NBA Accreditation and
Teaching – Learning in Engineering (NATE)
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Lecture 46
Simulation Approach to Instruction

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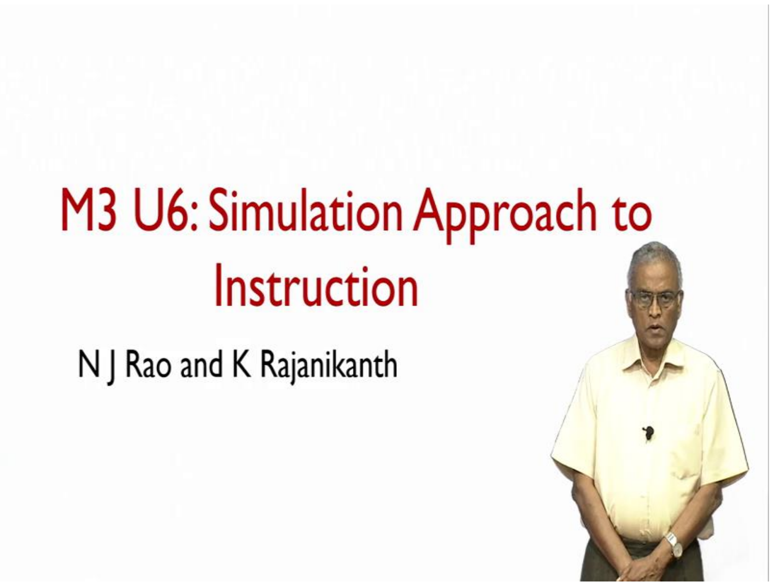

Greetings and welcome to NATE module 3 unit 6 on Simulation Approach to Instruction.

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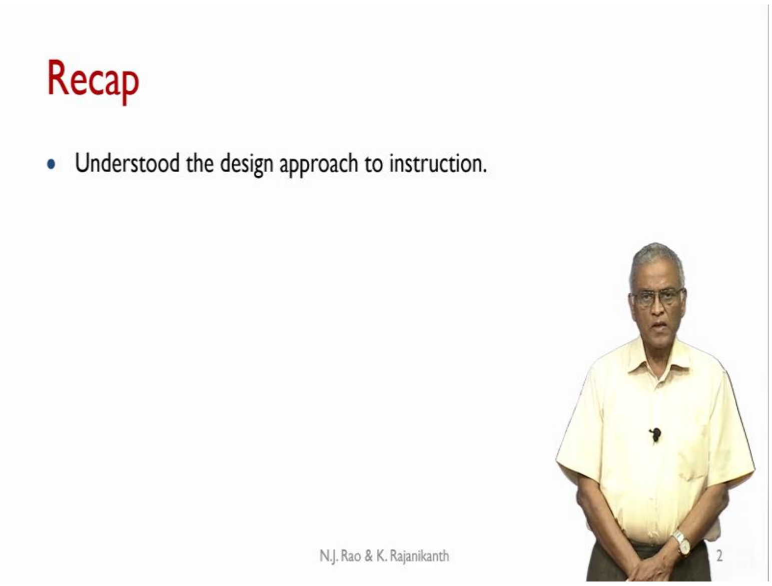

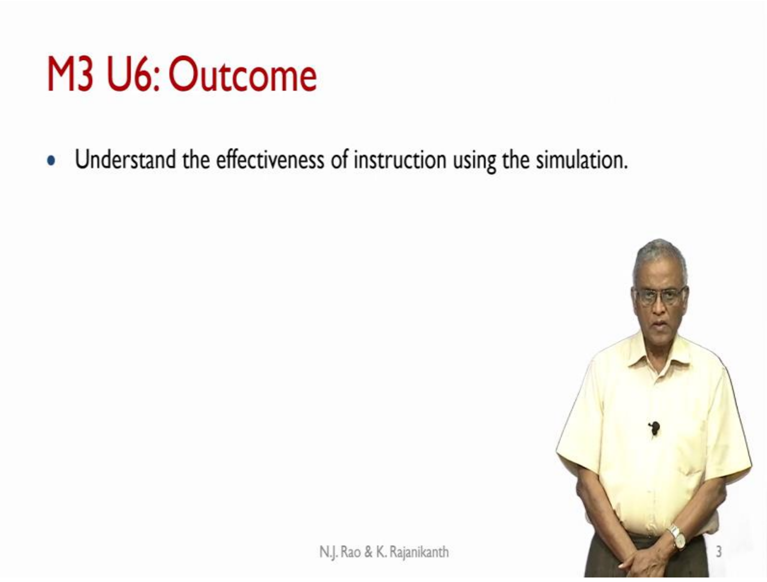

In the earlier unit, we looked at instruction for design thinking or what we call we try to understand design approach to instruction and in the current unit we will try to look at effectiveness of instruction using the simulation. And today the simulation has become a very powerful tool to look at complex systems and sometimes even simple but nonlinear systems. Simulation is a tool that is now dominantly integrated into both classroom instruction for projects and research.

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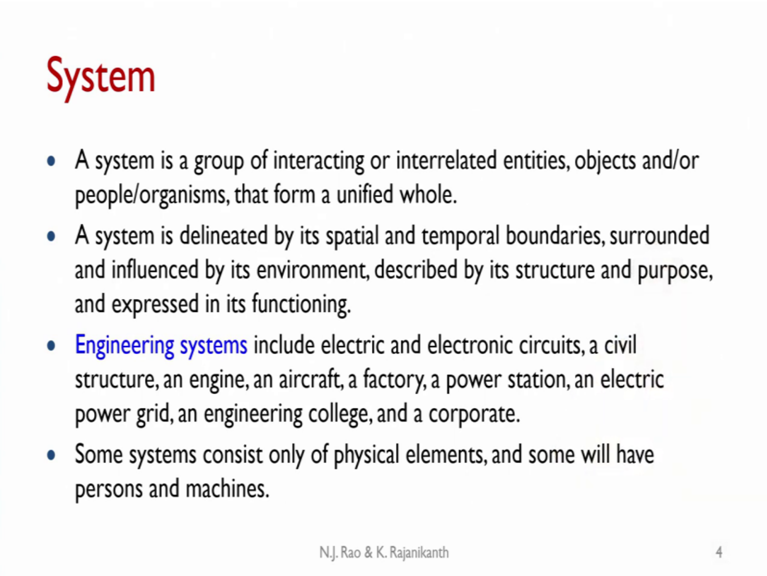

And we have to start with defining what a system is, a system is a group of interacting or interrelated entities, objects and or people organ or organisms that form a unified whole. What we mean by that is several entities are interconnected with each other. They are interconnected for a specific purpose and they together fulfill something, an element of a system can also be element of simultaneously can be element of some other system that should be remembered.

Because the purpose is different, the elements that come into the other system are different and the system is also is identified by the spatial and temporal boundaries, something is valid only from 1 point 1 point of time into the another and also there are certain boundaries once you cross the boundaries, the behavior of this the behavior predicted by your simulation is not necessarily true.

And engineering systems that we are concerned with can start with a simple electrical or electronic circuits a civil structure, an engine, an aircraft, a factory, a power station, an electric power grid or something like an engineering college and a corporate, they all are kind of engineering systems.

And when you look at some of these systems, some systems have only physical elements like circuits or a civil structure, there are only physical elements in that, but some of the things like a factory or if you want to look at even power station in engineering college a corporate will also have persons and machines together, that persons and machines are interacting with each other.

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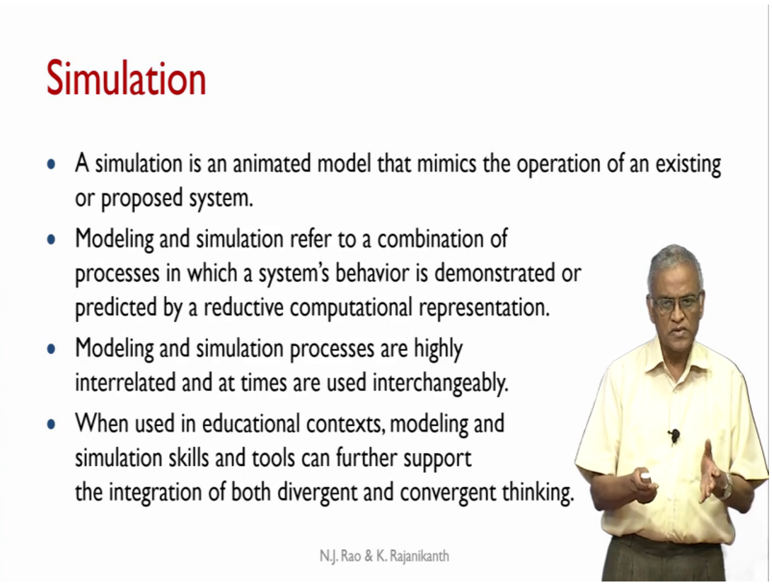

Now, what is simulation? Simulation, is an animated model that mimics the operation of an existing or proposed system. And essentially simulation, what it is doing is you are modeling a particular system or elements of a particular system and your simulate, the elements are interconnected. And you are now actually solving those equations. Because one may not be one may not have closed form solutions for many of them. So, you try to solve on a computer, the equations that you use for modeling.

And in this process, the modeling and simulation are two processes. They are highly interrelated. By just modeling and leaving it there, it does not serve purpose, but neither you can simulate anything without modeling. So, you essentially simulation consists of solving a large number of or at least multiple number of equations on a computer.

Let us say even in educational contexts, modeling and simulation skills and tools can further support the integration of both divergent and convergent thinking when you are divergent thinking means you are exploring some options and if you want to explore those options in a virtual world simulation is the only possible tool. So, you can look at, if I give some input to either a circuit or a civil structure or anything like that, then I am trying to find out what is going to happen because we cannot simply have closed form solution to any of those equations.

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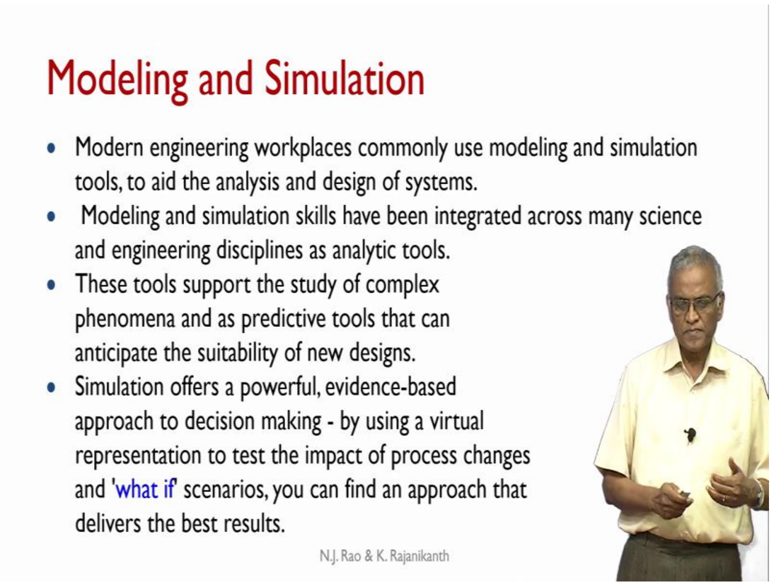

So, simulation today in today's world both modeling and simulation are going to be used to aid analysis and design of systems. And these skills, that is modeling and simulation skills have been integrated across many science and engineering disciplines, and what you have these tools support the study of complex phenomena and as predictive tools that can anticipate the suitability of new designs.

There is, and also what happens is you are essentially exploring the options like if I do something, if I change a parameter like this, if I give this input, if I change the boundaries, if I if I if if I, if I want to expand the time scale in which it is functioning, any of these things you want simulation is possibly today is the only tool that you will even have.

So, it is a powerful evidence based approach to decision making. And obviously, when you are using for decision making, you have to be doubly sure that your modeling is appropriate. If you make any error if you make any assumptions in the modeling and you try to go beyond the those assumptions, then the results that come from the simulation will prove to be wrong. And there have been any number of instances around the world where people have simulated or modeled something beyond the original constraints there was issued.

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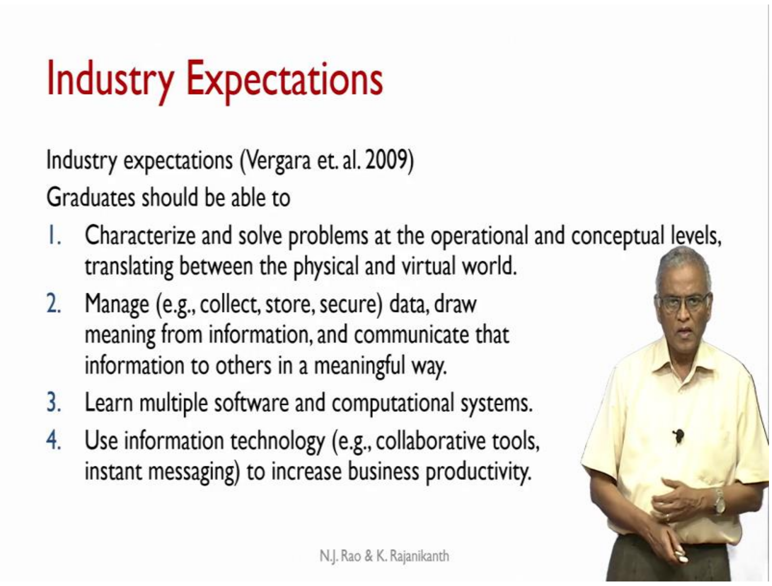

And here, let us look at where the where it comes into the education. Industry expectations as per survey done by Vergara in 2009, the graduates should be able to characterize and solve problems at the operational and conceptual level, translating between physical and virtual world.

Virtual world is modeling, and when I am modeling something, and I predict the behavior, how to constantly check back that my modeling has been appropriate, and it matches with the physical world. So, this business of constantly shifting from physical world to virtual world is a skill that every graduate should acquire, should make it a kind of habit.

And they also found, the industry wants this, the graduates to manage management's collect, store and secure data, draw meaning from information and communicate that information to others in a meaningful way. That is you should be able to process the data communicate to the concerned people, learn multiple software and computational systems. Your skills and knowledge cannot be confined, confined to one, one or two narrow scope, tools. And use information technology like collaborative tools or instant messaging to increase the business productivity. So, these were the requirements expressed by industry.

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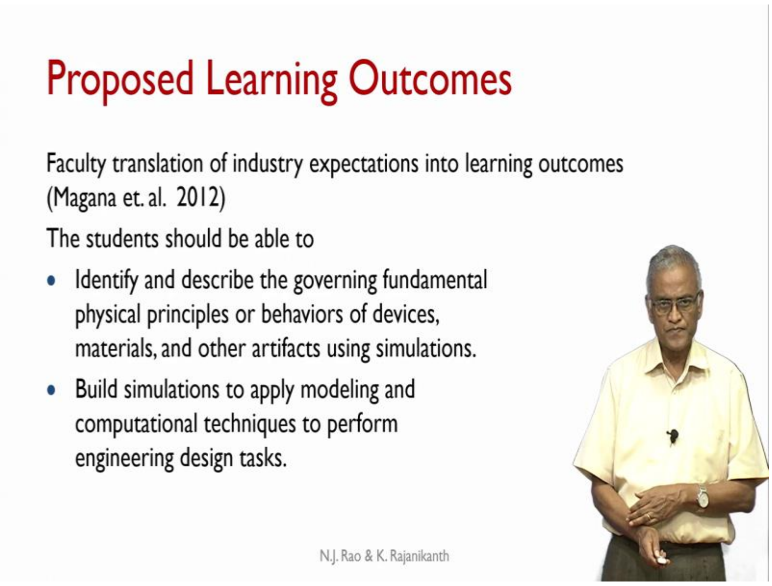

And how do the faculty look at it? Faculty from these sentences faculty have translated the industry expectations into learning outcomes, saying that the student should be able to identify and describe the governing fundamental physical principles or behavior of devices. Identify and describe the fundamental physical principles of behavior and devices, materials and other artifacts using simulations.

Like for example, if you have a transistor, which is a semiconductor device, if I want to predict its behavior, if I want to get into what do you call very detailed behavior under different temperature conditions, different voltages, different currents and so on, then my model will have to be fairly detailed, that means, I must be able to capture all the underlying physical phenomena.

And when you end up writing those equations, the equations may not permit themselves to produce a closed form solution and what am I doing those equations simultaneously if I, if I solve using a computer, it will produce an output that from which I can make some sense.

Now, what happens if I am putting a large number of transistors together like in today's world, the number of transistors on a single chip can run into almost a billion transistors on a single chip. Now, obviously every transistor is no two transistors are 100 percent exactly equal.

So, to that extent, I have to incorporate the behavior of each and every individual transistor and I need to create as you can see, the number of equations will be phenomenally large. And then I should the only tool that I have will be simulation. Obviously simulating such a chip or behavior will take a lot of time. And when you simulate, you may not be interested in the very very extreme details.

That is from p for second level behavior and I may not be interested in kind of instantaneous values all the time or a period of time. So, you are single your requirements of study may vary from one situation to the other and the equations will have to be correspondingly choose and then the faculty understand the student should be able to build solutions simulations to apply modeling and computational techniques to perform engineering design tasks.

Not only study the behavior of elements, but you want to perform engineering design tasks, that is I should choose certain parameters, I should select some parameters or add elements to get the required behavior and I need to make decisions about that. So, this is our faculty understand, and though it is not exactly the same what the industry is asking for but faculty in a formal program try to use simulation for these two aspects.

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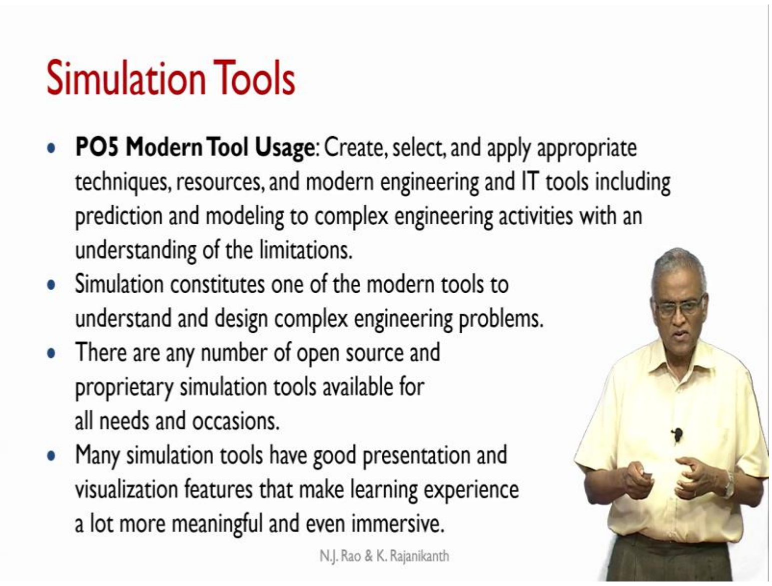

And in on the top of that, from our program outcomes as per NBA, PO5 is related to modern tool usage, what does it say create select and apply appropriate techniques resources and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations, see all the words that are there except that it did not say simulation tools it said IT tools.

IT tools can be either for what do you call, data processing, or simulation or communication it can be used for all. Here, what it is saying create, select and apply. So, these are 3 different activities. But at least the student in a in an engineering college may not be able to create is a part of a course or he may do small he may create a small tool with limited scope as a part as a project.

Because creating an operational simulation tool is a very, very large and complex process which cannot be fitted into a into a classroom activity. But mostly the students are going to apply or occasionally select from a limited set of tools that are available. So, to that extent, the PO5 does identify the modeling and simulation activities to either understand or design complex engineering systems.

So, simulation constitutes one of the modern tools to understand and design complex engineering problems. And there are any number of open source and proprietary simulation tools available for all needs and occasions. Most college students today are familiar with the two tools for circuit courses circuit branches as we call them, something based on PO5 is used are for other engineering systems to use something like MATLAB or Scilab and also these days, many simulation tools have good presentation and visualization features.

And what are these? These visualization feature is finally the output after the end of simulation, the output is presented in some graphical form, with proper possibly using colors and sometimes 3D features and so on. It makes the learning experience of that is a lot more meaningful and even immersive. That is, you are now through this graphic interface. You are really getting involved inside, you are getting immersed into the system.

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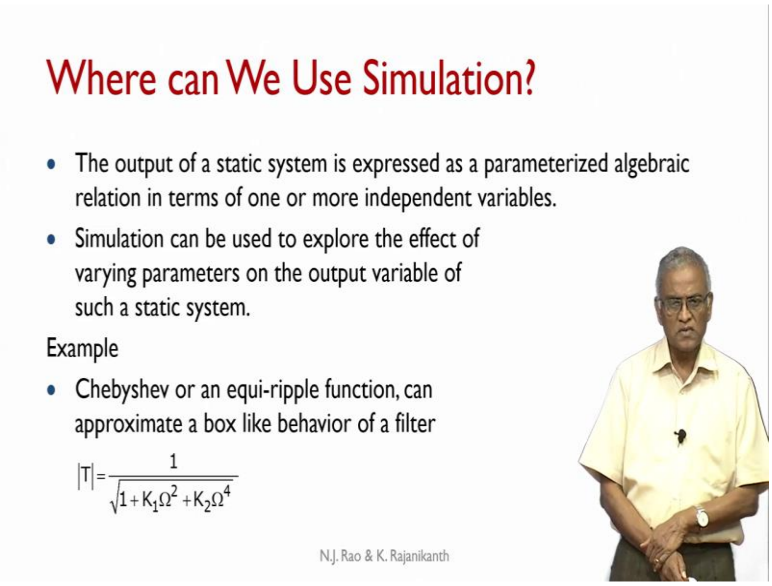

And where can we use the simulation? Let us say take now courses one is, there are two types of systems that we deal with one you can say static system, the other is a dynamic system. So, a static system is expressed as a parameterized algebraic relation in terms of one or more independent variables.

So, what happens simulation is used to explore the effect of varying parameters on the output variable of such a static system. Take the example here shape or an equi-ripple function can approximate a box like behavior of a filter and the equation is given like this magnitude of the transfer function T is given by 1 by root 1 plus K 1 omega square plus K 2 omega raised to 4. Now, we do not necessarily have a closed form solution for this or one can work it out at least at this stage.

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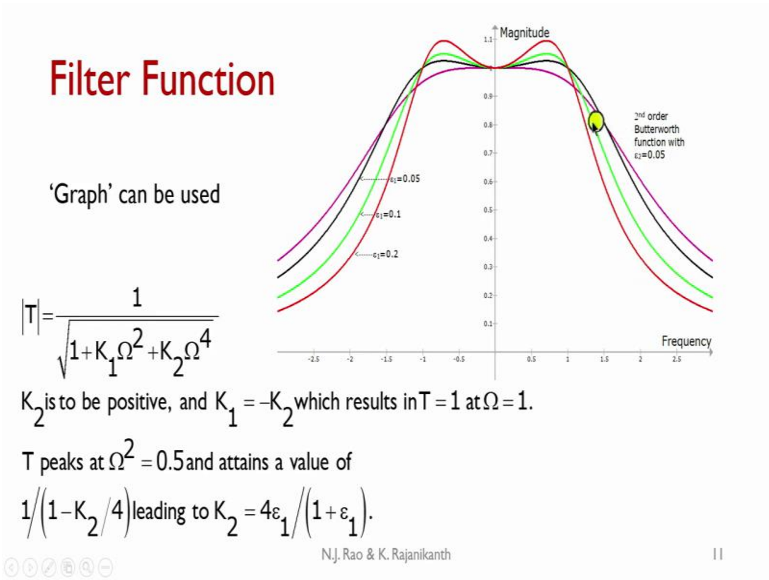

But if I want to keep on exploring the effect of these parameters, K1, K2 how exactly the magnitude of T changes, then simple tool called graph, which is open source tool and I can use this and it provides a lot of facilities, I can expand the y axis x axis I can put colors to different things, I can adjust the amplitudes and so on. And as a function of frequency the magnitude is plotted as a keep changing the K1 over several values. For example, here K1 equal to minus K2, so there is only one parameter as I keep changing the parameter.

So, here I can draw several curves. Now, I can see by changing the parameter, How does the let us say here this particular filter is likely to behave. If you look at this, the one that filter should have such a fast beyond the critical frequency or natural frequency of the filter, the rate at which the attenuation happen should be large that is a desirable characteristic.

If I you have that, but I have a little more ripple in the pass band in this top band it is desirable behavior whereas, for some other values of K you have better behavior in the past band, but less, what do you call less rate of attenuation in this top band. So, such properties can readily be studied by using a simple tool like graph. It is very easy to understand and very easy to use. And you get the behavior of a static system like this.

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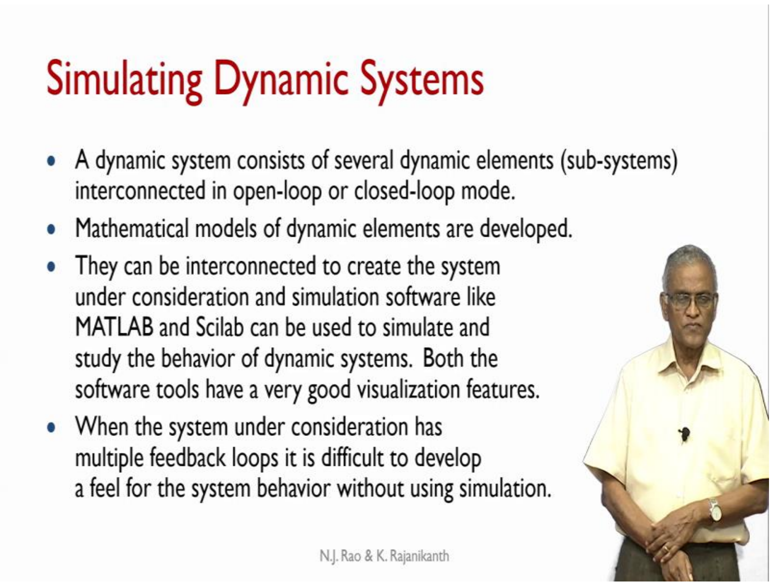

Then comes the simulating dynamic systems which engineering systems many of them are for example, many of the engineering elements, we are interested in their behavior as a function of time, wherever whenever variables change with time that means we have a dynamic system to be considered. So, a dynamic system consists of several dynamic elements or subsystems interconnected in open loop or closed loop mode and first thing is to develop mathematical models of the dynamic elements involved in the system.

And then they are interconnected to create a system under consideration and simulation software like MATLAB and Scilab can be used to simulate and study the behavior of the dynamic system. And these two software MATLAB is a proprietary one and Scilab is open source depends to which one you are used to. And both the software tools have very good visualization features. That is one major advantage. When the system and reconsideration has multiple feedback loops, it is difficult to develop a feel for the system behavior without using simulation.

Say for example, if you have a static system or even if you have one feedback system with one loop, it is by trial and error you can pick up a feel for that. What like if I, if I am changing some parameter what is likely to happen, I can have a feel for it. But when you have multiple feedback loops, especially if they cross each other, they happen when human beings are involved. And in such a case, it is very difficult to develop a feel for it and the only tool that you have is simulation.

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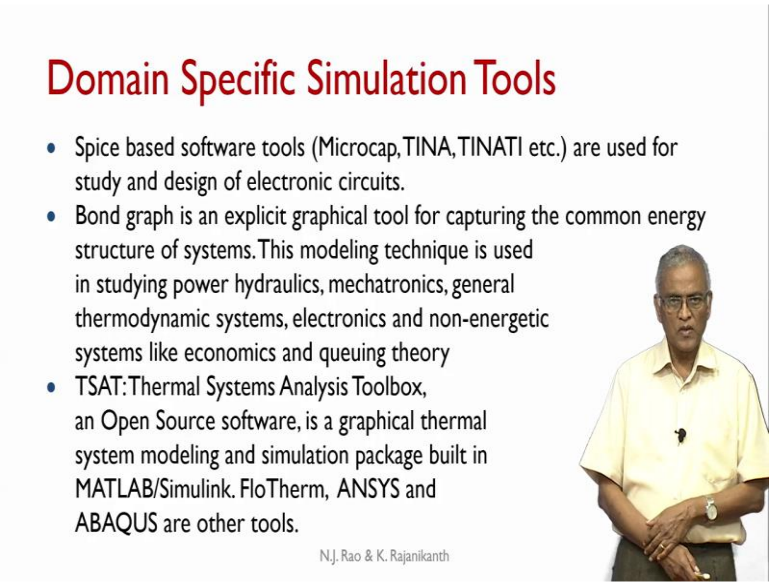

And once again we have plenty of tools, which are domain specific which are mastered and which are being used by the industry, which are domain specific. For example, spice based software tools like Microcap, TINA, TINATI are used for study and design of electronic circuits. That is you can piece the electronic components that you are going to use up amps resistors, capacitors, power supplies and so on.

You can just it is a drag and drop kind of thing and you can count these elements and then solve the related equations through simulation. Bond graph is another is an explicit graphic tool for capturing the common energy structures of systems. This modeling technique is used in studying power hydraulics mechatronics general thermodynamic systems electronic or non energetic systems like even economics and queuing theory.

So, when you have for example, let us say an engineering mechatronics system if you take you have fine mechanisms, you have electronic circuits, some of them will be analog, some of them will be digital and you have sensors when and what happens when you look at them the timescales in which these work can be quite different, like your electronic circuits respond in microseconds, sometimes nanoseconds.

Whereas mechanical elements will take a few milliseconds or more than more than possibly a second also. So, when you simulate behavior over such wildly time varying scales, you need to be careful about your modeling and the way you want to handle and predict systems for that kind of thing, bond graph seemed to be a very effective tool.

And similarly, TSAT Thermal Systems Analysis Toolbox in open source software is a graphical thermal system modeling and simulation package, again built in built into MATLAB and Simulink. And you have other things like Flo Therm, ANSYS and ABAQUS are other tools for thermal simulation tools. So, you have plenty of domain specific simulation tools that are being used in many of the engineering colleges and institutions.

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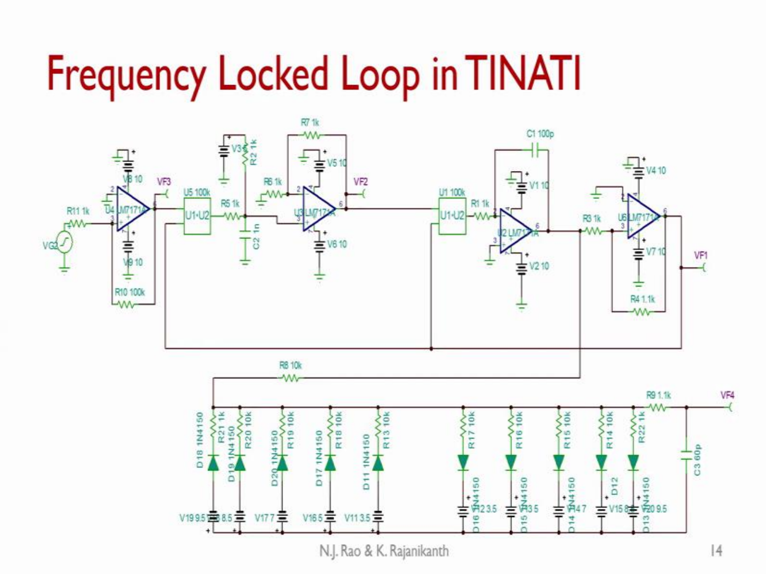

Like another example, using TINATI and if you want to study the behavior of this kind of sub acute, this is a frequency Locked Loop with multiple feedback loops, there is one feedback loop here. And there is another feedback loop like this. And on top of that there are highly nonlinear circuits here using diodes and resistors plenty of them and they all they are also part of this.

That means they are getting converted a square wave is getting converted into a sine wave using this and this is the EFL, if you want to study this. Let us say I want to change the sample, one capacitor value here and what happens to the system and there is no easy way by writing the equations and solving them to find out whereas if you use a tool like TINATI, which is right now open source, you can within a few seconds you can get the behavior, what is the behavior?

Behavior I need to see here at this point and I need to see the behavior here and I need to see the behavior here, I can simultaneously look at all of them and the visualization tool will present me all the waveforms over a period of time in one in one frame kind of thing.

So, this is a TINATI is a very effective tool, but the only thing is TINATI as we are calling it TI the ICs that are used, these up amps that are used, they are mostly selected from or they are selected from the from the components that are manufactured by TI. If you want to use some other companies ICs and components then possibility TI not the not the appropriate one to go for another, another such open source tool available in the market.

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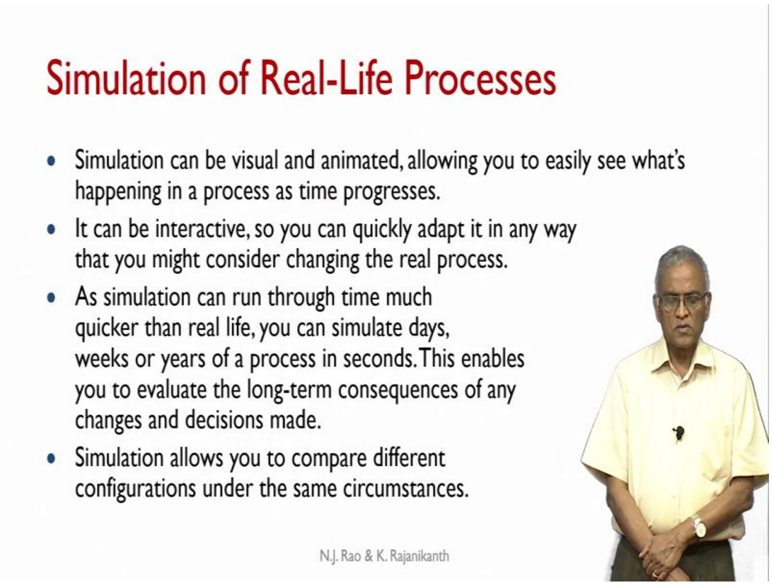

Simulation of Real-Life Processes, you can observe let us say you have a very slow process that takes minutes and sometimes hours. But we do not want to wait for hours to see what happens. So, present day computers will allow you to kind of compress the time because you have enough amount of power of computation available to you. You can see what is happening in the process as time progresses.

It also it can be interactive, so you can quickly adapt in any way that you might consider changing the real process. That means if you want you can slow down a process or you can speed up a process. For example if, as I said, if something is happening very slow, you can speed it up but sometimes very fast processes cannot be simulated in real time in spite of having a fairly powerful computer and powerful tool.

Let us say you are trying to design an IC integrated circuit using large number of transistors are our active devices and passive devices in that sometimes the simulation of a circuit may take several hours, even when you have a very powerful computer. And another advantage of this is you can keep on changing the configuration of the system also, if I slightly modify the structure, what happens under the same circumstance, and I do not think there is any other or any other alternative to study such behaviors other than simulation.

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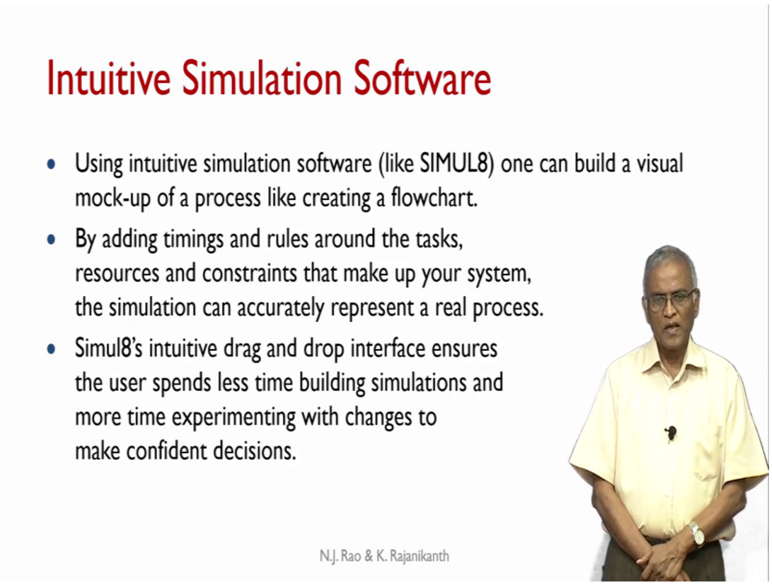

There is also what is called Intuitive Simulation Software tool called SIMUL8 where what happens people instead of starting from very detailed modeling and equations, it gives you a visual markup of a process like creating a flowchart. So, you have a list of things and which are available as a library.

From that you would drag and drop and quickly build a system as per what you think is the system based on maybe what he calls this is how I visualize my system I can quickly put it and add some timings and rules around the tasks. I can come to simulate a system very fast. So, sim, simulates intuitive drag and drop interface. ensures the user spends less time building simulations and more time experimenting with changes to make confident decisions.

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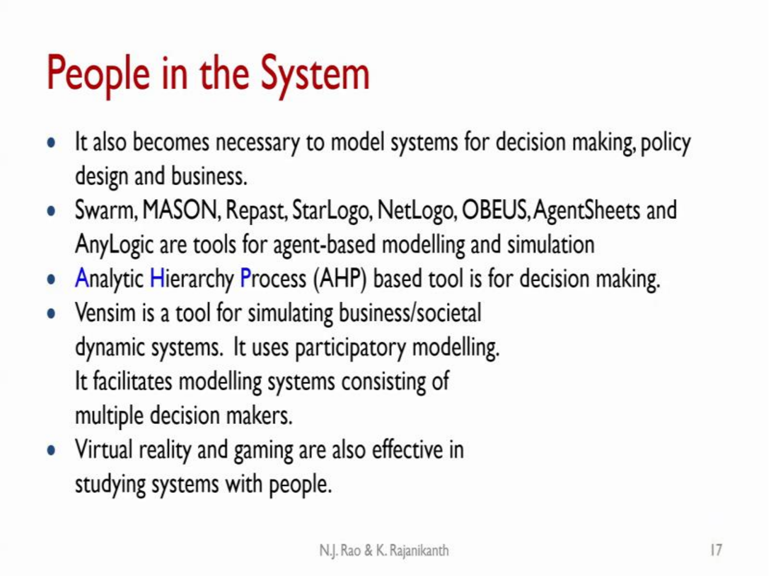

And when you have people in systems, this story is different. Now you have to model the decision making of human beings like policymakers or even any humans who are participating in that. So, here one approach is what is called agent based modeling. Like the software tools or Swarm, MASON, Repast, StarLogo, NetLogo, OBEUS, Agent system and AnyLogic are some of the tools which are agent based modeling and simulation.

And there is AHP based tools are their name expert software, expert systems which facilitates modeling the decision making when multiple decision makers are there, and each one has separately their own criteria of coming to a conclusion, but the system in which they are operating they are all interconnected for such a thing.

He analytic hierarchy process based expert system is a very convenient to. Yet another one called Vensim is a tool for simulating business and societal dynamic systems. It uses participatory modeling that means players are actors who are part of the system. They themselves can say this is how I make my decision. They can say that and we can capture that very quickly in a tool using Vensim.

So, they are also if there are multiple decision makers and we clearly understand how they make decisions, which is actually given by them. There are been several such things done very complex and big systems are simulated by using tools like Vensim and virtual reality and gaming are also effective in studying systems with people.

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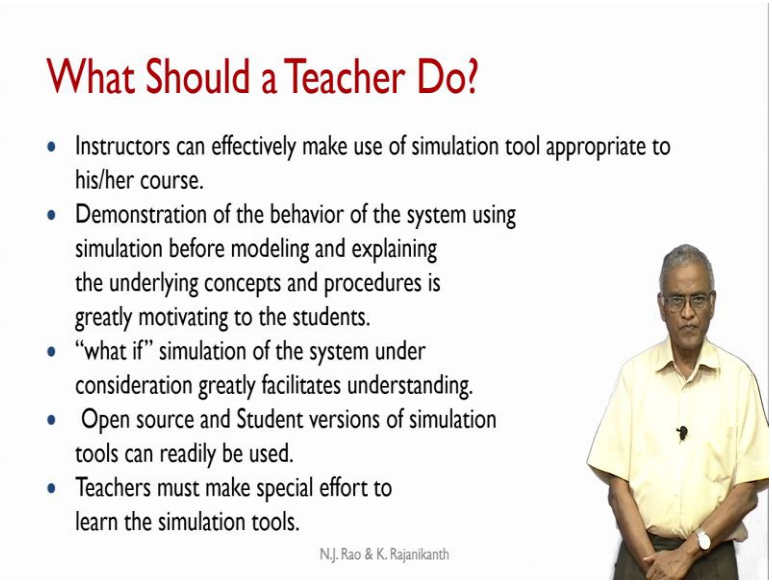

So, in all this what should the teacher do with in with respect to using simulation. Now, in many courses even I would say the first level mathematics course or a differential equation course. A teacher can use a simulation tool to develop a feel for the students with regard to what the actually a differential equation is if I change this parameter, how is the system likely to behave I can visualized the behavior of a behavior affects a dynamic system, which is modeled by a differential equation.

So, even in mathematics courses, or even chemistry, physics in all of them, one can use simulation tools. And you can use the simulation tools which is open source. So, even if the course directly does not demand that a teacher can effectively use this as a very effective instructional method, as we say, demonstration of the behavior of the system using simulation, before modeling and explaining the underlying concepts and procedures is greatly motivating to the students.

So, I can reverse the process before I before I actually start modeling the physical behavior. I can I already know how the system behaves, can demonstrate how the system behaves and that way various conditions and then say and then start modeling to explain that behavior.

So, in that sense, the students are motivated, first they understand how the system behaves graphically or in some kind of whatever graphic in a that tool provides you. First I have a field which will motivate them to get into the details of modeling and explaining also what if simulation that is, what happens if I change some parameters and that is a wonderful mechanism of learning the behavior of any phenomena and that you have open source and sometimes student versions of profit proprietary software are also available of free and they will, they can readily be used, for example, TINATI there is a TINA which is a professional to TINATI is an open source, it has some limitations in number in terms of the number of components and all that that you can use.

But as far as the course is concerned, generally it is adequate. It may not be adequate for a project if you want to do, but for classroom instruction, such student versions are quite adequate. But, you the teachers must make special effort to learn the simulation tools effectively. And you will be really, really adding a lot of value or improve the quality of learning of your students if we can bring the simulation into the classroom.

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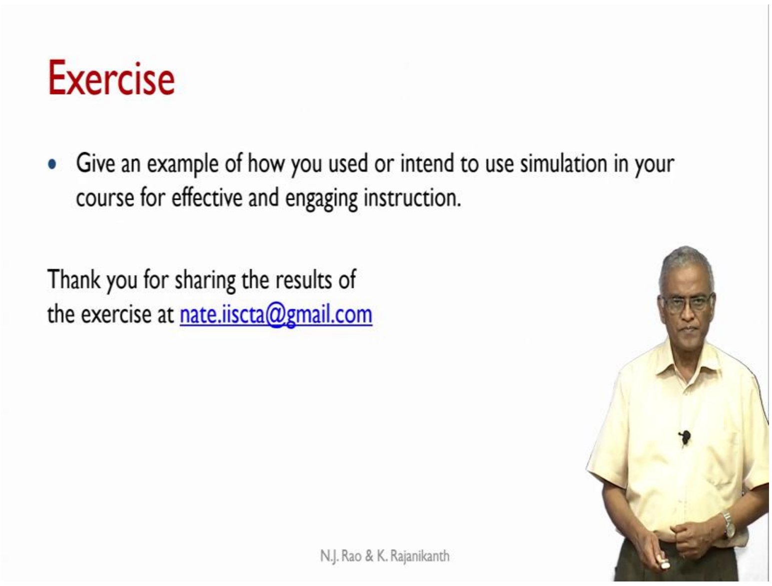

So, we request you to give an example how you used or intend to use simulation in your course, for effective and engaging instruction. Thank you for sharing the results of your exercise at this email id.

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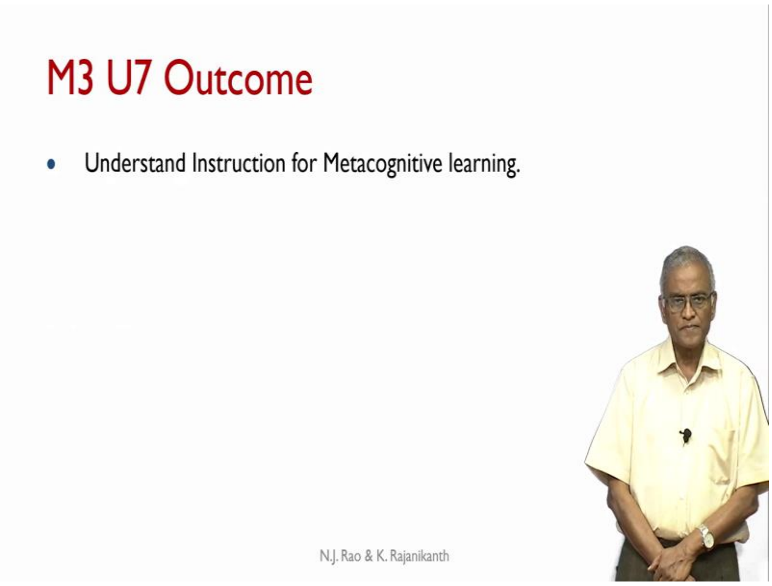

And in the next unit, we will try will attempt to understand the instruction for metacognitive learning. We have explained what metacognition is, but what kind of care what kind of things that you can incorporate into your regular instruction, which will facilitate metacognitive learning, which which becomes more important in colleges where you have students with less cognitive abilities. Thank you very much for your attention.