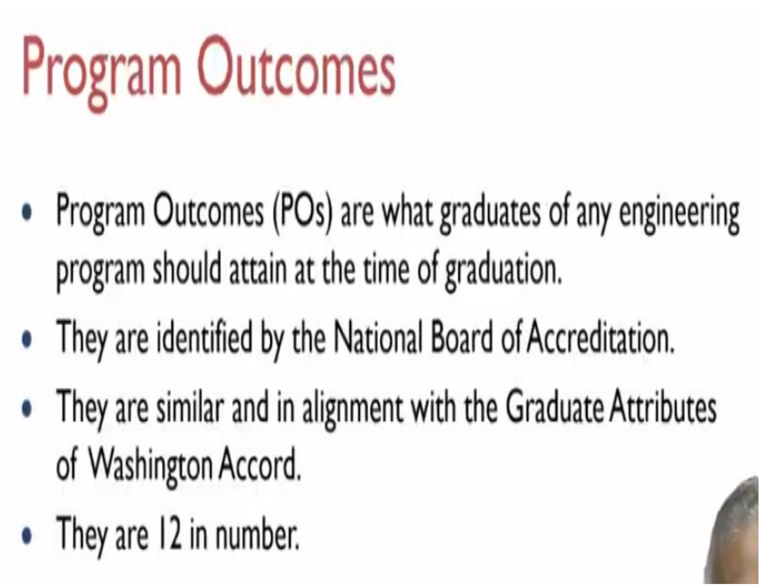

What are the program outcomes to recapitulate? Program outcomes are what graduates of any engineering program should attain at the time of graduation. These program outcomes are discipline nonspecific. That means graduates of all engineering programs have to attain this program outcomes. And they are identified by the National Board of Accreditation. So no institution as of in the current context of accreditation has choice of writing or changing the program outcomes.

They may change with time based on the feedback given by various institutes but that kind of modifications will take place once in a few years. And as of now, the program outcomes that are stated by NBA are very similar and in alignment with Graduate Attributes of Washington Accord.

Washington Accord is really the umbrella accord wherein all the signatory countries to the Washington Accord are actually committing that they will be conducting their programs; broadly as per the kind of outcomes or a Graduate Attributes that are identified by Washington Accord. We do not have to exactly copy the Graduate Attributes, but each country will rewrite their Graduate Attributes or program outcomes in the spirit of Graduate Attributes of Washington Accord. That is what India has also done. There the number of program outcomes are 12.

In some cases like ABET they are 11. But when you see them together, they are in the same kind of, they are as per the spirit of Washington Accord.

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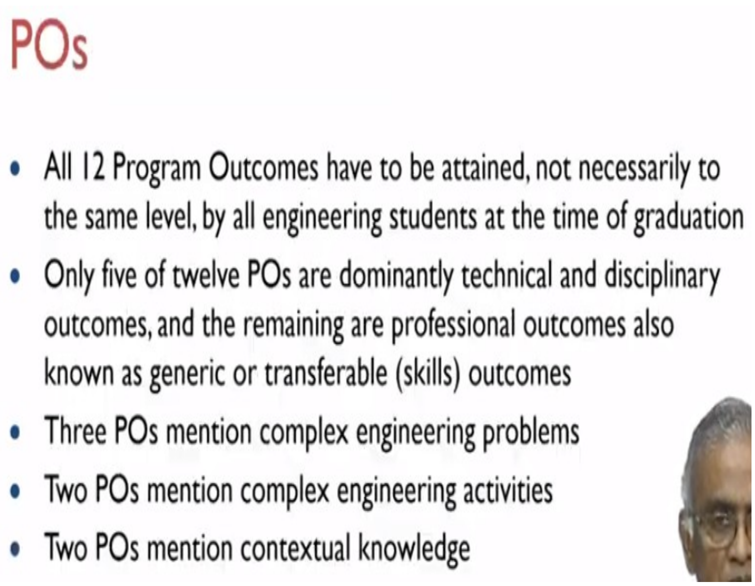

And all the 12 program outcomes have to be attained. As we will see the, it may not be that very easy to attain all of them to the same degree that you want to attain. So we will accept that, initially every outcome may not be attained to the same level by all engineering programs or by the students who are graduating from that.

If they cannot be attained to the same level, then what happens each program will put a target with respect to each PO okay with the resources, with the kind of students that you have, with the program that you have a particular PO may be attained only let us say whatever number that you associate with that at 50% level, 30% level that you can define for yourself. So it is not mandatory that all program outcomes have to be attained to the same level.

And a quick review of the POs indicates only 5 of 12 POs are dominantly technical and disciplinary outcomes. That means they can be related directly to engineering and they are technical in nature, only 5 out of the 12. And the remaining ones are what we call professional outcomes and they are also known by other people as generic or transferable skills or outcomes.

So one can see the POs as a combination of disciplinary outcomes or technical outcomes along with professional outcomes. And three POs mention complex engineering problems. The word complex engineering problem has been very strongly used by the POs we will make an attempt to understand what they are. Two POs mention complex engineering activities and two POs mention contextual knowledge.

One of the issues of any engineering problem that you talk about, a real world engineering problem is always situated in a given context. It is not as if I solve this problem and the solution is applicable universally. So there is a lot of contextual knowledge that gets incorporated into when you identify or formulate real world engineering problems. That needs to be appreciated by any engineer.

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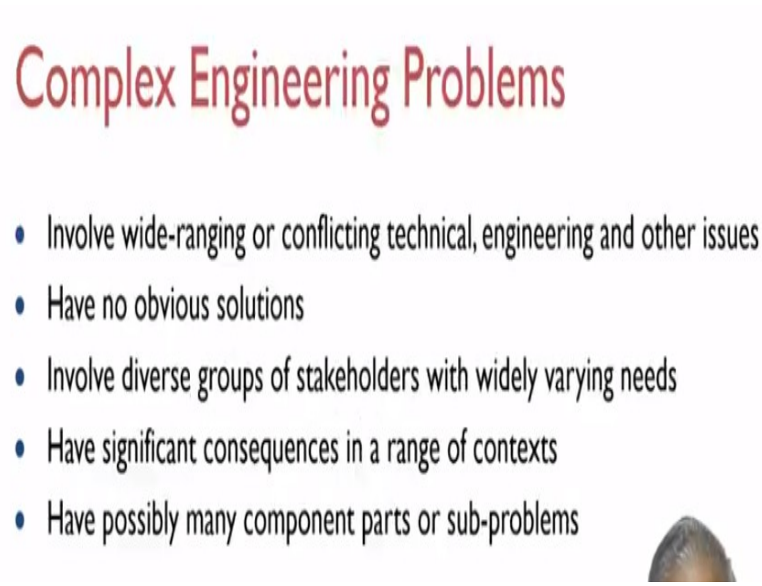

Now what are complex engineering problems as characterized by Washington Accord itself? They involve wide-ranging or conflicting technical engineering and other issues. What are the other issues? When you talk about a problem, when you take a real world problem, whatever solution you produce, it may be as per the, it may be adequate or it meets the requirements of a certain segment of the society.

But other segment of the society may get affected by that in a negative way. So whose requirements are we trying to meet? So many engineering problems are really complex in the sense you have wide-ranging as well as conflicting issues that come in. And when you talk about a complex engineering problem, it has no obvious solution. It is not like end of the chapter problem. There is only one particular solution you have.

For most of the end of the chapter problems in a text book there is only one solution available. Here a real world engineering problem does not have a single solution and also not an obvious solution. And another feature of that, they involve diverse groups of stakeholders with widely varying needs. And many times this widely varying needs cannot be compromised into a solvable problem.

Then the whole problem becomes kind of starts becoming political in the sense interest of which group are you trying to meet or whom are you satisfying and which segment of the society is going to be negatively affected and once again they have significant consequences in a range of context. Same solution in one context maybe desirable and the consequences in some other context it will be different. The consequence are different.

For example a solution that is offered let us say in an urban context may not be, the consequences of that if you try to apply the same solution in a rural context it may create a negative consequences. So that is another feature of complex engineering problems. And also a complex engineering problem has several component parts and several sub-problems. They will all have to be integrated together.

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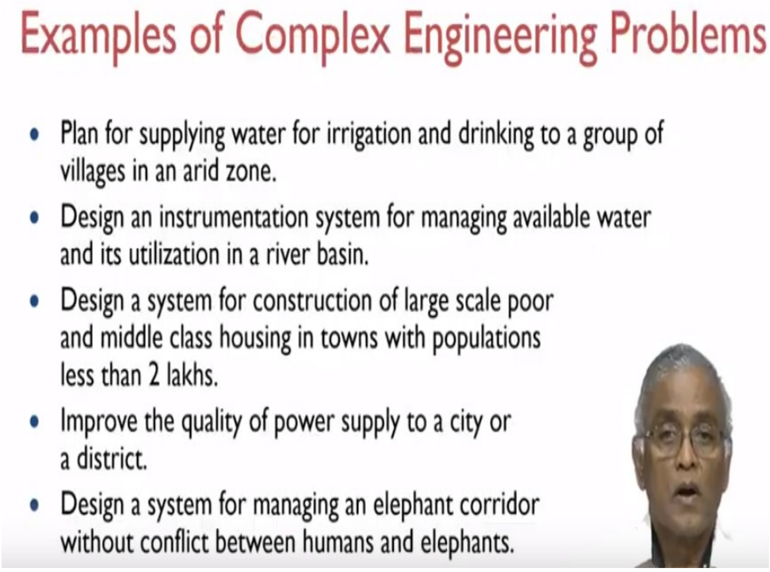

Some examples of complex engineering problems. Let us say planning for supply of water for irrigation and drinking to a group of villages in an arid zone. So it will provide a, it will lead to the features that we just mentioned. All those features will apply, have to be taken into consideration to solve this kind of problem. Design an instrumentation system for managing available water and its utilization in a river basin.

As you know at present, every river basin, being a, river water being a concurrent topic, there are always very major disputes between different states of the country. So trying to really resolve or trying to solve a problem anything related to managing available water resources, the river basin is a very very complex problem. Design a system for construction of large scale poor and middle class housing in town with populations less than 2 lakhs.

The issues are different in a city compared to smaller towns. Improve the quality of power supply to a city or a district. I think all of us have experienced this. The quality of the power supply is never satisfactory and to solve that things are not very easy and people do not agree with a common solution/with any proposed solution. Design a system for managing an elephant corridor without conflict between humans and elephants.

This is also recently experienced problem in the southern states of the country. And when the human populations increase, one may be encroaching on to the elephant corridors through which the elephants move and once you cross that there is always a conflict between humans and elephants. Now how do you manage the corridor is a both a technical and a complex social problem.

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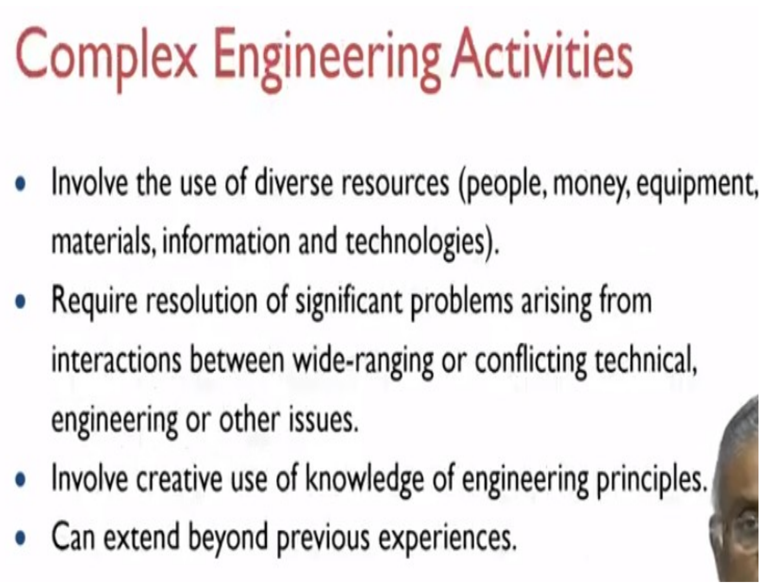

Now what are complex engineering activities? First of all, a complex engineering activity involves use of diverse resources, resources in terms of people, money, equipment, materials, information and technologies and they require the activities involve resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering or other issues.

That means complex engineering activities always call for using them together or dealing with all these issues together rather than take one single one and only try to find a solution for that. Involve creative use of knowledge of engineering principles. Can extend beyond previous experiences. There may not be any previous experience to bank on to provide a solution to a present a complex engineering problem at present.

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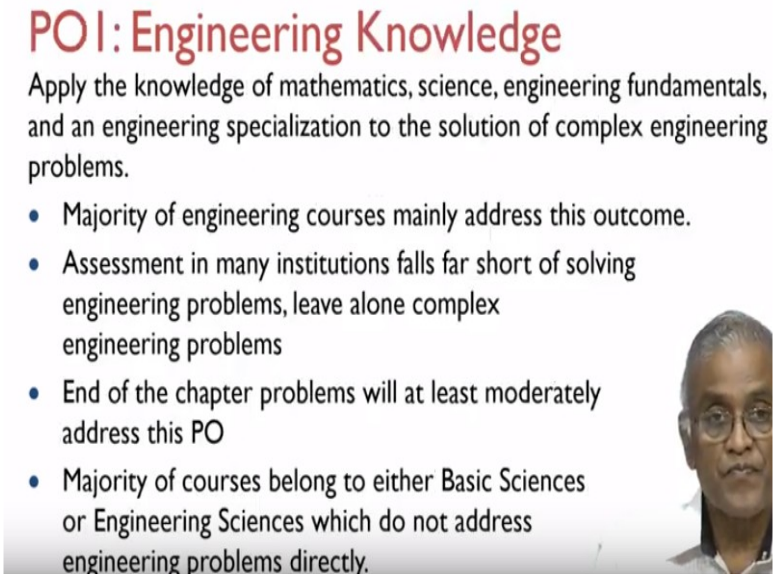

Now let us come to the PO1. That is the Problem Outcome 1. It is labelled as engineering knowledge. The statement says apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems. If you look at, let us spend a little time with all the keywords in that. The major goal is, actually the sentence could have been reversed.

I can say solve complex engineering problems applying the knowledge of mathematics, science, engineering fundamentals and an engineering specialization. That is what it, so solving complex engineering problem is the core of this. But you want to solve these engineering problems not in any what do you call intuitive way or ad hoc manner or by trial and error but applying the knowledge of the mathematics, science, and engineering fundamentals in a systematic manner.

That is what constitutes one of the program outcomes. In some sense majority of the engineering courses, mainly address this outcome. If you take any engineering course, one must differentiate also differences between engineering science and engineering courses. Like for example a course on thermodynamics I would consider it constitutes a engineering science course. But whereas any heat transfer, design of any heat transfer equipment under thermal engineering will constitute an engineering course.

But majority of the engineering courses may address this outcome but unfortunately assessment in many institutions fall far short of solving engineering problems leave alone complex engineering problems. Some institutions and some colleges in some subjects they do pose engineering problems in the if you look at the examination papers, they do so but not adequate, okay? The percentage of questions that are asked will be much smaller.

The end of the chapter problems will at least moderately address this PO. End of the chapter problems are dominantly well-defined problems. They may be difficult. Difficulty and complexity should not be interchangeably used. Every problem may not be easy but it does not become a complex problem automatically. So what happens as many courses will give problems in tests and examinations which are very similar to end of chapter problems.

So to that extent majority of these courses do address this PO to a certain extend. Majority of courses belong to either Basic Sciences or Engineering Sciences which do not address engineering problems directly. They will only prerequisites but not directly engineering problems.

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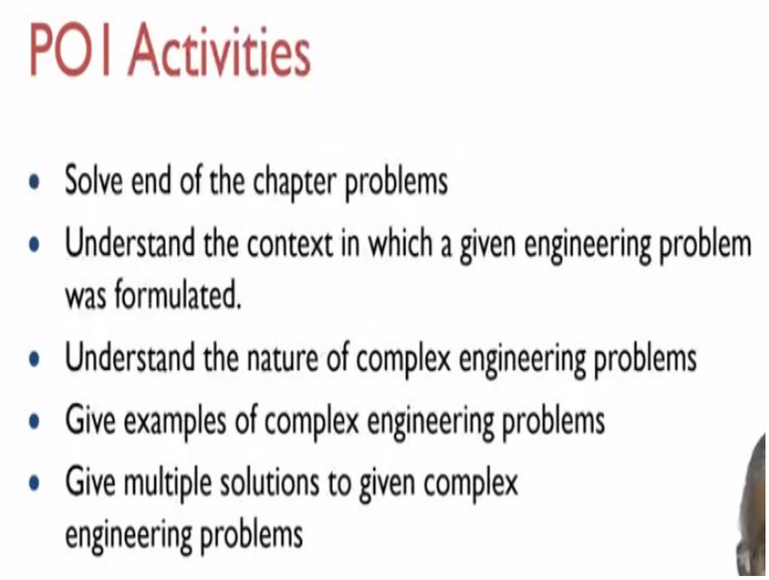

And some examples of activities. Now we are trying to give some examples where through these activities if you build it into your course, you will be addressing this particular PO. Like which are the activities? Solve end of the chapter problems. That is the minimum that you should be doing. Understand the context in which a given engineering problem was formulated. How can you do that?

By providing a case study, a description of a case study and running through that and through that you have to understand the context. The goal is to understand the context. Understand the nature of complex engineering problems. This also can be given through case studies and you can ask the students to give examples of complex engineering problems. You can broadly ask them to identify a problem in nearby area and ask them to formulate.

If not formulation, at least describe the various features of that particular engineering problem. And give multiple solutions to a given complex problem. That also can be only done as through case studies.

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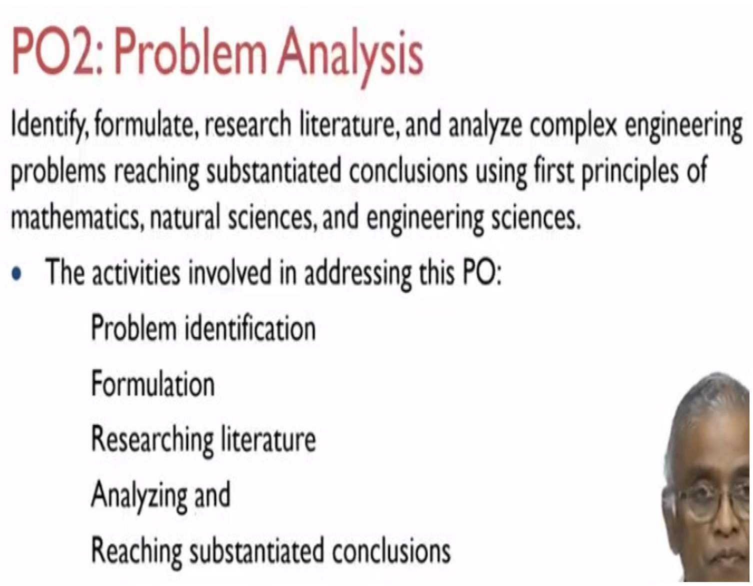

Now coming to PO2 which is lot more complex and difficult compared to PO1. Here the statement says identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. One emphasis is you should not be producing solutions intuitively and obviously or what you call ad hoc. You have to work out from the first principles.

That is what it means. Now if you look at the activities involved in addressing this PO if you take the keywords, first is identify, problem identification. That means if you are giving an experience to your students and facilitating them to identify problems, then only you are meeting this PO. Or having identified or at least if somebody has identified a problem, can you formulate the problem in a more technical sense?

So translating a verbal description of an identified problem into formulating in an engineering way will take a tremendous amount of effort and it will involve any number of assumptions and those assumptions are justifiable only in certain context but not in all context. So when you are formulating, you have to be clear about what the assumptions that you are making. And then having formulated, there would be lot of literature available.

And these days it is available on the net. You have to research the literature and identify the relevant literature and study that. And then you have to analyze the problem. That means you have to go to the next stage of further what do you call converting a ill-defined problem to a well-defined problem through a detailed analysis. And then you have to come to, you have to reach substantiated conclusions.

That means at this stage you are really finalizing in terms of the assumptions that you are making, the way you are formulating the problem, you reach a particular conclusion. But in all these through the analysis or researching the literature, formulation, you have to be always using first principles of mathematics, natural sciences, and engineering sciences.

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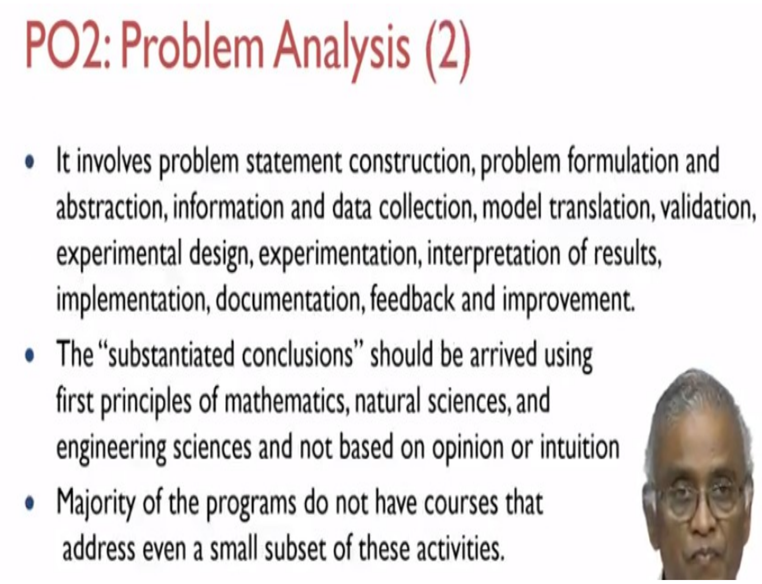

So once again to repeat, it involves problem statement construction, problem formulation, and abstraction, information and data collection, model translation, validation, experimental design, experimentation, interpretation of results, implementation, documentation, feedback, and improvement. It does not mean that with every problem you train the student to do all these, but in the program through various courses a student, an engineering student should experience all these activities at some stage or the other.

So you have 4 years and possibly 30-35 courses and you have maybe one or more projects. Through all that, all these aspects should be experienced. Student should experience and the program should be able to evaluate the student performance with regard to this criteria. The substantiated conclusion should be arrived using first principles of mathematics and engineering sciences and not based on the opinion or intuition which you have just stated there.

Majority of the programs do not have courses that address even a small subset of these activities. So what happens the way currently engineering programs are implemented or conducted more by rather none of the programs really address any of these consideration. So at all places the curricula and its implementation should be revised further, revised to make sure that the PO2 is addressed.

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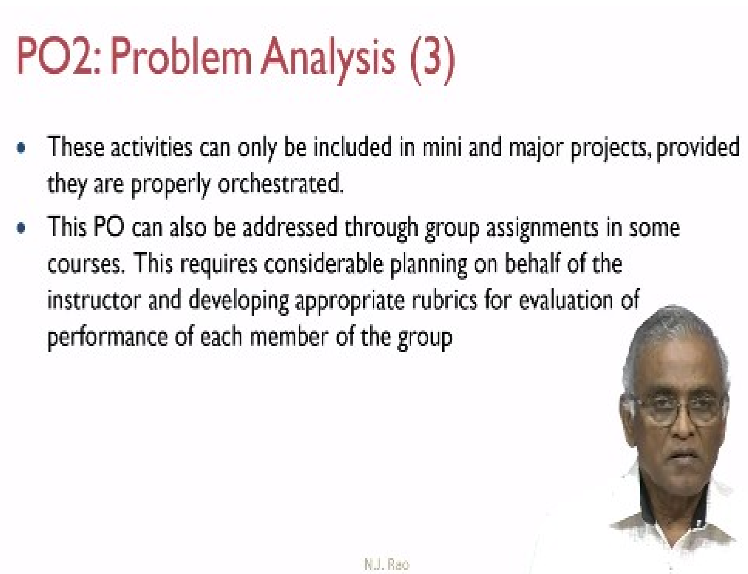

And many of these activities can only be included in mini and major projects provided they are properly orchestrated. Just saying mini project and major project does not work out. They have to properly orchestrate it and kind of the students have to be taken through all these modes and evaluated. And this PO can also be addressed through group assignments in some courses.

But this requires considerable planning on behalf of the instructor and developing appropriate rubrics for evaluation of the performance of each member of the group. A group assignment done over a period of let us say stretched over a period of 2 months. 2 months in the sense not full time activity but they do over a period of 2 months but as a group interacting. It is possible to design such assignments.

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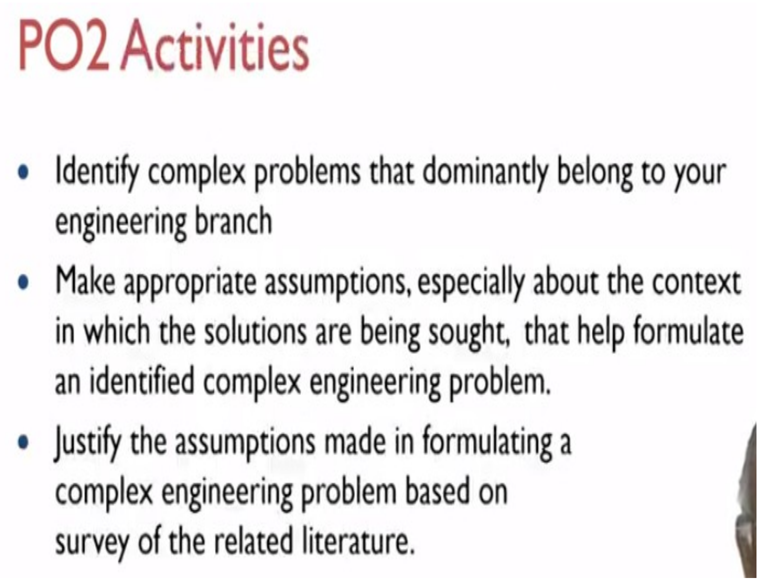

Here some activities of PO2. Identify complex problems that dominantly belong to your engineering branch. Make appropriate assumptions, especially about the context in which the solutions are being sought that help formulate an identified complex engineering problem. This is one thing that all engineering students should learn. When you are coming from a ill-defined problem to well-defined problem you have to make a large number of assumptions.

And these assumptions should be justifiable. And unless you articulate and write it down you cannot take anything for granted. So this is a very interesting and important activity and at least in 2 or 3 courses the faculty should incorporate this activity. Justify the assumptions made in formulating complex engineering problem based on survey of related literature. But this requires a lot of work and preparing a very very detail, several case studies of that where the focus is on identifying assumptions and justifying them.

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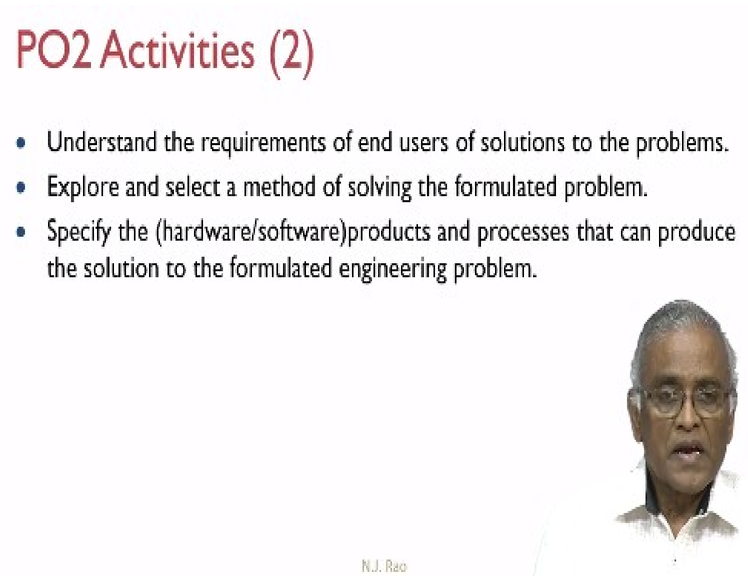

Further activities. Understand the requirements of end users of solutions to the problems. You can give, let us say you want to design a what you call traffic control unit in a certain area where you have to take the, take into consideration the number of vehicles, the types of vehicles, the way people move from one place to the other and the entire thing one can just study the problem and even write it down what are the requirements of. Such assignments can be given to the students.

Explore and select a method of solving a formulated problem. Once a problem is formulated, various solutions can be explored. Out of that you can select one method and (with its) giving full justification. That also is an interesting exercise. Specify the hardware, software, products and processes that can produce the solution to the formulated engineering problem. The process of specification itself, most of the engineering programs do not give that experience.

That itself is a very important activity and no engineering activity is ever done without starting with specifications and justifying them. So these are some possible activities but these activities are not merely textbook type nor just come into the purview of a what do you call our present method of examination.

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Coming to PO3, the title is design and development of solutions. The statement says design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety and the cultural societal and environmental consideration. This is a very tall order. Now trying to just kind of understand this particular PO, designing solutions for engineering problems can only be experienced through projects and assignments.

You cannot do that other than very small activity through tests and examinations. And because designing solution for an engineering problem is a time-consuming activity. For example if you take any examination paper even in the end semester examination, you normally, it is designed in such a way no question should take more than half an hour. That means an average student should be able to find the solution to a problem within half an hour.

You cannot design engineering problems to pay attention to all these criteria that fits into a half an hour type of activity. So the designing solutions like this cannot be fitted into, cannot be included in limited time written examinations. Whereas components of a system can be designed through smaller assignments in some identified courses. So you can say a mechanical component should be designed or a circuit that can be designed to perform some function, that part can be done. Components can be designed, at least within the limited time.

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The design criteria and specifications of components and processes need to be evolved from the solutions to a given problem. So here the one activity is design criteria and specifications. We will talk about this more when we come to the taxonomy. Criteria and specifications should play a dominant role in engineering education but unfortunately they do not even receive scant attention to this.

These criteria and specification should be developed taking issues related to the public health and safety and the cultural, societal and environmental consideration. Issues related to public health, safety and environmental consideration, how do you do that? You are not going to go and study public health, safety because it will become a tall order. But normally they do get addressed through what you call relevant standards.

These standards may come from the professional societies. Whereas a few engineering courses do consider relevant standards. But following standards is not a common practice in majority of the engineering programs. That is working with standards. That means you design a component or a subsystem to meet certain standards. So it will get reflected in the actual component design, the materials used, or the way it has to be assembled and so on.

There are a whole bunch of issues that will be involved if you are following a certain standard. Cultural and societal considerations will require inputs from non-engineering fields and incorporated into the non-functional specifications. There are for any product or system there are functional specifications and there are non-functional specifications. Non-functional means it should not occupy more space than you do, than given area or given volume.

Its weight should not be more than that and possibly it should not use some colors. The whole bunch of non-functional specifications and they will all come from let us say the many times they come from cultural and societal considerations.

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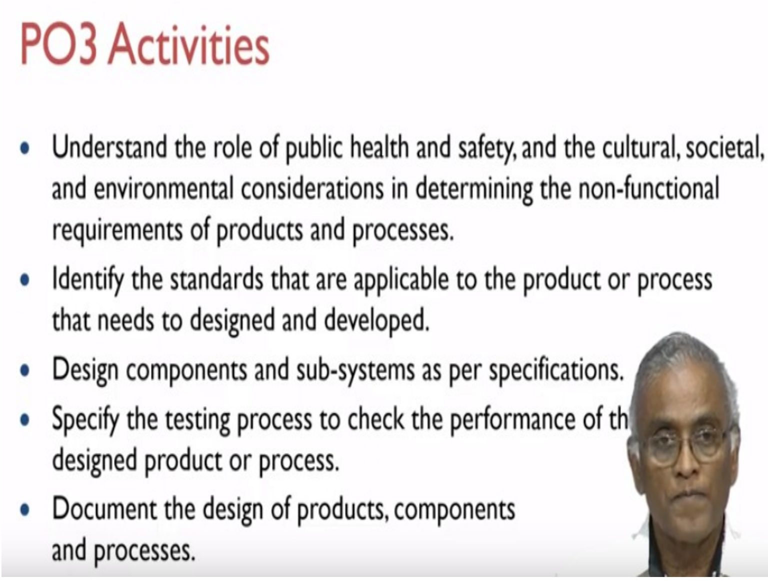

Which are the PO3 activities? Understand the role of public health and safety and the cultural, societal, and environmental considerations in determining the non-functional requirements of products and processes. Identify the standards that are applicable to the product or process that needs to be designed and developed. Design components and sub-systems as per specifications. So you start with specifications and design.

Specify the testing process to check the performance of the designed product and process. That is whether it meets a particular standard. Can I design a lab experiment where the testing is done to whether the product meets the some certain standard. Document the design of products, components, and processes. Documentation itself is a/can be a major learning tool.

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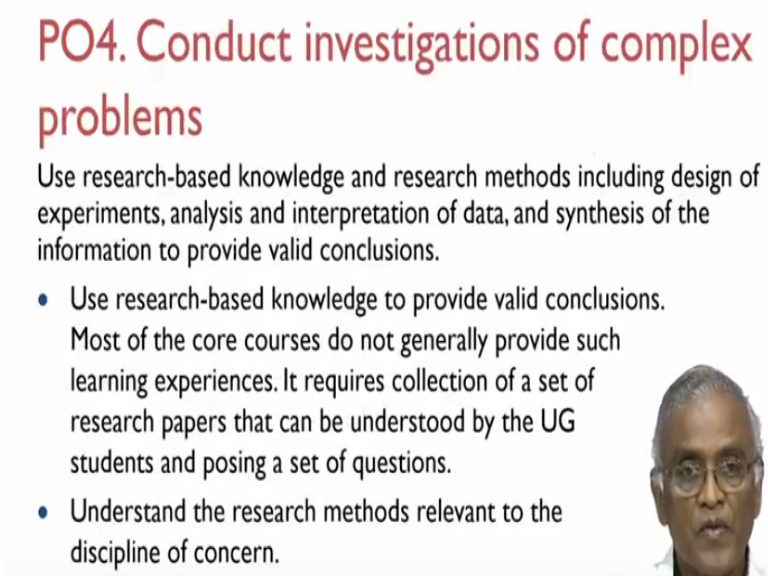

Now fourth one, conduct investigations of complex problems. Again, use research based knowledge and research methods including design of experiments, analysis, and interpretation of data and synthesis of the information to provide valid conclusions. What does it include? Use of research based knowledge to provide valid conclusions. That is one part of the statement. Most of the core courses do not generally provide such learning experiences.

It requires collection of a set of research papers that can be understood by the UG students and then posing a set of questions on that to the students. That requires lot of preparation. Understand the research methods relevant to the discipline of concern. So each branch has its own research methods. Whether they could be included. This is doable and it can be incorporated into some of the courses.

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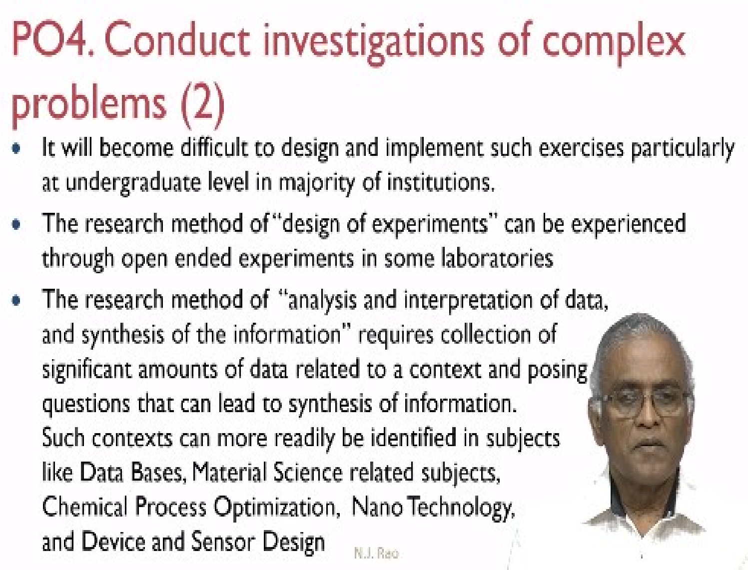

And now further it will become difficult to design and implement such exercises particularly at undergraduate level in majority of the institutions. For example research method of design of experiments can be experienced through let us say open ended experiments in some laboratories. The research method of analysis and interpretation of data and synthesis of information that requires a collection of significant amount of data related to a context and posing questions that can lead to synthesis of information.

Once again as you can see many of these things can be addressed if there are what do you call collect lots of case studies supported by related information which generally is not found in the textbooks. Such context can more readily be identified in subjects like databases, material science related subjects, chemical process optimization, nano technology and devices and sensor design. These are some examples, but any innovative teacher can find activities that would meet these outcomes.

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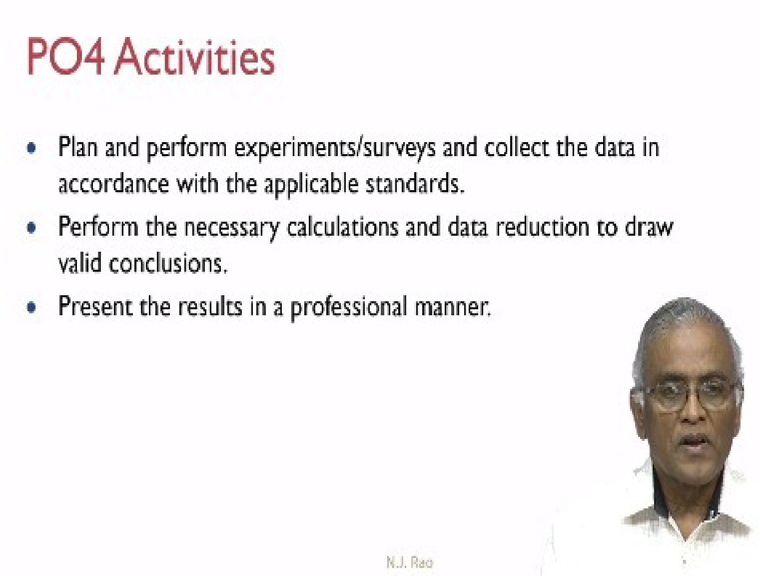

Further activities under PO4, plan and perform experiments, surveys and collect the data in accordance with the applicable standards. Perform the necessary calculations and data reduction to draw valid conclusions. Present the results in a professional manner. So these are some proposed activities. By no means this is exhaustive. So the faculty should explore such activities to address this particular PO.

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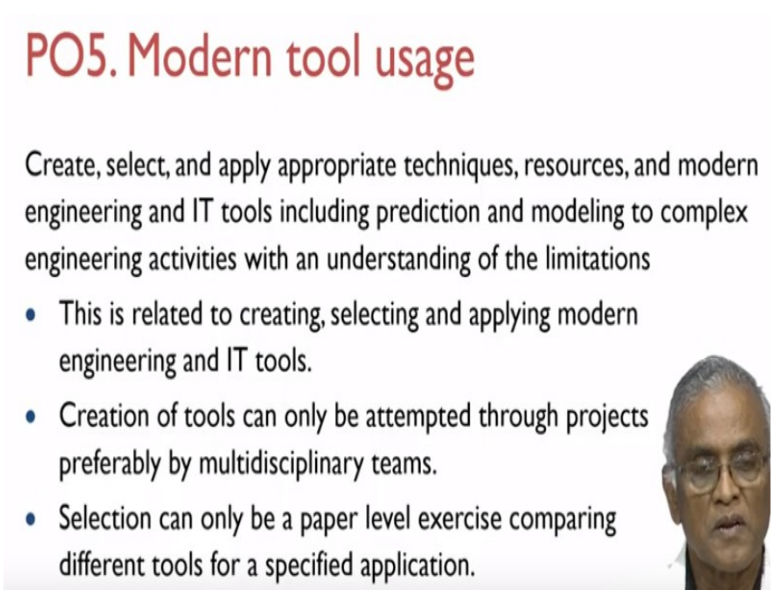

Finally, the PO4 the modern tool usage what does it say? Create, select and apply appropriate techniques, resources and model engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations. This is related to creating. Once again, keywords are creation, selection, and applying. All the three are involved of modern engineering and IT tools.

That means they can be modern engineering tools like equipment or IT tools. Some of the IT tools these days many engineering programs are familiar with. So creation of tools can only be attempted through projects preferably by multidisciplinary teams. Selection can only be paper level exercise comparing the different tools for a specified application because one may not have access to all the tools for comparison.

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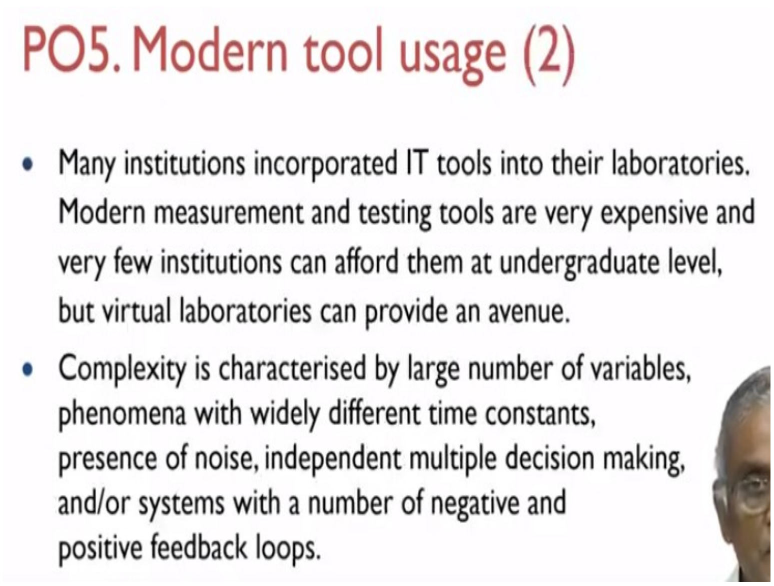

And many institutions have already incorporated IT tools into their laboratories but modern measurement and testing tools are very expensive and very few institutions can afford them at undergraduate level but one can this is where one can use the virtual laboratories, can provide an avenue for this.

Now coming to what is a complex, complexity is characterized by large number of variables, phenomena with widely different time constraints, presence of noise, independent multiple decision making, and or systems with a number of negative and positive feedback loops. We just state the nature of a complex problem only in terms of this and we will come back to that at a later date.

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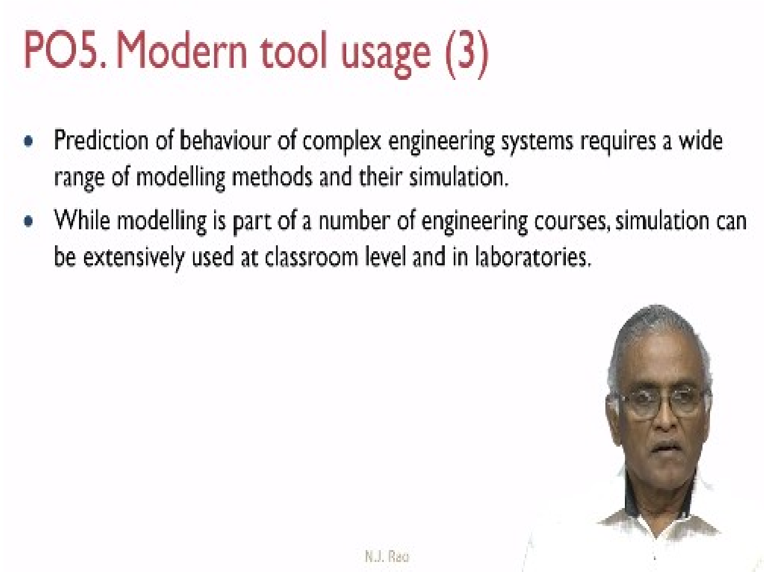

And prediction of behavior of complex engineering problems generally cannot be done even in the simpler cases without using extensive simulation. So simulation now becomes a very important tool to address this particular PO. While modeling is a part of number of engineering courses, simulation can be extensively used at classroom level and in laboratories.

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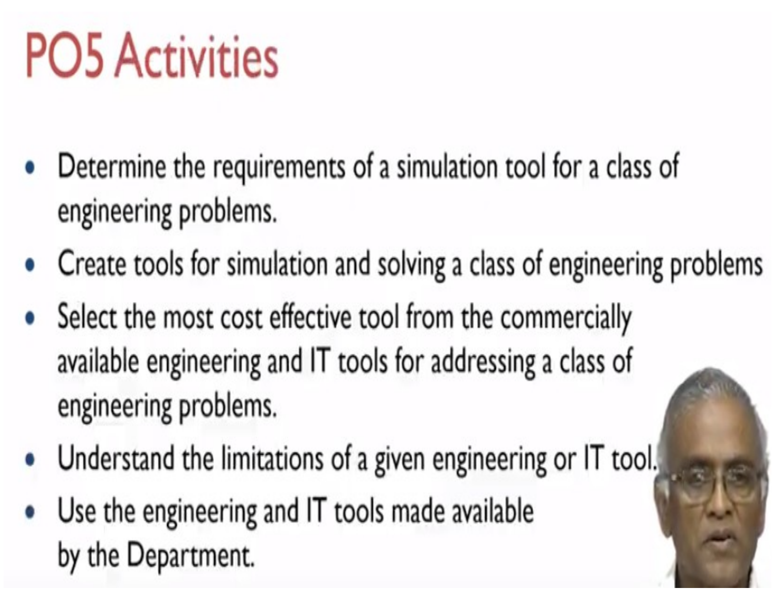

So these are some of the activities. Determine the requirements of a simulation tool for a class of engineering problems. Create tools for simulation. Solving a class of engineering problems preferably through a project. Select the most cost effective tool. Understand the limitations of a given engineering or IT tool. Use the engineering and IT tools made available by the department. So these are some PO activities.

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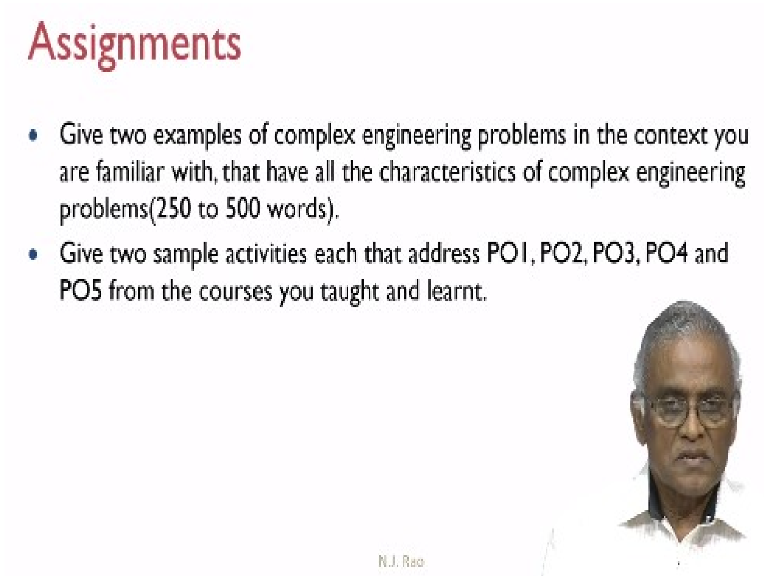

Now that is nearly the end of this unit. The assignments include, give two examples of complex engineering problems in the context you are familiar with, that have all the characteristics of complex engineering problems. Initially you write 250 to 500 words and maybe later they can be further expanded. Give two example activities in your view that address PO1, PO2, PO3, and PO4, and PO5 from the courses that you taught and learnt.

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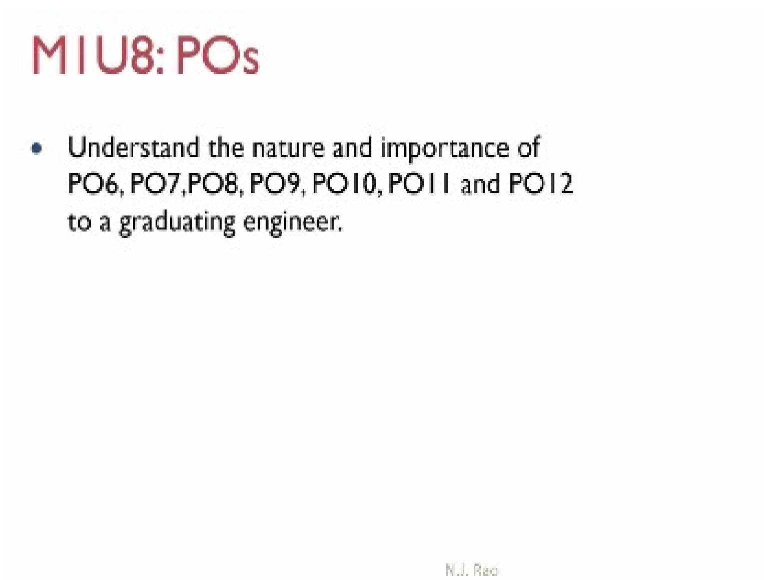

The next unit will address the remaining POs namely from PO6 to PO 12 that are relevant to a graduating engineer. Thank you very much.