Introduction to Research

Prof. Prathap Haridoss
Prof. Abhijit P. Deshpande
Prof. Renganathan T
Department of Metallurgical and Materials Engineering
Department of Chemical Engineering
Indian Institute of Technology, Madras

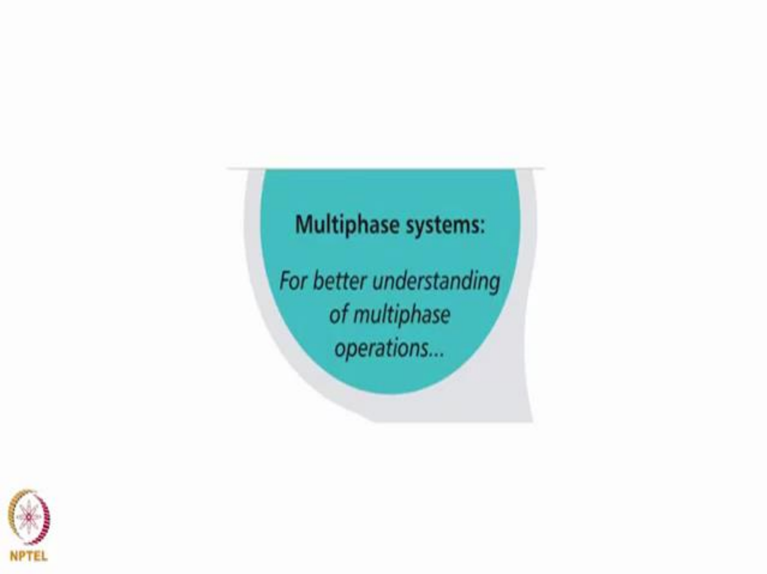
Lecture – 33
Research in Chemical Engineering

Prof. Prathap Haridoss: Hello, so in this module we discuss Chemical Engineering. So, to discuss Chemical Engineering, we have 2 faculty from the Department of Chemical Engineering at IIT, Madras, who has joined us this morning. We have with us Prof. Abhijit Deshpande, he has a PhD from the University of Washington, he is been a professor and a faculty here at IIT Madras for 20 years now, so he has a lot of experience in teaching and carrying out research in an academic setting, his areas of interest ..research areas of interest include polymers and rheology. We also have a Dr. T Renganathan, he has a PhD in Chemical Engineering from IIT Madras. He is been a faculty here and associate professor here and been with us as a faculty for 6 years and he is also guiding all the incoming PhD students through their initial training processes here, as they get on to carrying out their research in the department.

Between them they have a lot of experience in guiding students, in handling them, leading them through the initial years here and so perhaps they will be able to share their experience with us and tell us a lot about what chemical engineering is about. So, let me begin with this general question, what are you know, of course chemical engineering is one of the old fields of engineering has been around for a long time, what are typically considered as a traditional areas of research which have been there for a very long time in chemical engineering?

Prof. Renganathan T.: Okay. That traditional areas would be based on, let's say fluid flow heat transfer, the courses which are very much familiar to the undergraduate students, Fluid flow when I say applied to systems where you have multiple phases present, simultaneous presence of let say a gas bubble sparged in a liquid column which you called as a bubble column.

(Refer Slide Time: 02:11)



And just like student study fluid mechanics in undergraduate, we study the fluid mechanism in multiphase systems. There has been on traditional area a lot of work was has been carried out across all IIT's, there was also on traditional areas. And then not alone fluid flow, mass transfer are occurring in this equipments the heat transfer and then students to be familiar with the residence and distribution studies. All these are aspects are carried out in detail for these systems.

Prof. Prathap Haridoss: Okay you yourself are an expert in multiphase systems and classification.

Prof. Renganathan T.: Right, right.

Prof. Prathap Haridoss: Okay so, these are, you may mention about traditional areas. So, an incoming graduate students would, if they picked up these kinds of areas you know to work in then there is a lot of pre-existing literature in these areas spread across several years.

Prof. Abhijit P. Deshpande: Also I wanted to add that sometimes these very traditional areas are very essential for a very new topic also. For example, fluid flow in a micro fluidic channel, so again we have lots of chemical engineering researchers doing work on this, they are actually doing fluid mechanics, but they are doing it for a micro channel where again multiphase may be involved or we have also heat transfer where micro wave heating is being done for a very large scale sterilization.

Prof. Renganathan T.: Fluid flow in a fuel cell, there also flooding phenomenon is involved the flooding phenomenon.

Prof. Prathap Haridoss: Yeah.

Prof. Renganathan T.: Is involved even in a traditional column and absorption column or you are flooding even in enough fuel cell. So, the field of multiphase system are evolved and now applied to newer problems like Fuel Cells and Microfluidics.

Prof. Abhijit P. Deshpande: So, more I mean good way to think about it also may not always be traditional versus novel in terms of area as a whole, but one specific topic may have a more traditional feel to it versus the newer feel to it depending on what precisely you are trying to do in that topic.

Prof. Prathap Haridoss: Okay so, I mean I do understand that you know there is no hard and fast demarcation of.

Prof. Renganathan T.: Similarly, experimentation, for example, like gross measurements where in terms of overall measurement pressure drop and so on. But as it evolved let's say PIV measurements, local measurements were done, so the depth to which measurements were done or even let say even in terms of modeling, reactive level modeling and then CFD level modeling now, let say lattice Boltzmann modeling so, but still applied to a let's say a multiphase system or a fluid flow phenomena.

Prof. Prathap Haridoss: So the difference is in the details.

Prof. Renganathan T.: Details both in terms of experimentation and in terms of modeling.

Prof. Prathap Haridoss: Okay so, I mean I do understand that you know I think across all engineering divisions this is probably similarly true, that you know there is no hard and fast division between old topics versus new topics. But at the same time, I mean are there areas of research that you feel have really come up in the last let's say 5, 10 years which would be, which people I mean consider as a newer areas of research, where may be there is not enough literature from the past and where there lot of new activity going on?

Prof. Abhijit P. Deshpande: Just before we go to the new areas which are there, there is couple of other examples, where it's the old areas with a very new emphasis. And one example is something called Process intensification. Where the idea is that the earlier way of doing chemical processing with multiple operations can be now intensify the process in such a way that we can integrate 2 or 3 processes in 1 operation.

(Refer Slide Time: 05:34)

Prof. Prathap Haridoss: Ok.

Prof. Abhijit P. Deshpande: So, this whole field is called Process intensification where you are doing reaction and separation simultaneously.

Prof. Renganathan T.: Or miniaturization of equipment.

Prof. Abhijit P. Deshpande: Miniaturization of equipment. So, that all of this is actually again you are doing quote and quote traditional work, but actually at a much more efficient way, much more much less energy consumption, may be much more demine in terms of environmental impact. And so these are again examples where processing.

Prof. Renganathan T.: For example, heat transfer as in traditional area inter looking.

Prof. Abhijit P. Deshpande: Yeah.

Prof. Renganathan T.: Pool boiling flow boiling etcetera, but now same thing applied to microwave heating as taken a new view and so on.

Prof. Abhijit P. Deshpande: And, similarly we also have systems and control where again the controls that we can do and the systems we can analyze has with our mathematical computational tools, we can do far more now compared to what we could do earlier and the decision making that we need to do in a chemical plant again we can do it in much more integrated scale, we can borrow ideas from signal processing that electrical engineers have developed for communication and then use them here. So, again this is again border line of novel and traditional area.

Prof. Renganathan T: Earlier it was conventional strategies that have been done, later on evolved to process systems engineering, which involved the whole flow sheet design and then system identification, more on data analysis as they are integration electrical engineering department.

Prof. Prathap Haridoss: Ok.

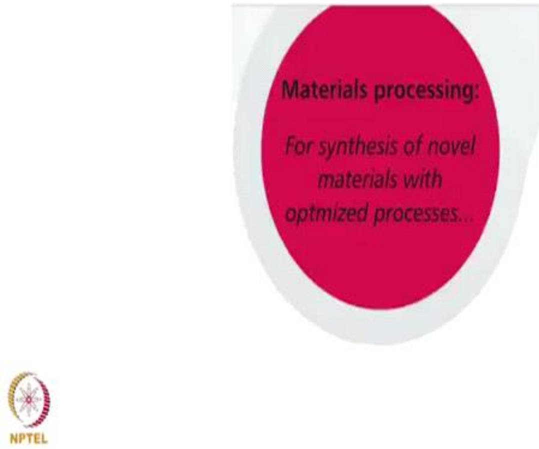
Prof. Renganathan T.: Now applying the same principle to what distribution it works, fuel cells control of micro fluidic devices, but still the principles are all controlled. But now evolved to more encompassing, more domain; same time apply to modern tools, modern devices and so on.

Prof. Abhijit P. Deshpande: Talking about new areas, we generally in chemical engineering extremely exciting topics are being researched. For example, polymer which we use for insulation, but these days devices are being made from conducting polymers.

(Refer Slide Time: 07:20)

Colloidal systems are being designed for photonic or drug carrier applications. Drop drying, which is a simple fluid mechanical technique is being used to diagnose materials of course with all the emphasis on smart devices, novel electrode materials are being prepared using nano materials. Excitingly also we are using bio processing, so using microbes to actually prepare nano particles. So these are all exciting new areas where chemical engineering is doing more and more research these days.

(Refer Slide Time: 08:11)



As important to do research on these materials; how to process these materials? How to optimize them? Is also equally important and for example, one important area in the last 2 decades or so has been how to process materials for semi conductor applications? We also have more and more foods coming from an industrial setting instead of being done in our kitchen. So, large scale processing of food materials, for example, in micro wave heating thawing of materials is an important research area.

And all of the topics that we have talked about so far have been about information gathering as well as analysis at large scale, but chemical engineers by definition can deal with atoms and molecules and chemical transformations. So it is natural that we work on molecular scales and very powerful simulation techniques are being used at the molecular scale to understand material behavior and their processing.

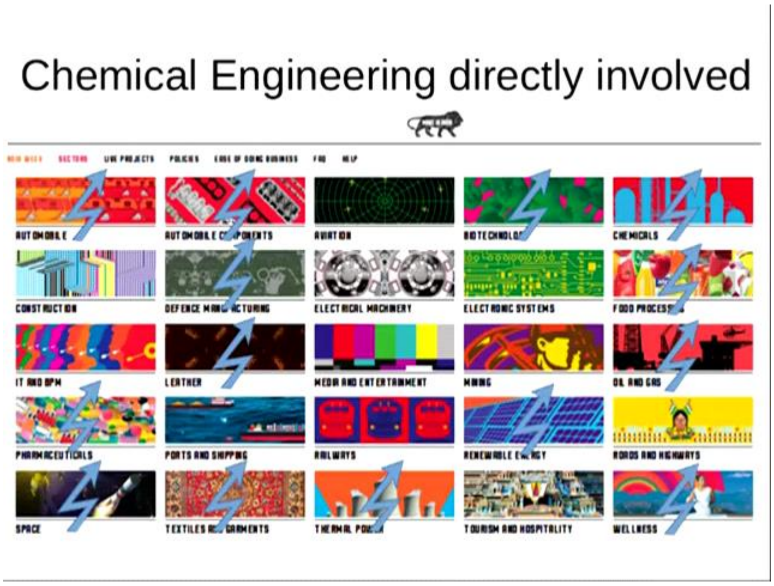
Prof. Prathap Haridoss: When you look at post graduate degree like MS or a PhD especially in engineering, there is always this perception and partly true that you know we think of the people who complete these degrees as being experts in that area. So, I mean may be that lends itself more naturally to an academic setting. But what degree is industry interested in what the research activities that go on in the general field of chemical engineering?

Prof. Abhijit P. Deshpande: Fine, yeah, if you look at that the best way to look at that is because we have lot of talk about make in India now, and if you look at the sectors that sort of have been identified as key sectors where India should make an impact and lot of investment is being sort.

(Refer Slide Time: 09:49)

And so, if you look at, there about 25 areas which the Government of India has identified and if you look at the sectors where chemical engineering is directly involved.

(Refer Slide Time: 10:04)



We have fair bit of, there is oil and gas of course, pharmaceutical, chemical sector itself. But we have also the areas like biotechnology and even wellness where it's let's say research related to the traditional medicines, so in all of these chemical engineering is involved in terms of raw material processing, separations and then the process engineering and then finally getting a material of a desired quality. And even areas such as avionics and electronic system there is significant research that is going on.

Let's say for in our department, where the people are looking at sensors, either for a environmental application which is a very chief sensor or looking at sensor in terms of trying to replace an artificial muscle where it's both sensor as well as actuator. Such applications are being done even in chemical engineering and so all of these are industry relevant topics.

Prof. Renganathan T.: Example related to energy ozone, gasification, biolysis then micro reactors are supplied to pollution treatment devices although then CFD studies applied to various chemical engineering equipments and other equipments as well.

(Refer Slide Time: 11:12)

Prof. Prathap Haridoss: So, I think scale in sense very large chemical industries out there you know in both nationally and internationally.

Prof. Abhijit P. Deshpande: Internationally.

Prof. Prathap Haridoss: So, I think many of the activities you do, I think really help them move to in your levels of sophistication and how they handle it there.

Prof. Abhijit P. Deshpande: Yeah.

Prof. Prathap Haridoss: So, if you look at you know incoming MS, PhD students and you know maybe the things that they are anxious about, the things that they are unfamiliar about and so on. I think may be in school or college, undergraduate college there is clear metric, on you know how well they or how successful they are, there is always an exam, there is a grade and there is a mark and so on.

Now, when they get on to it early to the especially to be early part of their research carrier, I think many things are not very clear. So, in your experience I mean having both done a PhD and now having guided many students, having spent a lot of time in the academic setting. What could you recommend students to look at, as ways of understanding their progress in research or their success in research? How should they determinate? How should they evaluate it and you know how should they you know look at it?

Prof. Renganathan T.: Okay so, when a PhD students or graduates, at least the way in which we look at it, is whether he has a clear understanding what he has done, the bare minimum. And then he is able to explain that to others at different levels, maybe his own friend present before professionals, working his area that something bad. Then next stage maybe to identify the scope of the work he has done, you should know the limitation.

Any research is not complete, so you should know the boundaries with in which he has done his work. That immediately sets him the goals for his future research as far, so can identify research topics or research areas to work on and then of course, he is able to carry out research independently so that he can take up students when we go and takes academic carrier especially. All those are good metrics which you can say that it is a successful researcher at the end of his PhD program.

Prof. Abhijit P. Deshpande: Yeah. And also, of course given that in research is important to communicate our ideas, we have to have publications that come out of research. There has to be a fair representation of his ideas in the open literature by communicating, some papers, having some papers at the end of the PhD.

Prof. Prathap Haridoss: So that I mean sets the standard in terms of, it is a piece of work that they have carried out, that is peer-reviewed, accepted by the peer group. Fine okay so, again as I mentioned earlier typically, students finishing MS and PhD are considered you know experts in that area. So, what sort of positions do they tend to get? What sort of I know placement or positions do they tend to get after an MS or a PhD degree in chemical engineering?

Prof. Abhijit P. Deshpande: So, it varies basically, further research work so, for example, MS going on to PhD or PhD going on to post doctoral work is one set off. Then the other is in terms of academic positions. So, master students can also join a teaching position and a PhD student can also join an academic research teaching position and then industrial R and D. So, the mix is usually all of these depending on some years for example, in 2005 period my perception was lot of them were joining industrial R and D because there was an expansion of industrial R and D in India.

In the last few years, we have see that there have been more academic positions but again that might change, depending on in our lab for example recently 2, 3 people have joined industry again. So depending on the group the topic that you do, as well as depending on the time when you graduate the mix of these 3 vary; further studies, further research, academic position or industrial R and D.

Prof. Renganathan T.: And few even ideas of entrepreneurial thing, my own student is planning to sort of entrepreneurial, identifying ideas to setup his own.

Prof. Prathap Haridoss: So now, see if you look at the mix of students who come into engineering departments in certainly into chemical engineering and so on. So they come from various backgrounds different types of training that they have had and so on. And they are coming into an academic setting which may be has it is own culture and processes in place. Are there specific issues that students tend to face not just in our department, but in generally in chemical engineering as a whole, when they come in for post graduate studies? Is there something in the undergraduate study that is not know completely preparing them for a post graduate kind of study in the chemical engineering? And I mean what sort of approaches then they would they would need to take to you know overcome those shortcomings?

Prof. Renganathan T.: Okay so the first one can be termed in terms of the course work what they take in their institutes and then in IIT. The number of causes may be less here, but then the rigor the level of analysis that is being done in any course is very detailed. So they will have to like climb up to get that level of attending classes and then analyzing and then submitting assignments and so on. So, rigorousness of course work is one I would say.

Prof. Abhijit P. Deshpande: For the graduate school, it is always much different compared to an undergraduate.

Prof. Renganathan T.: Yeah, that's right. Then of course, in terms exposure to the computation and techniques not, let's say MATLAB or a CFD tool or a simulator tool and so on. That is almost like integrated part of few courses here. And having known them was useful to just take on, rather than learned that after coming here, that is one. Now, once again the students are introduced to the lab classes in their as part of the UG curriculum, but there even not pay attention to preciseness, accuracy and repeatability and so on. Just say a lab class, but now when they start up MS program or a PhD program where enough detail attention has to be paid to the experiment, the way it is carried out preciseness reputation. They should hear for that as well, which is we do not expect to UG and graduate to get train for that as part of the undergraduate labs. That is one the way in which they look at experiments it should be different.

Prof. Prathap Haridoss: There is something of retuning their mind set approach.

Prof. Renganathan T.: Yeah, yes.

Prof. Abhijit P. Deshpande: One other important retuning that has to be done is at 2 different levels, one is always going back to an undergraduate course as a starting point to think about any set of research area and all that that may not be always very useful. So, like we already said. So, say I want to do in heat transfer may not be a very useful idea because what you have to see is, what are the research area related to heat transfer and they might require very different fields for you to work on that topic. So even though notionally it might seem like there is heat transfer involved in the topic it may not be related to the undergraduate subject that you have done.

So, you need to delink little bit of your aspiration for research with respect to the course work that you have done. It's a good starting point but it's not going to be, because as we always keep on it is in the book then it is not really research then. Something much more than what we have been exposed to as course work will be involved in research. The other extreme of it is to sort of be completely swayed by the new buzz words of a nano technology, again and that is not again is something we should always, we can examine research topics for their details and things like that and then pursue them.

Rather than get swayed, saying that I am working in nano technology, so by definition whatever I will do will be ground breaking because in the end you will have to, as we said you will have to learn techniques, you will have to understand, you will have to be able to explain, you will have to be able to achieve generate new results and then analyze them and communicate. So all those are very important rather than either just hopping back on one course subject or looking at very hot new area. So, much more holistic, we should be other research, we should be tuned to looking at in a more holistic way rather than pigeon holing our own research topics or our own research areas.

Prof. Prathap Haridoss: Okay so, I been I think in this all the points that you made about you know how the view of a student should change in evolves they become a graduate student. I think one of the things of in a post graduate study, life of a post graduate student is the fact that you know a fair part of your learning process, part of your performance is also got to do with how well you interact with a rest of your group, how well your interact with your advisor and so on. So in this context, in sort of in a mundane way, how often you think students should really meet their advisor? Is there like a guideline that you gave and what are you looking at in this kind of scenario?

Prof. Renganathan T.: When you come to the meeting advisor, the frequency of meeting changes as the progresses along the program. So, let say initially in 1 year he may be meeting very frequently and then for everything he may just go to the guide and so on meet him. Other than that, of course all faculties usually have weekly a formal meeting with the students, other than that of course he can meet him any time whenever required and so on.

So as the years progress and then the number of meetings gradually come down and then also in the student point of view, he will become more independent not to approach the guide for every small thing, which he comes across and one more point of meeting that I would say is he should go on meet his guide when he is not getting result for a prolonged period of time. The results may be wrong that may be interesting may would have happened there. So, the guide based on is such experienced can identify whether it is a wrong observation or something interesting. Students should not be in a shell that something wrong, he should not be afraid to go and meet the guide. So, these things I would say.

Prof. Abhijit P. Deshpande: And also, the other big situation that we are in as a researcher is actually we will have not just the advisor but a whole lot of other people working around us. So it's a good idea to develop this habit of talking to your own other research scholars because that is a good sounding board also. So, not only should we meet advisors very regularly as Ranga mentioned and every week is probably very good in the beginning and maybe it can become once in 2 weeks if let say you are progressing very well and you are doing very well.

But once in a week is certainly a good idea, but also it's a good idea to every month at least sit down with one of your colleagues and then try to discuss and try to see some broad results, what you have got, are you thinking along in the right direction. If you are planning a major initiative may be just discuss with 2 other students in the lab and see you know this is what I am thinking about, before I meet the advisor I want to check with you. So such exchange of idea is not only with your advisor but with your peers is a very good idea.

Prof. Renganathan T.: And it depends on the guide towards end, instills him more confidence in him that he can do independent research. So that he can do independently, in order at the same time develop some more ideas for his future research and so on.

Prof. Prathap Haridoss: You are recommending that the slowly evolve to becoming independent that something that they should look forward to.

Prof. Renganathan T.: In fact, you are asking how do you judge? One judge is successful he is. Suppose, he knows more than his guide at towards the end that is big mark for us that you are happy that yeah, yeah.

Prof. Prathap Haridoss: So, I think we will yes I would like to conclude by asking you very general question, there are lot of students out there who are looking forward to careers in research, research in chemical engineering. What are your words of advice for an aspiring chemical engineering post graduate student?

Prof. Renganathan T.: As our Abhijit was mentioning, we work in the recent areas of chemical engineering but the principles involved are still based on our fundamentals of fluid mechanics mass transfer and so on. Our interview process, selection process we do test the fundamentals only. Of course, first we have a short listing and then a written test and then interview process both the written test and interview process test their fundamentals. So, it's good for them to be very good at by the fundamental so that they are successful in that machine process and that is one major. As he said they should know distinguish between the fundamental courses and the research areas what we are we are doing in. It is better to go through a website and then get familiar at least have some glance, what kind of research is going on, so that they know that they should not be looking from a fluid mechanic a master sensor point of view, but look at topics where this principles are involved.

Prof. Abhijit P. Deshpande: Yeah, my general advice is not specifically related to students per say, but generally brought comment about chemical engineering as a discipline saying that you know chemical engineering is one of those few engineering areas where the molecules are still at the center of our considerations. So therefore, going from molecular scale all the way till engineering scale, wherever molecular transformations are involved chemical engineering will be involved.

With that in mind if you approach chemical engineering research you can see boundless sort of opportunities and that is why we showed you how a make in India also out of 25 area, there are 13, 15 areas where chemical engineering is centrally involved. So therefore, if you are sort of looking and considering career in chemical engineering research go for it I would say it is going to be very promising with all the developments that are happening in processors, materials, and energy everywhere chemical engineering will actually play a role. So there will be lot of scope for R and D in chemical engineering in future also.

Prof. Prathap Haridoss: Okay Great, on that positive note; Thank you Abhijit for joining us. Thank you Ranga for joining us and sharing your insight on us.

Thank you.