Effective Engineering "Teaching" in Practice
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Lecture - 02a
From Traditional Lecturing to Helping Students Learn (Part - 1)

Welcome back. In the previous lectures, we looked at some aspects related to inexperienced teachers and how they could affect the learning by students. Let us move forward, this is the second topic in the course. The title of this topic is from traditional lecturing to helping students learn; the wide difference between the two and we look at some of those aspects. And of course, there is a huge overlap between the two also; it does not mean that students do not learn from lecture. However, we need to be aware of where all lectures fail and so on and so forth so that we can look to strengthen lectures and give appropriate lectures.

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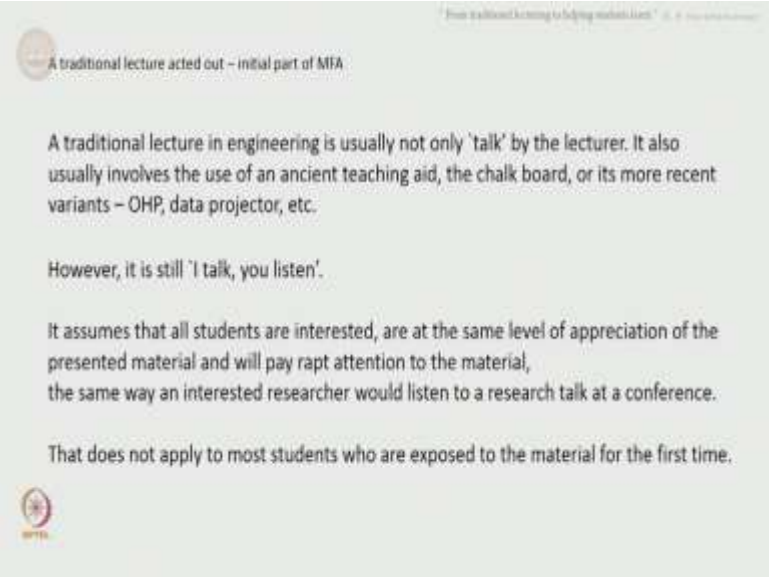

Let us move forward. What I am going to do first is act out a traditional lecture and then let us discuss that lecture. It would be a short one and I will choose something that is familiar or that you will all feel comfortable with, any engineer would feel comfortable with. It is again based on material balance principles that we covered in some detail in the previous lectures. This is the traditional lecture assuming that the lecturer, the teacher is somewhat experienced; how would a traditional lecture be.

Good morning students. Let us discuss today; how to apply material balance principles to analyze a cell. The main theme is called metabolic flux analysis that is what material balance gives when you apply it to a cell.

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It is called metabolic flux analysis - MFA for short, and this is based on material balance. We have all done material balance in the previous lectures; so you know what material balance is. Now let us apply it to a cell here. Let us for illustration purposes take this particular scheme. Let us say there is a substrate S_0 here that is getting into the cell to become S at a rate of r_0. S can become either A at a rate of r_1 or B at a rate of r_2 and A can get converted to C at a rate of r_3 and B gets converted to D at a rate of r_4. C and D come out of the cell.

Now, if you write a material balance on let us say one of the species. The overall material balance you know that the input rate plus the generation rate minus the output rate minus the consumption rate equals the accumulation rate. In this case, if it is, we are writing it on A, it will be somewhere here and it is this.

Now, if you write a material balance on, let us say S here right; you all know how to do material balance you know the system; if we choose the system then let us write the material balance on A. You know that if you take the various terms here you will find that $r_0 - r_1 - r_2 = \frac{dS}{dt}$

Of course, the methodology will take a long time to get across. I am not trying to do that at all. I am trying to give you a flavor of a traditional lecture.

You would find some resonances in what was done here in the earlier part of your teaching program. So, let me now tell you some of the features of what was done just now and later on come back to the board. A traditional lecture, in engineering is not just talk. The talk is in probably some other fields. By lecture it just means talking by the instructor in some fields whereas, in engineering, it also involves the use of the ancient teaching aid - the blackboard or the chalkboard right, if we write using chalks or its more recent variants such as the overhead projector, data projector and so on so forth.

They are all teaching aids. The main aspect of the traditional lecture is I talk, you listen. Or I teacher talks, you students listen. It kind of assumes that all the students that are present there are at the same level of appreciation of the material that is presented. They will all pay rapt attention to the material and thereby absorb the material in the best possible fashion. That seems to be the underlying assumption to follow this method.

It is fine if all the students are interested, and they are all tuned in and they eagerly get in everything right. Like you know, if you go to a conference and you listen to a speaker you are interested in the area, you are working in the area. So, you would like to know exactly what is going on or the entire aspect of what is; what the speaker is talking about; therefore, you pay rapt attention and so on so forth. But there is a whole background of interest and work that goes along with you paying that attention, whereas, in the class that is not really valid or that may not be really valid, this does not apply to most students who are exposed to the material for the first time.

Especially for the first time. They may or may not have an interest. They may have something else in their mind and so on and so forth. Therefore, this approach is usually not effective for almost all the students except for the 1 or 2 who are well into the course, who are very interested and pay a lot of attention. What I am going to do next - I am going to act out the same piece that I did earlier, the beginning of this particular slide. I am going to tell you how it can be improved. So, let us go back to the board one last time and tell you a slightly better method of presenting the same material ok.

Let us begin the slightly different way of doing it, or probably a very different way of doing it - as far as the understanding of the learners go. Welcome! Good morning. In the

previous classes we did material balances right which is essentially based on the principles of a mass balance. We got a useful form of the mass balance based on the principles that mass can neither be created nor destroyed as long as you are not working with nuclear reactions or not traveling at the speeds of light.

Here what we are going to do today is look at the application of that material balance form, the useful form to a cell and let us see how useful information or what useful information we can get by applying that to the cell. Recall that the basal material balance equation was the input rate of a particular species.

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Also recall that you can do a material balance only over a particular system. The balance that you do is highly system dependent or dependent only on the system. And we typically do the balance either on a species or a group of species and so on and so forth; these two you should remember.

So, coming back to the balanced equation, for a particular species, the rate of input minus the rate of output plus the rate of generation minus the rate of consumption equals the accumulation rate of that particular substance.

$$r_{in} - r_{out} + r_{gen} - r_{con} = \frac{d(m)}{dt}$$

This is material balance and therefore, the units of each one of them is mass per type. This you all know. Now we are going to apply this to a system which is a cell. The system boundary I am going to represent by a dotted line here and let us say that the substrate S_0 gets into the cell at S. We all know that thousands of reactions happen in the cell. We are representing just a few of those reactions.

Let us say that the rate at which this happens is r_0. This goes to A a rate of r_1 and goes to B at a rate of r_2. A gets out of the cell to become C at the rate of r 3 and B gets out of the cell to become D at a rate of r 4. Now let us apply the material balance equation for each species that we are given here. S, A, B, C, D are the species.

So, let us start with S. That is the first thing that we are going to write. We are going to write for each and everything. Now what is the input rate of S. It is through this, this is the system here, this is crossing the system boundary. Therefore, it is an input and therefore, r_0 is the input rate. What is the output rate of S? Can you work it out? You see that it is not going out of the cell at all. Therefore, there is no output rate. Is S being generated in the cell? No, this is just coming into the cell, this is not being generated in the cell, right. You can account for it either as coming in or being generated. You cannot double account and therefore, that is 0; the consumption rate is through r 1 and r 2 to get to A and B and therefore, the consumption rate is $r_1 + r_2$. This must equal the rate of accumulation of S in the system. Therefore, if we simplify this,

$$r_0 - r_1 + r_2 = \frac{d(S)}{dt}$$

Now, can you do this for A and tell me what you get? Apply the material balance for A and tell me what you get. I will give you some time. You need to give them enough time, you just cannot get back immediately. Give them enough time, much more than what you would take to write down because they are doing it for the first time. Assuming that we have given them time.

Let us see what you have. Can somebody come to the board and write it or can somebody say it? Yes; you know that there is no input of A therefore, the input rate is 0. The output rate of A; A is not going out, so that is 0. The generation rate is through r_1, right therefore, the generation rate is r_1. The consumption of A is through this reaction C,

$$r_1 - r_3 = \frac{d(A)}{dt}$$

Now can you write it for all the six species that are there? We have already written it for S and A? Therefore, I did for S. Write it for B first, taking the cell to be your system. When we go to the extracellular metabolites, the trick here is you need to consider everything else apart from the cell as your system. We will get to that, but first write it for B and then we will continue.

Now that was the same lecture, same part of the lecture which was given in a slightly different way or in a very different way whichever way you want to look at it.

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So, how was the lecture improved? You can think about it, take your time to think about it right. If you want, you can pause the video here and think about it right.

Let us move forward. In the improved lecture, the students were not assumed to be the same level as the teacher. Very obvious, started out at the very beginning. What was done earlier? How do we apply it to this and so on so forth. They were invited to participate in the process. Can you do the balance and let me know. After giving them, how to do the balance, showing them how to do the balance. Can you do the balance, let

me know. Initially it was guided and then completely can you do it on your own, that kind of a thing.

The rationale was made clear at all the relevant places - starting from where they were. Right, they are starting out, they are looking at it for the first time. Therefore, starting from where they were, whatever thought process was needed, whatever the basis was, the logical basis was, that was provided; which could have been very obvious to a person who is a, who is experienced, who has taught it so many times. But it is not obvious for the student. The thought process at every stage was made clear and many other things that you can find and probably discuss on the forum. If you do all this, it essentially leads to improved learning in students and that is what we are after. So, the same lecture slightly differently done, you can improve the learning of students significantly, understanding of students, their application, possibilities of the application of the material; all that can be improved significantly.

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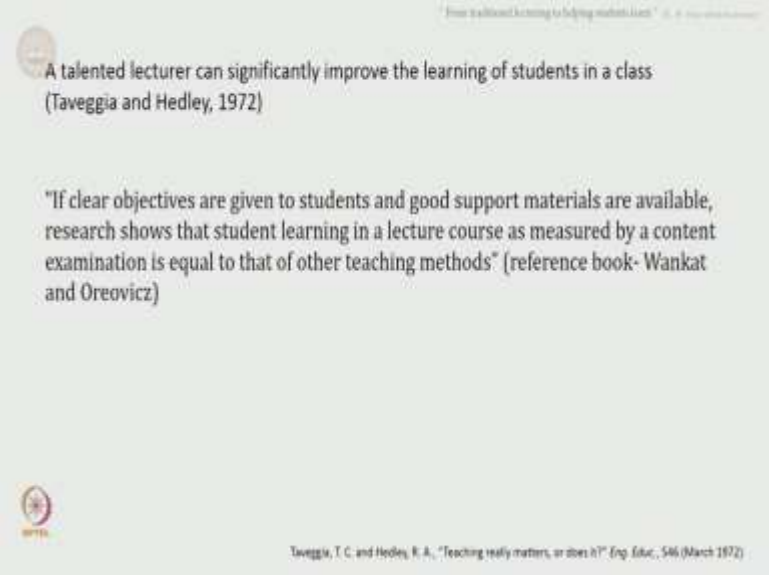

'A talented lecturer can significantly improve the learning of students in a class' - was the statement made by these authors, the sources given here from this paper. Teaching really matters or does it in engineering education way back in 1972. So, there is nothing wrong with a basal lecture if you can look at a lecture in its complete sense. This is from your own reference book Wankat and Oreovicz. If clear objectives are given to students and good support materials are available, research shows, somebody has gone and done

clear controlled research with these things, research shows that student learning in a lecture course as measured by content examination is equal to that of the other teaching methods. This has actually been found. This lecture when done fine, when done well can actually improve learning.

So, lecture is not the culprit here. It is the way the lecture is done that is the culprit. In fact, we will take a look at learning in a lecture course throughout the course later at different points in time. I will not point it out, but you can yourself figure out what learning in a lecture course is; understand better what learning in the lecture course is as we go along. There are various advantages of the lecture as reviewed by Wankat and Oreovicz. Some of their own work and some, many pieces of literature that they have quoted in their textbook. It has an audience focus; in other words; if it is a class of about 50 or 60, you could tune the lecture to that particular class depending on the background and so on and so forth which is very easy to do in a lecture. That is one of the big advantages.

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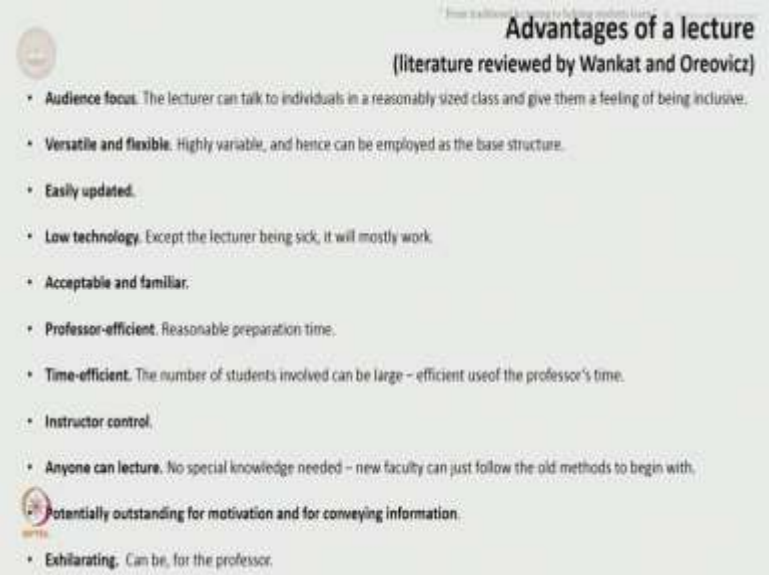

It is a versatile and flexible. It is highly flexible. You can do it whichever way you want it and so on so forth and therefore, it can be used as a very strong base structure on which you build and make things a lot better. It is easily updated. Just go and read, put it as a part of your notes, it is all done; you do not have to look at other means you know, various other, let us say online resources and so on so forth.

Lot of preparation needed for updating. It is a low technology, which means it will work most of the time hopefully. As long as the person does not fall sick - that is what the book says. It is acceptable, it is familiar. That is a very big advantage to students as well as the instructors. Acceptability is very high. It is professor efficient. The same professor can talk to a bunch of 15 students in a class depending on the registrations or maybe even 500-600 students in a class if the lecture is appropriately tuned. Large classes are a challenge in their own right and you need to appropriately tune your lecture to address large classes.

It is time efficient. The number of students involved can be either large or small; it does not matter. The instructor is usually in control of the lecture and pretty much anyone can lecture and that is what we rely on really. When a new faculty member joins, we give them a course and ask them to teach and since the person has undergone lectures earlier in their own fields of study, the person tries to imitate it, imitate the earlier lectures to begin with and then starts learning. It is potentially outstanding for motivation and conveying information.

Motivating people is best done through lectures, all said and done. And all those motivational speakers speak. And it could be exhilarating for the professor. Depending on the kind of person, it could really be exhilarating for the professor. These are all the advantages that are listed here and a few more are listed. You can go and look at the reference book. However, the same lecture if done badly can be highly disadvantageous and let us see a few disadvantages of the lecture, again as reviewed by Wankat and Oreovicz in your reference book.

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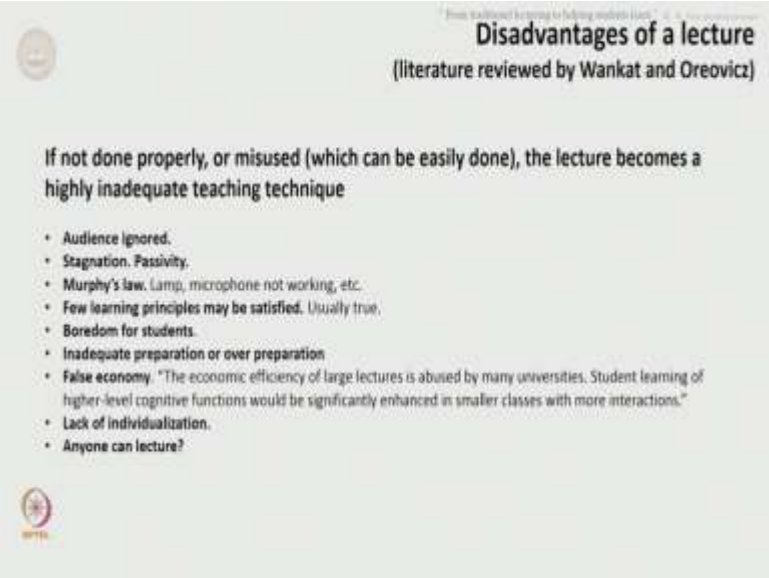

If not done properly or misused, which can be very easily done - that is the unfortunate part, the lecture becomes a highly inadequate teaching technique. The audience can be ignored. You talk to walls or you know if you are not comfortable with an audience, if you have stage fright, if the lecturer has stage fright and so on so forth, the audience could be completely ignored and then the lecture fails.

You could stagnate. You know you have a lecture, set of lecture notes, you go and talk the same thing year after year after year without updating it; it can be very, it can very easily go bad. Although it is not technically intensive, even the small technical aspects such as, let us say a microphone can go bad, especially when you talk to large classes. So, that can happen. Few learning principles may be satisfied. This usually happens in most courses if the teachers/lecturers are not aware of the learning principles, then it is very difficult for them to incorporate that into the lecture and one of the major aims of this NOC, the NPTEL online certification course is to give you those principles.

When the lecture is done badly, it can be highly boring for the students. People can get away with inadequate preparation or they can put in too much time into preparing for it, both of which are not desirable. It also leads to something called false economy. The economic efficiency of large lectures is abused by many universities is what your reference book says. Student learning of higher level cognitive functions would be significantly enhanced in similar classes with more interactions is what they say. Smaller

classes are much greater is what they say, but the administrators may want large classes just for the sake of it or for the wrong reasons and that is bad.

Lack of individualization can happen if the teacher is not sensitive enough. So, anyone can lecture. Is it really desirable? The person who is unable to do anything, if the person comes and lectures; what would the learning be? It can be extremely stressful for a lecturer and the students sometimes if the lecturer is not up to lecturing properly. So, all these, the same things that were advantages for a lecture can turn completely disadvantages if those were not done properly.Tthat is the point that the book is trying to make.

Let us talk a little bit about the content of the lecture right.

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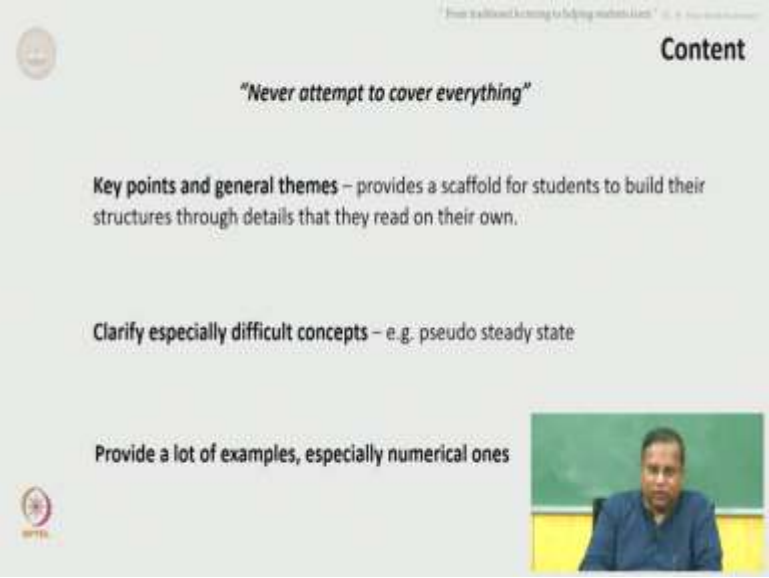

The first thing - is never attempt to cover everything. There is this nice story that I have heard through many people. This is about Professor Kelkar; who was the first director of IIT Kanpur, a learned person, a person with the vision and so on. One of the young faculty members walked up to him in his early days; the early days of IIT Kanpur and said 'Professor Kelkar; I do not have time to cover the syllabus'. And then Professor Kelkar in his wisdom sat down the person, gave him a cup of coffee and said, Young man, I hired you not to cover the syllabus, but to uncover a part of it'. And that is all we are supposed to do - uncover a part of it. You are not supposed to cover the syllabus ok.

So, do not attempt to cover everything. It is good to cover the key points and the general themes alone. It provides a scaffold for the student to build their structures and to build their understanding and so on and so forth, when they go and read. You need to provide them with enough scaffolding, so that when they go back and read, that scaffolding is good enough for them to make up their own knowledge, to create their own knowledge. And that is actually a very well accepted theory of constructivism which we will deal with a little bit later. Clarify, definitely clarify, especially difficult concepts. There are concepts which take time to assimilate, to accept, to understand and so on so forth and definitely spend a lot of time.

The concept that comes to mind in my recent course is that of pseudo steady state. When you have 2 processes of widely varying rates, then the unsteady nature of the faster process can be ignored, if the interest is in the slow process. That is essentially what pseudo steady state is, it is an assumption. And to get this across, you need to know, prime the students well and then make it very clear probably through an example and so on and so forth. My book, the transport, the fluxes and forces book, continuum analysis book has the example if you want to, if you are interested, then you can take a look at it.

So, you need to do all that and then provide in very clear terms the principle; in as short a time as possible. That is the best way that they can get it, or one of the best ways that they can get it. There could be many ways. Provide a lot of examples, especially numerical ones for engineering that would be very relevant, that would improve the content.

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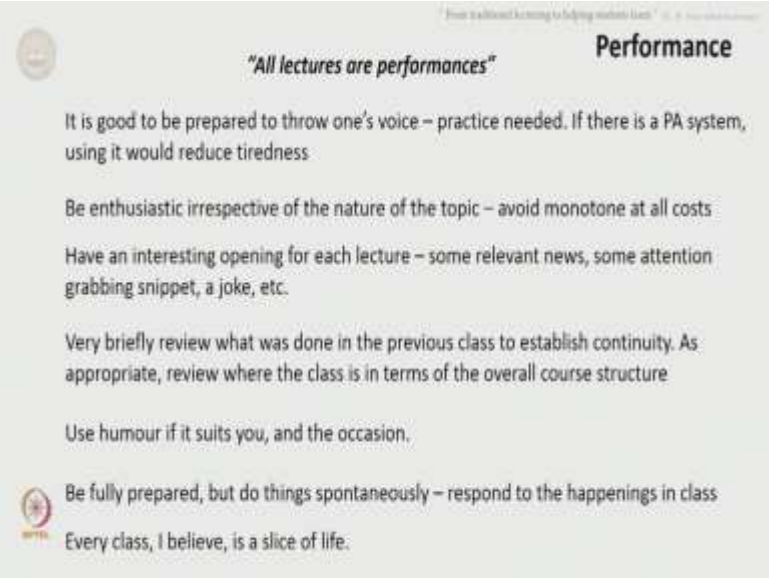

Performance; when I teach I am performing and it is well known that all lectures are performances. That is a well-known quote. I have heard it in many different contexts. All lectures are performances; it is like being on stage in a play and performing. You are communicating with the audience. It is good to be prepared, to throw one's voice especially if you do not have aids - the microphone and so on so forth if you do not have, it is good to practice throwing one's voice so that it reaches the end of the class. Definitely a lot of practice is needed for that. But what I would have suggest, this is a personal suggestion. If there is a public address system, please use it because what I find is when you throw your voice and so on and so forth, you need a lot of stamina. You can get tired easily and that can be easily avoided if you have a public address system. My voice, initially when I started teaching, I had analyzed all these things and gotten input from students. My voice goes like this and the lows could be really low. I am not very conscious of how my voice goes, especially when I am into the material and actually it goes something like this and the lows are really low. Students find it very difficult to hear what I am saying when my voice is low. That can be offset by using a public address system. Be enthusiastic irrespective of the nature of the topic. This is something that we will have to do. We all have the aspects that we are naturally interested in, naturally the aspects that we are naturally excited by those would not be a problem, but that is not all that there is to a course. There will be parts of the course that we do not really like and so on and so forth.

But let that not show. Just force yourself to be enthusiastic, irrespective of the nature of the topic and definitely do not use the same tone of voice throughout the lecture. That should be definitely avoided. Have an interesting opening for the lecture. If it is, if it comes easily to you, maybe some news, some attention grabbing snippet and so on so forth. Maybe a joke if you are of the humorous kind. If you are not of the humorous kind, try to avoid a joke. The jokes should work and only people who can make it work should even try it. All this is based on one's own strengths, but try some interesting opening, that is always good. Definitely review briefly, what was done in the previous class to establish continuity, that is an absolute must. We must practice doing that. You will find me doing that in these lectures also. And as appropriate, review the class in terms of the overall course structure from time to time. That always helps to give them a sense of the course structure, overall course structure.

As mentioned earlier; use humor if it suits you and the occasion and if they do not match it will backfire badly. So, if you are, a if you are a humorous person, bring it to the full advantage while teaching a course. Then this one is important - be fully prepared, but do not have step by step delivery in mind. You be fully prepared, the material, then go with the flow, right. Do things spontaneously, that is the best that can happen and you need to respond to questions, respond to happenings in class. There will be various different things happening in class, some of which you need to ignore, some of which you cannot ignore. You need to address those things as you go along. All that is a part of a lecture and my personal belief is that every class is a slice of life. It has every single aspect of life in it, some humor, some moroseness, some boredom, some excitement and so on and so forth and I think that is what makes a very lively class.

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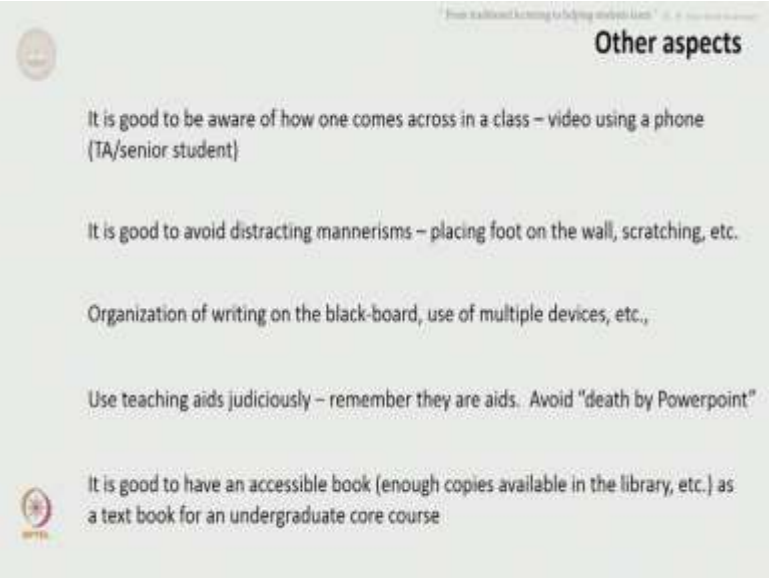

Other aspects of the lecture; it is good to be aware of how one comes across in the class and it is difficult to find out for yourself. Therefore, it is good to have somebody videotape your lectures. You could ask either a teaching assistant or a friend or one of the senior students who has already taken the course to come and sit at the back and video lecture. Nowadays you could do decent video lecturing recording even with a cell phone camera, a decent enough camera. But ask them to focus on this part and your gestures if you can and that would give you a very good input. Replaying that and seeing how you have done gives you a very good input.

It is good to avoid distracting mannerisms. For example, what I used to do very early, this was 24 years ago, is while I talk I used to move one leg and put it on the wall. You know when I am at the board and the board has some wall beneath it, a free wall and I used to put one leg on the wall because that was my natural way of talking, which irritated a lot of people. And when I asked them for it they told me that we do not really like it because it makes marks on the wall and so on so forth, see how ugly it looks and from that time onwards, I have been consciously avoiding that. Nowadays, I do not do that at all. And then people do various kinds of things, various kinds of ticks. It is good to avoid that, but first you need to know what to avoid. It is good to get input, the video input would give you most of it and then it is good to ask for input from the students also.

Organization of writing on the blackboard - that is very important. Or for that matter, using multiple devices, being organized in its use is very important. For example, the blackboard, it is best to start from one end and move very smoothly, continuously in an organized fashion towards the other end. And then start erasing from this end when you need more space. That would give them enough time to take down whatever you are writing on the board and so on and so forth. Taking down appropriate notes would become much easier. Many teachers pick this up in the early parts of their lecturing career, but some do not.

Use teaching aids judiciously. Remember they are all aids, they are all there to help your teaching. They do not replace your teaching, right. So, treat them as aids and definitely avoid death by PowerPoint. See I am also doing PowerPoint here right, but if I go through it and keep reading things just without explaining anything and not making any sense of what it is. I have prepared a set of notes, I just go and flash those notes on the board through PowerPoint, then that is what is called death by PowerPoint. Please avoid that, it is a very common phrase I think Felder coined; Professor Felder. It is good to have an accessible book for reference, for a textbook and so on and so forth. Make sure that there are enough copies of the book in the library. Maybe there is an e copy of the book available and so on and so forth, but students need to have access to that and you need to make sure that it is available before you begin the course.

Definitely for an undergraduate core course, the graduate level can use a lot of reference material, you can give the material in class and so on and so forth. The students are mature enough to pick it up, but not the undergraduate students. Undergraduate students need one book that they can use at least for most parts of the material that is covered in class or uncovered.

Building rapport with students through lectures - try to address students by name. For people like me who quickly forget names, this might be a challenge. It might take time. How I do that is, I take attendance by names, essentially to connect the names with the faces. Still takes me quite a bit of time to become comfortable with all the names and then I start using the names to address them.

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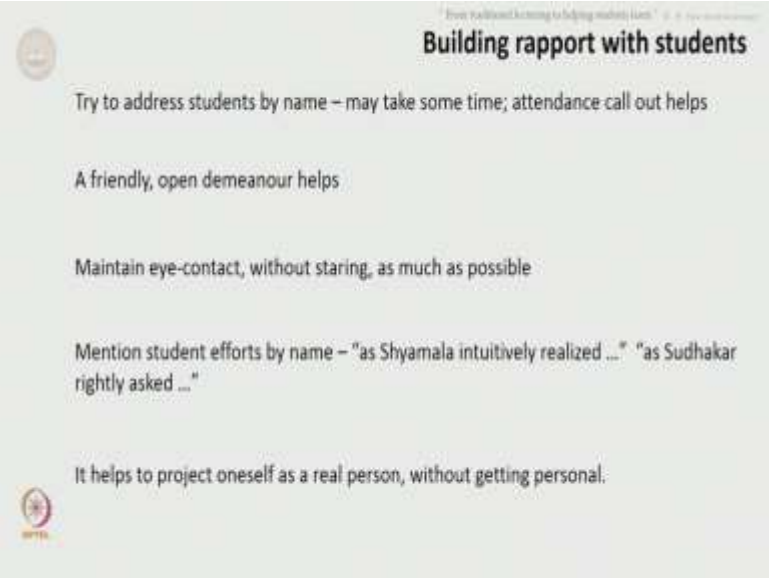

A friendly open demeanor helps. Maintain eye contact. Eye contact is absolutely important, but do not stare at them. Scan, but scan through your eyes in catching them for a fraction of a second and that is as you scan and catch their eyes for fraction of seconds and so on so forth, that improves communication significantly. Mention student efforts. If they have done something, definitely mention the efforts by name. For example, as Shyamala intuitively realized, this is true; as Sudhakar rightly asked, you know use the students' name. That builds a rappo very nicely. And it helps to project oneself as a real person, not one of those robotic persons who just come, say something and goes away.

But do not get too personal right. This is all said and done. A teacher student relationship - never get too personal. But at the same time, you do not have to get personal, but you can talk about personal aspects which are appropriate; your likes and so on and so forth these are appropriate. And therefore, it helps to project you as a real person. That balance takes some time to achieve. The other important aspect is story telling. What I am going to do is to stop this lecture here, we have been at it for quite some time. Let us let us stop the lecture here.

And in the next lecture, let me take up story telling. This is also in the same chapter, as going from lecturing to making students learn. Story telling is a very important aspect. Let us meet the next time. See you.