NBA Accreditation and Teaching – Learning in Engineering (NATE)
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Indian Institute of Science, Bengaluru
Lecture- 45
Instruction for Design Thinking

Greetings, welcome to module 3 unit 5 on Instruction for Design Thinking.

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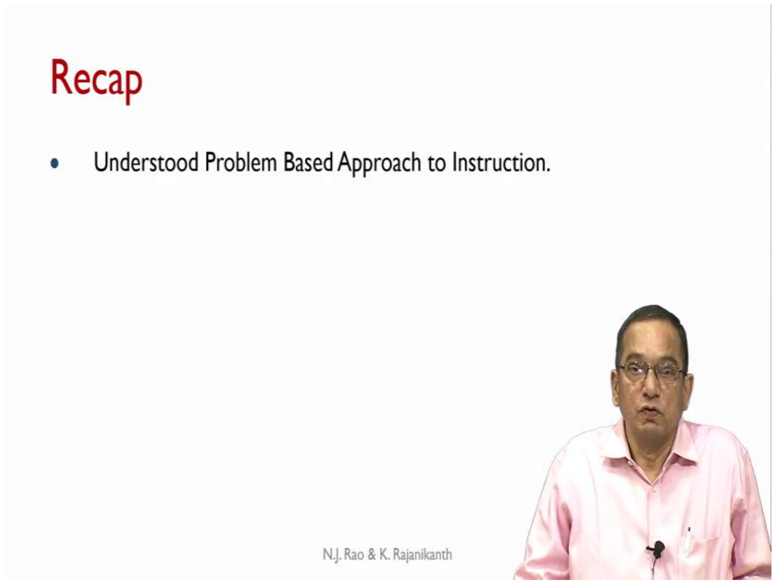

We understood problem based approach to instruction in the previous unit.

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We look at instruction for engineering design thinking in this unit. So, the outcome for this unit is, understand instruction for engineering design thinking.

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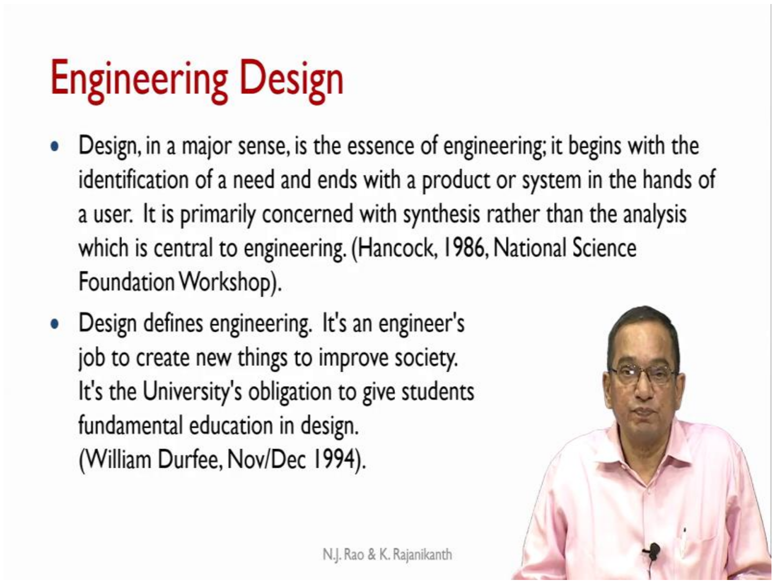

Design in a major sense is the essence of engineering; design begins with identification of a need and ends with a product or system in the hands of the user. The product or the system must meet the requirements of the user. Design is concerned with synthesis. Most of the engineering courses deal with analysis. Design is concerned with the activity of synthesis.

It has to produce a product. Another definition is that design defines engineering. It is an engineer's job to create new things to improve society. It is the University's obligation to give students fundamental education in design; this is due to William Durfee.

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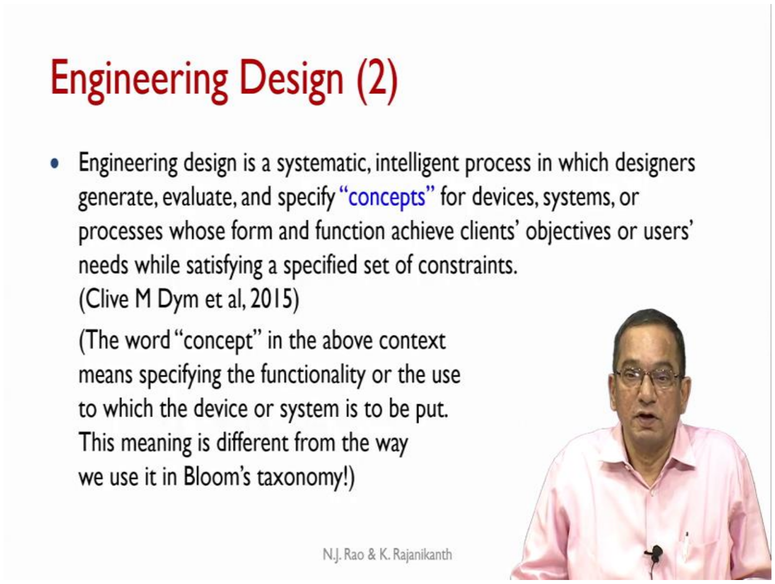

Another definition due to Dym et al is as follows. Engineering design is a systematic, intelligent process in which designers generate, evaluate and specify concepts for devices, systems or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints. This looks like a pretty elaborated definition, it is elaborate. However, it captures all the major features of the design process.

But please note that the word concept in the above context is used in a peculiar fashion. It means specifying the functionality or the use to which the device or system is to be put. This meaning is different from the way we normally use the word concept in the Bloom's taxonomy. Dym et al use the word concept to mean this specification of the functionality.

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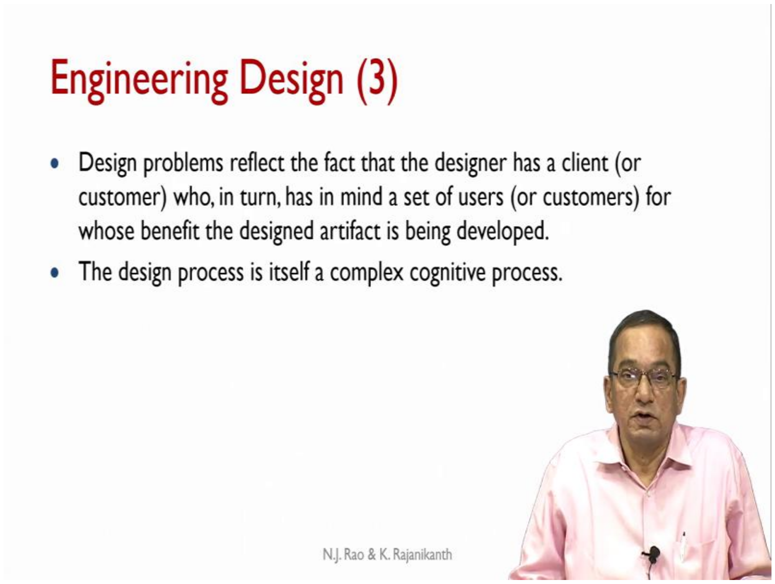

Design problems reflect the fact that the designer has a client or a customer who, in turn has in mind a set of users or customers for whose benefit the designed artifact is being developed. The artifact is designed to meet the requirements of customers. The design process itself is a complex cognitive process.

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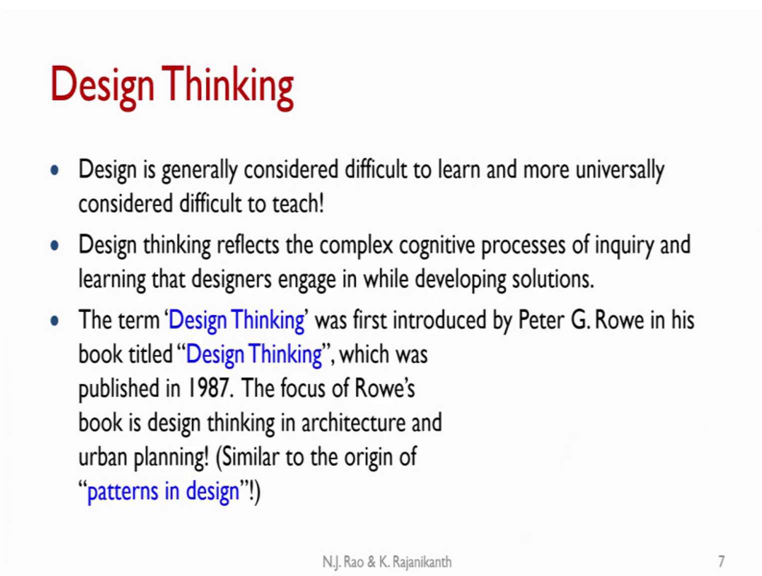

Design is generally considered difficult to learn and more universally considered difficult to teach. Design thinking reflects the complex cognitive processes of inquiry and learning that designers engage in while developing solutions. These solutions must need the identified requirements. The term design thinking was first introduced by Peter G. Rowe in his book titled Design Thinking. This book was published in nineteen eighty-seven.

The focus of this book was design thinking in architecture and urban planning. This book did not deal with engineering design. Its focus was architecture and urban planning. In some way this is similar to the origin of patterns in design. The concept of patterns in design also arose in the context of architecture. Subsequently this concept was integrated into the engineering disciplines.

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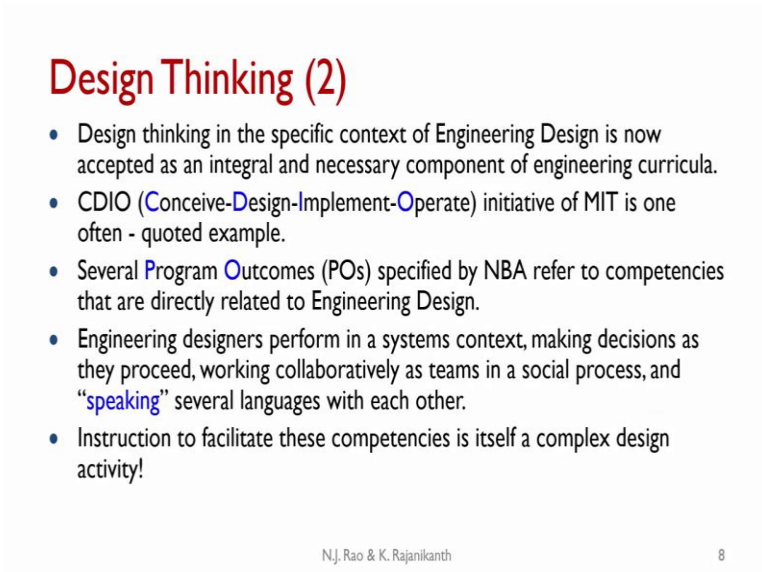

Design thinking in the specific context of Engineering Design is now accepted as an integral and necessary component of engineering curricula. The CDIO initiative of MIT is one often-quoted example. CDIO stands for Conceive Design Implement Operate. The D school of Stanford is also often quoted as an example; but D school is not specifically concerned with engineering design.

Several program outcomes specified by NBA refer to the competencies that are related directly to engineering design. Engineering designers perform in a system context, making decisions as they proceed, working collaboratively as teams in a social process and speaking several languages with each other. Instruction to facilitate these competencies is itself a complex design activity.

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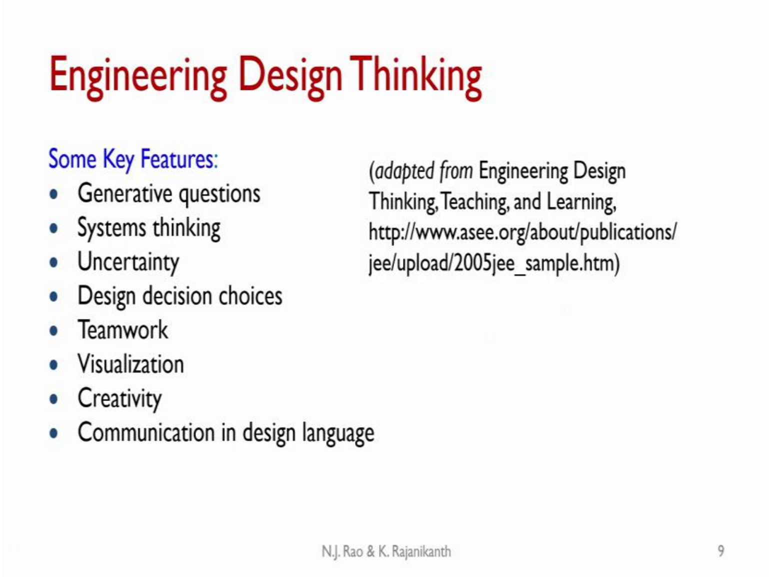

Some key features of Engineering Design Thinking are as follows. Generative questions, systems thinking, uncertainty, design decision choices, teamwork, visualization, creativity, communication in design language. There are other features but this list of features more or less captures the essence of engineering design. This is adapted from engineering design thinking teaching and learning at the link which is shown in this slide.

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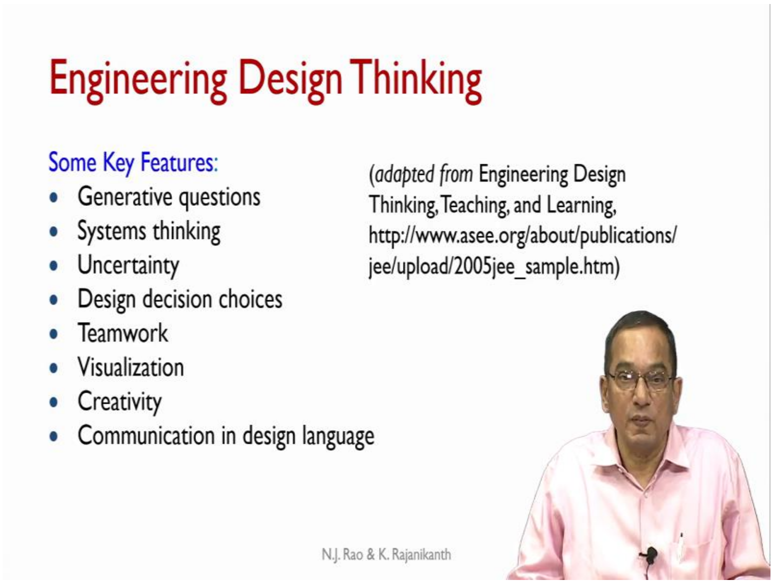

Let us look at these features in brief. Traditional engineering courses invite deep reasoning questions and the answers must coverage to “true” answers in the relevant knowledge domain.

The objective of these questions is to arrive it to true answers. By contrast questions that arise during design thinking are exploratory in nature. The objective of the questions raised during design thinking is not to arrive it true answers.

Their objectives is to generate additional ideas and intense of the customer. Their objective is to extract the hidden intent of the customer. Often customers are not very clear about their own requirements. Generative questions help to bring out additional ideas and intense of the customer. These would be useful for framing the solutions space.

So, the questions asked during design thinking are qualitatively different from the questions whose intent is to arrive it to true answers. Generally, these two types of thinking are called convergent thinking and divergent thinking respectively. Convergent thinking tries to raise the questions to arrive it to true answers. Divergent thinking tries to raise questions whose purpose is to make a clear intent of the customer.

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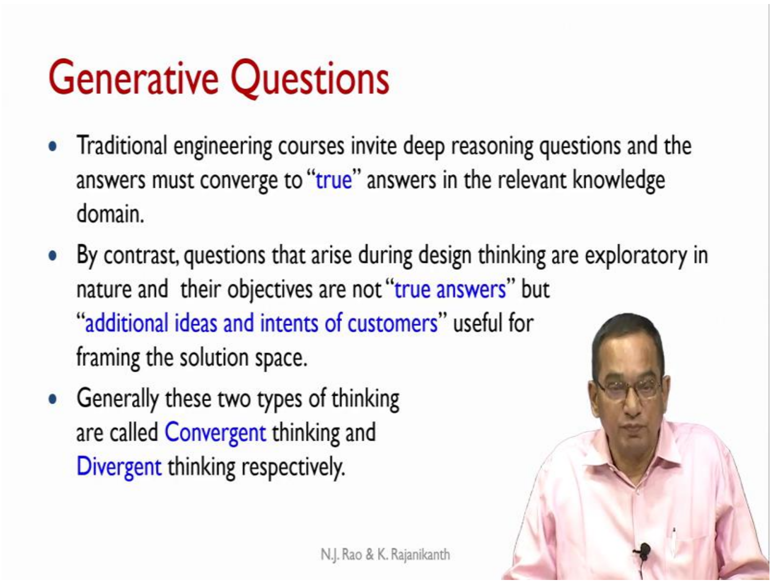

Teaching divergent inquiry in design thinking is generally not addressed in engineering. Case study based group discussions may help students in learning to ask generative questions. Instructors must plan these case studies carefully and monitor the learning process of the students carefully; to ensure that they acquire the skill in generating such questions.

Interactions with real clients, where possible, and subsequent guidance from instructors would be of great help. They promote the ability for divergent thinking. We can also have role plays, simulation games to promote divergent thinking. Institutes must consciously plan for such activities. Promoting divergent thinking requires conscious, explicit planning by the institutes.

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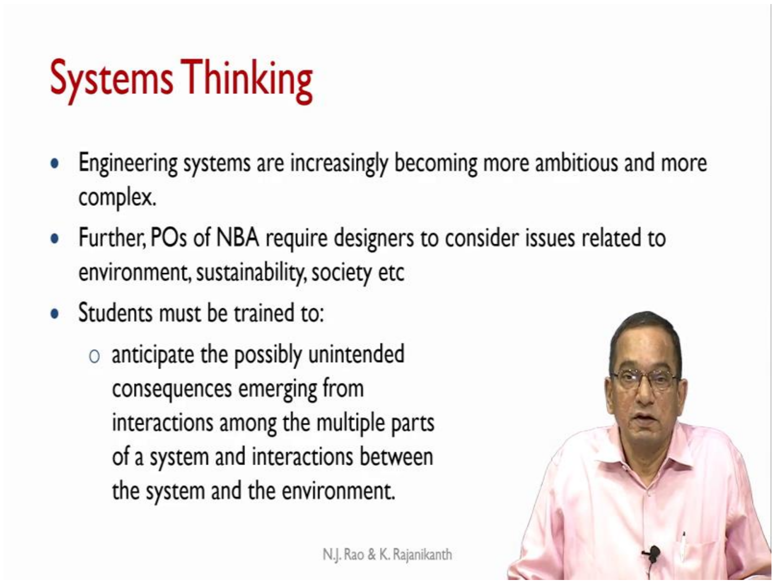

Engineering systems are increasingly becoming more ambitious and more complex. Further, the Program Outcomes specified by NBA require designers to consider issues related to environment, sustainability, society et-cetera. This means that students must be trained to anticipate the possibly unintended consequences emerging from interactions among the multiple parts of a system, and interactions between the system and the environment.

Students must be trained to anticipate the consequences of interactions between the systems and the environment. Students must be trained to assess the impact on the environment of the solutions proposed by them.

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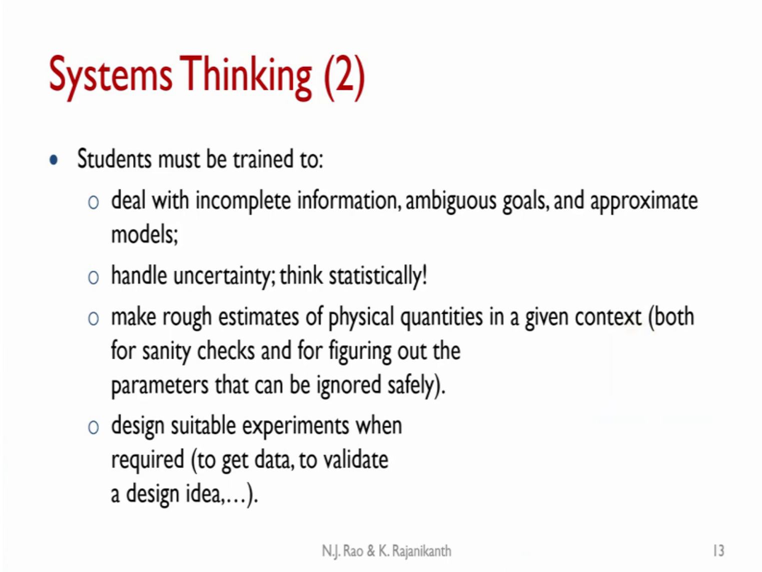

Students must be trained to deal with incomplete information, ambiguous goals and approximate models. Systems thinking would involve the ability of the students to deal with incomplete information, ambiguous goals and approximate models. When designers start building models for a real system, their models often tend to be approximate. The reality is too complex to a model easily. Students must be trained to work with proper approximate models.

They must also be able to understand uncertainty, think statistically. Often designers make rough estimates of physical quantities in a given context. These rough estimates are both for sanity checks and for figuring out the parameters that can be ignored safely. Students must be trained to make such rough estimates. Students also must become capable of designing suitable experiments when required. These experiments may have to be design to get relevant data or to validate a design idea. Students must be trained in the art of designing experiments.

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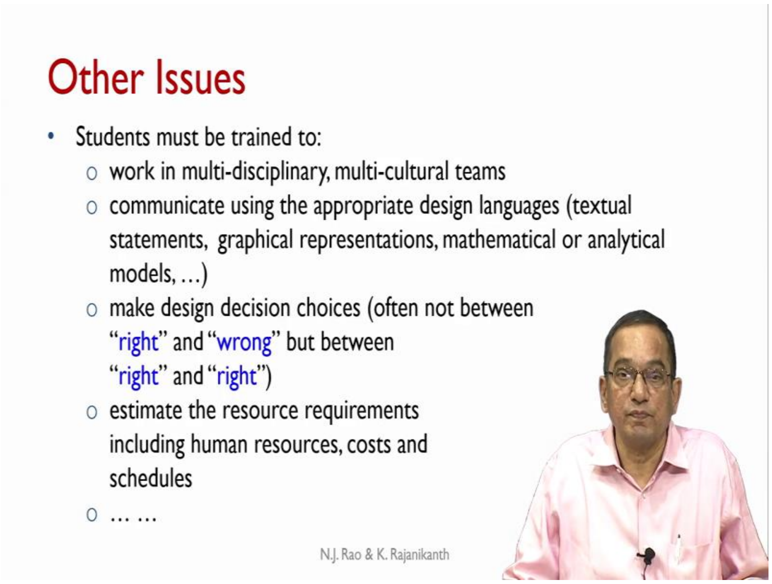

Students how to work in multi-disciplinary, multi-cultural teams? As professionals they would be required to work in such environment. Thus it is necessary that students are trained to work in multi-disciplinary, multi-cultural teams. Allowing the students to work in multi-cultural teams may be somewhat difficult for many institutes. However, they can provide an opportunity for the students to work in multi-disciplinary teams certainly.

Students also must be trained to communicate using appropriate design languages. A variety of design languages exist; they can be textual statements, graphical representations, mathematical or analytical models, domain specific schemes. There can be many different design languages, depending upon the domain in which the students are working. They must be trained to communicate with appropriate design languages.

They also must be trained to make design decision choices. Design decision choices are characterized by the fact that the choice is not between right and wrong decisions. A design decision is often a choice between right and right decisions. We have to prefer one right solution to another right solution. There can be several criteria based on such a decision is taken. Students must be trained to make such design decision choices.

It is also necessary that students are trained in estimating the resource requirements. The resource requirements include human resources, material resources, cost, schedules, several other aspects are involved. It is necessary to provide some training in the art of estimating the resource requirements also.

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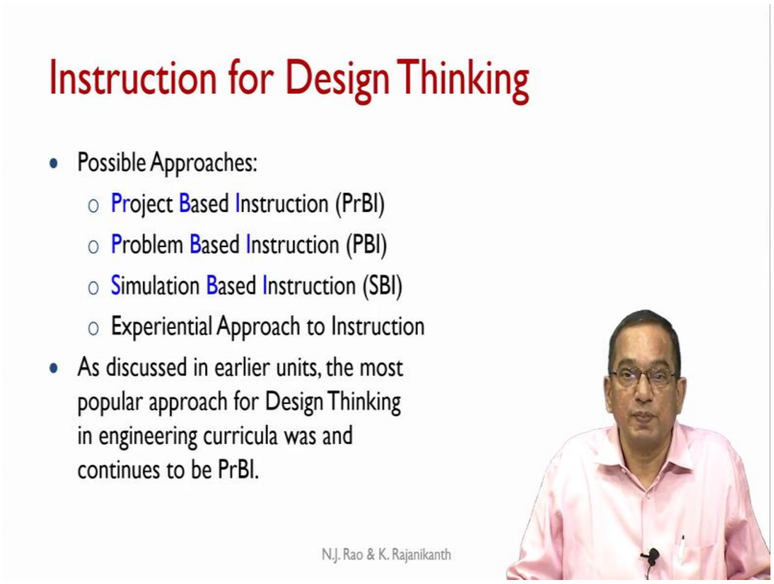

So, what are the approaches possible for instruction for design thinking? We can use project based instruction or problem based instruction or simulation based instruction or experiential approach to instruction. There are other approaches also possible for instruction for design thinking; but the above four are the most common approaches.

As discussed in earlier units, the most popular approach for design thinking in engineering curricula was and continues to be project based approach to instruction. Project based approach to instruction provides most authentic experience to the students in the process of design thinking.

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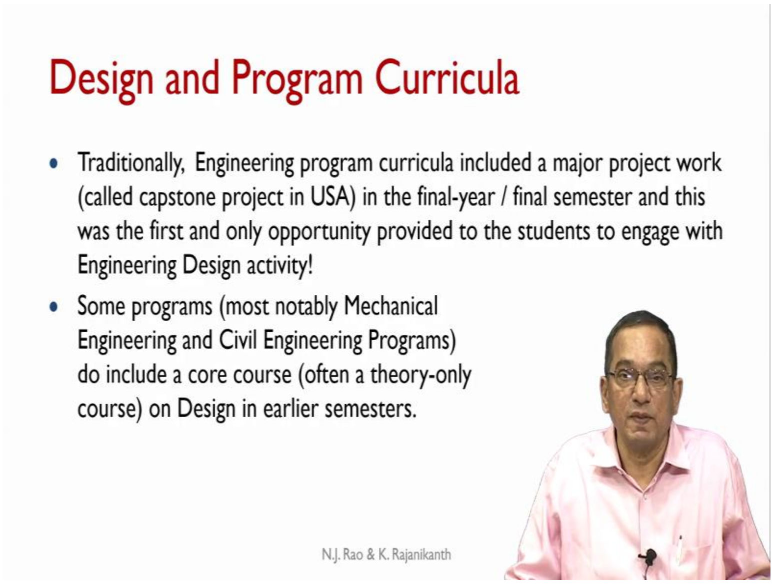

Traditionally, engineering program curricula included a major project work in the final year or in the final semester. Such a project work is generally called as a capstone project in US. In India we are accustomed to calling it as the main project. This main project was the first and only opportunity provided to students to engage with engineering design activity.

Students get exposed to the design activity only in the main project which comes in the final semester or final year. Some programs most notably Mechanical Engineering and Civil Engineering programs do include a core course on design. This core course on design usually is a part of the curricula of earlier years.

In some institutes it may occur in second year, in some institutes it may occur in third year. But this feature of having a separate course on engineering design is not common in many other disciplines. The courses on engineering design when they are part of curricula are typically core courses.

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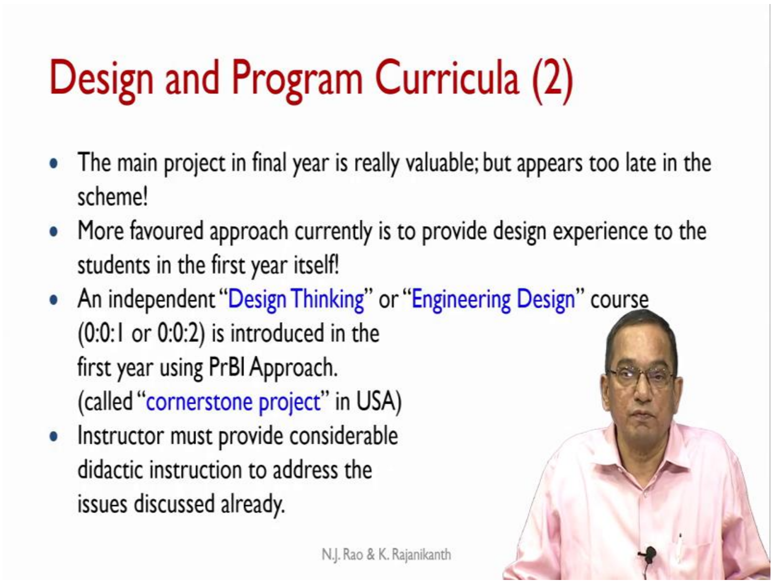

The main project in final year is really valuable; but it appears too late in the scheme. Typically it is a part of only the final year activity, or final semester activity. More favored approach currently is to provide design experience to the students in the final year itself. An independent design thinking or engineering design course is introduced in the first year itself using problem based approach to instruction.

The course can have no theory component, no tutorial component, but only a practical component. So, the credit structure can be 0:0:1 or 0:0:2. 1 or 2 credits of practical work only would be involved. Instructors must provide considerable didactic instruction to address the issues discussed already. So, though the course is only the practical oriented; certain amount of theoretical inputs must be provided to the students by the instructor.

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If we have an engineering design course in the first year, what are the challenges? Students may have considerable difficulty with the initial problem statement and final formulation of the problem. The problem is stated in a natural language at the beginning. Students must be able to translate it into a formal engineering problem. This may be difficult for many of the students when they are in first year.

We need to form multidisciplinary teams and that also may be a very challenging issue. Students need some core competencies in order to work with projects. These core competencies include familiarity with concepts, tools and also an appropriate attitude for undertaking design activity. Students may not be competent in these aspects.

Teachers may have to provide some initial training to the students in all these aspects. They may not be familiar with the design process to be used also. There is another issue which is the load on the faculty. If all the first year students are to be engaged in a design activity; there is considerable load on the faculty.

Further, assessment of the work of the students also imposes substantial load on the faculty. Faculty how to assess? The finished work as well as the compliance to the process. Faculty how to assess? The individual contribution as well as the work of the team as a whole. All these activities would mean considerable burden for the faculty.

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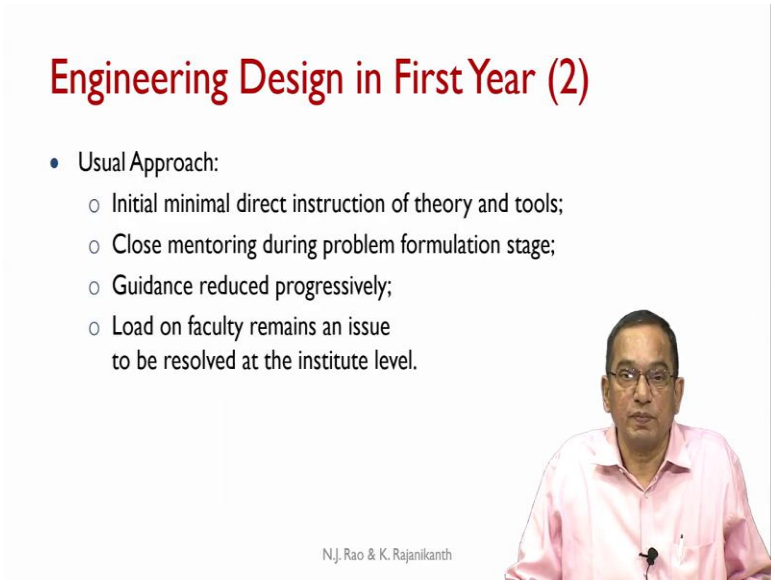

Several approaches can be tried when engineering design is introduced in the first year. The usual approach is as follows: Initially students are provided with some direct instruction. The direct instruction would include some basic concepts of design theory as well as familiarization with some of the essential tools.

There will be close mentoring during the problem formulation stage. Gradually the guidance is reduced. The students begin to work independently on the projects. Still the load on the faculty remains an issue to be resolved at the institute level.

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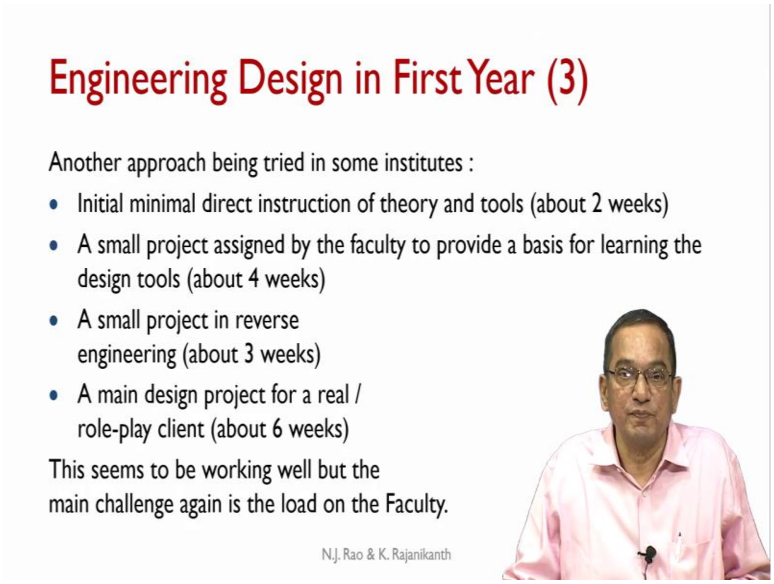

Another approach is being tried in some of the institutes. This approach consists of splitting the design activity into multiple phases. Initially again students are provided with certain minimum information regarding the theoretical concepts and tools to be used. This may last for about two weeks; then a small project is assigned by the faculty.

This project provides a basis for learning the design tools. This scope of the project is fairly small and students work on this project to gain some practical experience with the design activity, and familiarity with the design tools. This activity may last for about 4 weeks. Then a project is assigned to the student, which engages them in reverse engineering activities; this activity may be for about 4 weeks.

A complete product given to the students and students have to figure out through reverse engineering activities; how the product was synthesized. After these three luminary activities, a main design project for a real or role play client is assigned to the students. Students would have about 6 weeks to complete this design activity. This seems to be working well but the main challenge again is the load on the faculty. Faculty how to find adequate number of resources to be provided to the students for all these activities?

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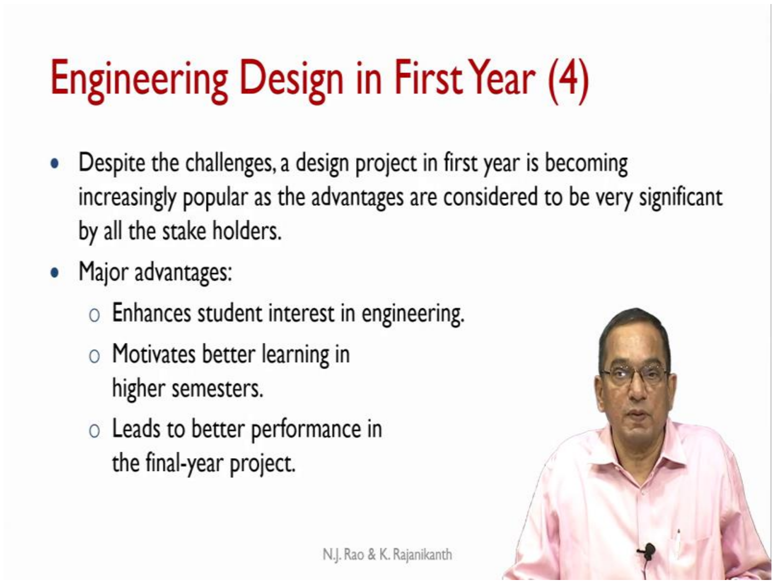

Despite the challenges, a design project in first year is becoming increasingly popular as the advantages are considered to be very significant. All the stake holders seem to agree that a work on the engineering design in the first year as substantial advantages. The major advantages claimed for the design activity in the first year are as follows. It enhances student interest in engineering. It motivates better learning in higher semesters.

The experience in many institutes seem to indicate that the students perform better in higher semesters academically; when they are exposed to design activities in the first year. It leads to better performance in the final year project also. Students have already had exposure to the design activity in the first year. They tend to do better when it comes to the final year project also.

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Student engagement with design in final year is quite well established and student engagement with design in first year is being introduced in increasing number of institutes. Some institutes are experimenting with a design project even in second year and or third year. Advantages are very clear, but providing the necessary resources can be quite a challenge for the institutes. Institutes need to experiment and decide what is best for them.

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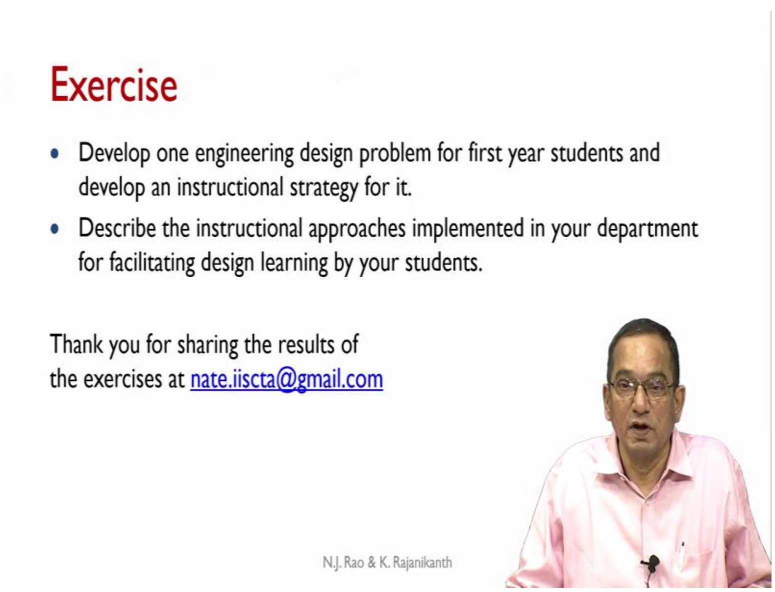

Some of the activities that can be adopted in an institute would include many projects in some of the courses. They could include design activity in second year also. They could include design activity in third year also. So, please indicate what are the instructional approaches implemented in your department for facilitating design learning by your students. That is one exercise for you.

Another one would be develop one engineering design problem for the first year students and develop an instructional strategy for it. Two exercises for you: please share your experiences. Thank you for sharing the result of the exercises at nate.iiscta@gmail.com. Thank you for sharing the result of the exercises at nate.iiscta@gmail.com.

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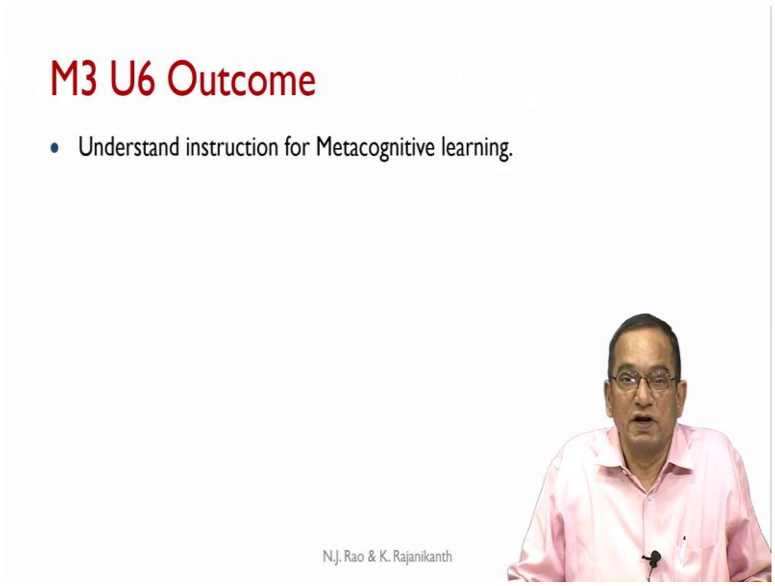

Will understand the instruction for metacognitive learning in the next unit. Thank you.