Introduction to Research
Prof. Prathap Haridoss
Department Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture – 20
Technical Writing

Hello. In this class, we are going to look at with some detail at this topic on Technical Writing. Now, technical writing is a very important part of doing formal research and that's the reason why we are going to spend this class looking at technical writing. It's also important to go through this class because technical writing is very different from other forms of writing. And so, through this class, I will try to highlight, what is special about technical writing, what are aspects that you should be aware of, that you should pay attention to as you do technical writing, so that, it's something that comes off well when you attempt to do it.

Okay so, when we say technical writing that's actually a more general phrase that I have put there. More specifically, what we tend to do is to publish - as it is called - publish articles in journals okay. So, there are journals in which we publish articles. So, this is what we refer to as technical writing in the context of research okay. And incidentally, while I go over this class, there is one very good reference book for this, which I have personally found very useful. So, I would encourage you to take a look; it is called The Craft of Scientific Writing by Micheal Alley and it is a Springer publication book. So, if you get a chance, please take a look at the book. It's a very nicely written book which very methodically explains to you, what is scientific writing and how you go about it. Actually, it talks about the broader range of scientific documents that one might write.

In this particular class, I would focus more on journal based writing, but this talks of a much broader range of kind of writing that scientists might do including publishing in, you know, more general audience kind of articles. So, if you get a chance to take a look at the book, it's a very well written book, very easy to read, doesn't get it into too many difficult technical terms, you can follow it very smoothly, and benefit from it, and implement it pretty nicely. So, that's something that when you get a chance take a look. In any case, we will go over this topic in a more focused manner with respect to journal

articles. So, that's what we will do.

So right so, one of the things that we will look at, first of all, is we will have to revisit some of the ideas that I have presented right at the beginning. Towards the end of the class, we will look it again, but just to get you an idea of what is involved here. When you say a journal article, there is a certain process involved. So, it is very different from the process involved from various other things; so that's why I thought I should first highlight the process for you and then we will get on to the topic by itself.

So the general process is this. So as a researcher, you run some experiments in the lab or you run some simulation in the lab and you get some results. So, if you have found something new, so that's one of the important underlying concepts here. That it is something that is new; new with respect to what? New with respect to all the body of information that is out there okay. So, these are things that we will have to revisit in a moment, but I will just tell you in any case. So, it is something new that you have discovered in your lab and that you want to communicate it to the general scientific audience out there okay. The process by which you do that is called as journal article.

So, you write an article in which you write, you know, this is the experiment you did; these are results you obtained; this is the significance of the result that you obtained; this is the context in which the result has to be understood, and then, you send it off to a journal. So, there are many journals out there. You have to pick a journal which pertains to, which publishes articles in the same area that you are trying to publish, and then, the journal will receive your article. It will then send it to some number of independent experts in that area. So, they don't just publish it simply because you have sent it, they will send it to some bunch of independent experts, who will review that article, who will look at the article that you have sent, and then make an assessment - whether that article indeed represents something new in that area; is it something significant in that area? Is it something worth publishing? So, they will send their recommendations. So, they may say, you know, that it is very good, you can directly publish it or they may say, no, specific things we need some clarification on, and once you provide that clarification, it can be published. So, they will give some recommendations; you will have to respond to those recommendations. And when that process is complete, if the result is positive -

meaning the reviewers, those people who are the experts, who reviewed your article, if they are happy with the article – in that it represents new scientific work and it is significant work, then they will recommend to the journal saying this is worth publishing. So, then your article gets published; it gets printed. These days with online journals, with many journals having online versions, it will first appear on an online site as an official publication, as an official paper published in that journal okay. So, that is the general process.

So over the years, people have been publishing like this in established journals. So, journals get established in specific areas; so, there could be one in mathematics, there could be one in physics, there could be several in physics, several in mathematics, several in material science, and even in material science, there may be something related to welding, there may be something related to nano materials and so on. So, for various topics, there are journals okay. So, in those journals, historically, articles have been getting published in a very specific area okay. So, that constitutes a body of formal information that is available of experiments that have been conducted by various researchers all over the world okay. You may do research in a lab which you have never ever informed anybody, so that is not something then that is formally available for people to refer to; only when you publish in a journal it is something that other researchers can look at.

Similarly, when you do research, you look at these same journal articles published by other researchers, so that's the way in which we first gauge that we are doing something that is new. I mentioned right at the beginning, that for you to publish in a journal, one of the defining criteria is that it is new work okay. So, how do you first of all prove that it is new work. One way in which you prove that it is new work is you compare it with the work of other researchers in the same area. And you do this comparison using articles published by them. So, you use prior published journal articles to justify your current article okay. This is the process by which you are now comparing your work with previously published journal articles. And if it compares favorably, if there is something nice in it, something new in it, then it adds to that same body of information and your article also now becomes a journal article okay. So, that is the process. So therefore, journal articles, and therefore, technical writing is a very important aspect of research.

And as researchers, this is one common activity that we participate in.

In fact, in a very general sense, one of the measures of scientific contribution is the journal articles that you publish. It is not the only way to measure how good your work is, but one of the measures is how many journal articles you have published, in which journals you have published because some journals set standards, which are considered very high, and therefore, it's considered very difficult to publish in those journals. And so if you publish in those journals, it is automatically assumed that you have done a very high quality work okay. So, that's the general context in which we talk about publication in journals.

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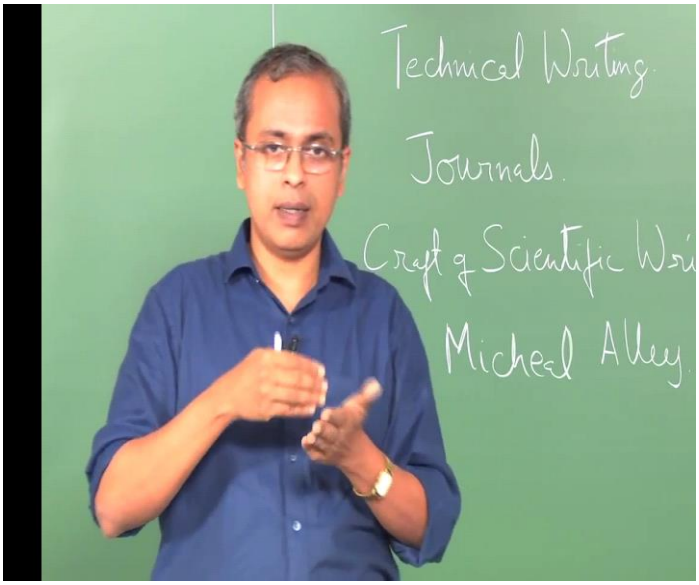

So now, one of the issues that we… okay so, we are now going to talk about this journal article process, and the journal technical writing process, and some of the details associated with it, but before we do that we will take a step back, and I will just, very briefly, introduce to you things that you already know. And, the reason I will do that, is it is exactly for this reason - that you know these other things that I am going to show you - that technical writing is challenging. And that's the reason I am going to show them to you.

So as a general person, many of the things that you read are different forms of literature. For example, here are a set of story books. So, these are novels, famous novels which you have lightly read and there are many more. These are old classic novels, there are many more recent novels and so on. This constitutes a form of literature. This is available; you can buy it; you can read it; this is also published okay; so, this is published literature. The other thing that you are very familiar with on a daily basis is newspapers. So, you get newspapers everyday, delivered to your home or to your office, and we will tend to look through them, leaf through them, read them, and there is a wide range of different types of articles that appear in newspapers. This is again something that you are very familiar with.

These are magazines okay. So, this is again another form of literature that you are likely familiar with, and you have seen many times. This is just some samples that I have picked up, but there are many other journals and many other magazines that you would have read. So, these are common place literature okay; that's commonly available and this is the kind of written material that we are more familiar with. Growing up, these are the kinds of things that we read okay. So, I have some more examples here. So, these three, for example here, these are journal articles. So, these three that I am going to show you here are journal articles okay; these are journal articles; this is what we are going to look at in greater detail okay. This is a journal article. I will again get to show it to you detail and also explain various parts of it and so on, but this is a journal article. There are three articles here: one, two and three; and you can look up many more such articles on the Internet.

So right, the reason why I showed you these different forms of written material that you can access, is that they represent totally different styles of writing okay; that is the first thing that you should recognize - that you have literature out there, that you are likely reading very often, but much of that is very different. First of all, they are different from each other, and they are certainly very different from a journal article or a technical scientific document, and most of the time the greatest difficulty that students face is recognizing this difference okay.

For example, if you take a story book, so when you look at story books, the intent is to…

they are all written for various different intentions, but then basically one of the underlying ideas that you see is that the author would like to keep you interested in the book, try to make any person who picks up the book, get engrossed in the book to read all the way to the end of the book. So, that's intended to be something that any person picking up will stick to the book and try and read to the end of the book. So, that's the kind of intent with which the book is written. Often, if it's a mystery novel or a suspense novel, etcetera, specific details will be hidden; specific details will be hidden so that all the way to the end as a reader you are confused, you are unable to latch on to that specific technical detail which they have hidden somewhere very nicely in that story, and at the end, the greatest pleasure that you get from the book is how well they have hidden the detail from you, and you know, you feel thrilled that, you know, it was right there in front you, and you never noticed it, and the author springs the surprise on you. So, that's how a typical suspense novel is written.

Newspaper articles, on the other hand, are written on day to day events that occur. So there the focus is the urgency with which that information is being conveyed to you. The key details that are being presented to you, and the you know, the concise way in which they are able to get expert opinions and put it out there for you; so, that's how a newspaper article gets put together.

Magazine articles extend what the newspapers provide to you; they give you much more, you know, they give you some context in which issues are being discussed. Again, they are written by various different people and presented to you based on the nature of that magazine; so, there may be a magazine on interior decoration, then they only talk about interior decoration articles; there may be others on current events and so on.

So these are all different, they are all written for different audiences, different level of depth, different level of reading patience that they except from you and so on. But one of the things that you notice about these is that they are not necessarily sent to three reviewers to get reviewed, etcetera. They may have some review process, the publisher may have some reviewer process to understand whether it is something that they want to get into, but in a fundamental sense they are not in quite the same way that a technical article is written. Technical article formally requires the multiple experts to review it to

say that it is new work, and that's how it becomes a technical article, but there is more to it. To enable this process to occur smoothly there are various aspects associated with technical writing that we have to become familiar with okay. So that's what we will look at.

Right so we will now look at why we do technical writing? So, why should you do technical writing? The primary reason why you do technical writing is to get credit for your work. Okay so the primary reason for technical writing is to get formal credit for your work okay. As a researcher, as I said, one of the things that people look at is the number of publications you have, as some measure of how much you have been contributing to the scientific community. It's just one measure, but that is a measure and when you publish in a journal, it means that you have done something new, which other people have not done before, which certainly other articles and journals have not mentioned before, and therefore, you are now credited with it.

So in future, people will say that so and so was the first person who did this work okay. So, that is the important reason for this - to get credit for your work and that is the particular reason why you should be coming up with technical writing. Of course, what you do when you credit for your work is also you are informing people about new results. So, that's another important thing that you are doing in the process, so you are conveying information, conveying important new information okay. So, you are conveying important new information.

So what this information gets used for is a different story. So for example, based on what you have discovered some public policy may be changed okay. For example, if people are trying to fund one form of fuel verses another form of fuel, and your work is the first work that shows that one form of fuel is cleaner than the other form of fuel, and you are able to convincingly prove that, then may the government will then fund the first kind of fuel in preference to the second kind of fuel or at least this will be one of the factors that will help them decide. So, there is a lot of public policy that is affected by research that is done. And in all cases, it's not just a person's view that gets taken into account; it is what they have actually published that really makes the difference. So, not only you get credit for your work, your work then gets formally used for other purposes including

forming polices and so on. Therefore, technical writing is important; it is good for you, for your profession. It is good for the scientific community because it helps the scientific community in a systematic manner. Keep track of all the accomplishments of various scientists around the world and to help the scientific community share this information between various scientists, and therefore, it is very important, and then, it also gets used. So this is the reason why you should do technical writing okay.

So now, having understood why you need to do technical writing, we immediately, I think, should address this point - as to why it is difficult? So, why is technical writing difficult? So first of all, I must step back a bit and tell you that most students - most research students - if you ask them, most graduate students, who are writing are in the initial years of their graduate studies or post graduate studies, who are writing their first paper or second paper, most of them will tell you that it is a difficult process. It's not an easy process and there are various reasons for it. The main reason is that most students are not aware of what is required in a technical document, what is required in a journal paper, and therefore, they write things that are perhaps not appropriate for a journal or not in the appropriate format for the journal. And one of the primary reasons for that is exactly what I showed you right at the beginning, is that we are very familiar with things like magazines, newspapers, novels, mystery novels, and so on. Those are the more common forms of literature that we are very familiar with.

And as I mentioned, they all have a different style of writing, and because they have a different style of writing, and they are intended for a different audience, and more importantly they are intended for a different purpose, because it is like that, when you read that, that is in the back of your mind saying, you know, that is how an article is written. I read this book, it felt really good; so, when I write a journal article, for it to be good, I should write along those lines. That's kind of imagination that we end up having, and that's exactly wrong, primarily because that was intended for a totally different purpose, a journal article is intended for a totally different purpose. So, the manner in which we write these two ends up being very different. You may think that may be even though the purpose is different, you can still write the same way; it doesn't work that way. If you write the same way, the journal article becomes a very poor journal article; it will get returned to you saying that this is not the way you write it okay. So therefore, the

familiarity we have with other forms of writing actually works to our disadvantage in the case of technical writing at least till we become aware of it. Once you become aware of it, its fine; you can always read all forms of writing, recognize that they are different from a technical journal article, and then, continue writing a technical journal article. So, that's, therefore, the primary thing that we have to become alert to, aware of, and implement appropriately in our activity. So, therefore, it is generally very difficult, and so mainly because of, as I said examples that we are familiar with, examples that we are familiar with - which mislead us – inadvertently mislead us - because they were just written for a different audience. Unconsciously, we just pick up those habits and try and pass it off to journals, to our technical writing, which doesn't work correctly.

And very high expectations of first draft. If you talk to a graduate student this may be the most common complaint that you will listen to from a graduate student or a post graduate student, who has just started writing papers about their work. They will say, you know, I wrote something, I gave it to my advisor and then he wanted some changes; I made those changes, I sent it back, he wanted some more changes. So, this is the process that goes on and the student feels frustrated thinking that, you know, I have finished the work, why are we wasting time, let's just put it out there. And primarily, the issue is that they feel that the very first draft that they wrote is already fine, all the results are there, let's just go put it out there; but with experience you realize that often the first draft - certainly, the first draft of your first two-three papers, after which you will learn, for sure you will learn how to write it better; the first draft of the first two-three papers that you write tends to be very poorly written from the prespective of technical writing. And therefore, it becomes very frustrating to the student because they don't know that they are not doing it correctly and they end up writing the wrong thing all the time. And it gets corrected and they don't completely appreciate what is being corrected in the paper. So, those are the things that I hope that when you get done, you will have a better sense of what is excepted in the technical paper, with various sections of the technical paper, and also therefore, have a better sense of why there are changes being suggested in your paper and how to incorporate those changes okay.

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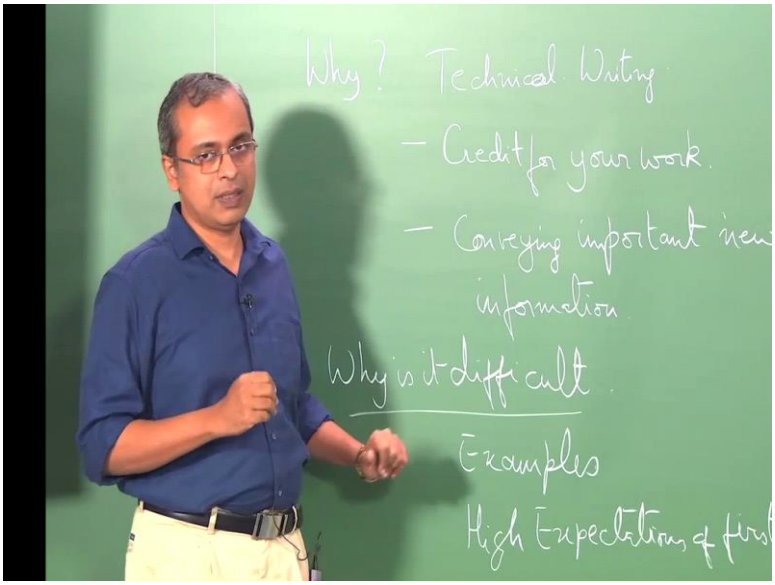

So what we will do is, we will look through this journal paper and look thorough what we can learn from the paper. So one of the points that I will make here is actually a singular, a specific point that I want to alert you to, which if you keep in mind will be the background idea which will affect all the things that I am going to tell you about a technical paper okay. And, that point is simply got to do with the purpose of technical writing. So what is the purpose of technical writing? This is the thing that we have to understand - what is the purpose of technical writing? Once you understand the purpose, all the other details that I have mentioned will make sense okay; so, that's what we are going to do. The purpose is basically, you can say, okay you are trying to convey your work. You are trying to inform some reader; you are informing your reader of some work that you have done okay. So, that is the purpose. And sometimes, in the process of informing the reader, you are also trying to argue something about that concept that you have presented, but in principle you are trying to inform the reader, may be persuade the reader about a particular point of view.

For example, as I mentioned, if you are trying to say one fuel is cleaner than the fuel, you are going to inform the reader of the experiments that you did, and then, use some arguments to say why that the results of experiment clearly show that one fuel is cleaner than the other fuel. So, you are also doing some level of persuasion of the reader; so that

is something that we will look at. So, inform and persuade. But may be the most important thing that you have to understand of technical writing is that you have to do these two things or you have to do all of these efficiently okay. This is the important work: you have to inform the reader of the work that you have done which means you are presenting the data that you have collected; you have to persuade the reader which typically represents a discussion of the data that you have provided. So, those are two different things; that itself is something that I will highlight as a difference. You inform which is to provide the data, persuade which is discuss the data, and then, both of these you have to do in an efficient manner. So, the key here is efficiency; how efficiently are you going to do this process and that is the most important aspect of technical writing. So all the other details that I am going to tell you, I will keep drawing your attention to this word of efficiency okay.

So, with that we will now take a look at the journal paper, and then, we will go over what are all the parts there, and how this idea that I am mentioning starts appearing at different places in the document. Okay so, what we are going to do is like I said, go through some parts of a document, and the reason I also want to do this is to encourage you to keep reading journal papers with all these ideas in mind, and once you understand these ideas, you can evaluate, you can access the journal papers to see if they are all also meeting these criteria. In that process, you will become a much more critical reader of those papers. When you become a critical reader of the papers you become a critical reader of your own paper also.

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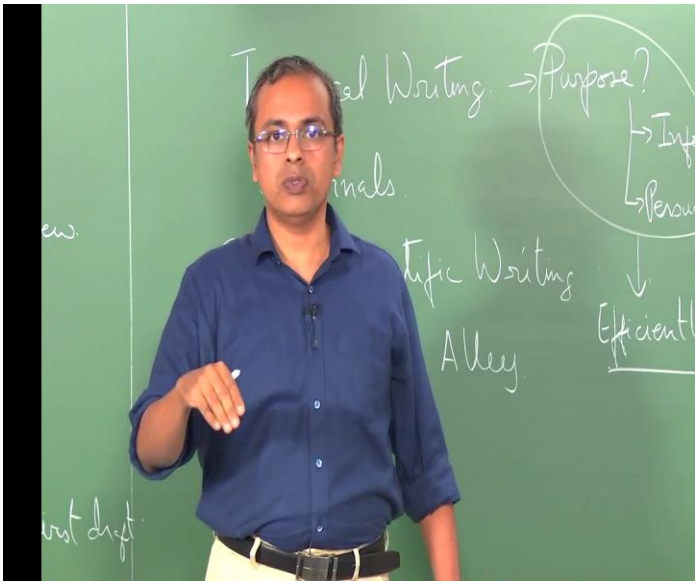

So, then, when you write your third paper or your fourth paper, automatically the first draft of your third paper or fourth paper ends up being much better than the first draft of your first paper or second paper okay. So, it's important to understand these things, look at papers with these ideas in mind, and then, slowly improve your ability to write your own papers. So, that is the thing that we are going to look at.

So now, if you look at a journal paper there are various parts to it. Broadly, you can look at it as a beginning for a journal paper which would consist of a title okay, then you will have an abstract, and then, you will have an introduction okay. So, these three parts constitute the sort of the beginning of your paper okay.

And in this also, there are certain things that are normally expected. So for example, in the title, you sort of indicate what is the area in which you are doing research okay. So, for example, it could be on, say, rechargeable batteries okay. So, you have to talk about the area of research and also what is unique about your work. So, that should come somehow get highlighted in the title. So, if you just write area of research, and you simply say rechargeable batteries, that does not immediately convey to a person picking up the paper what you are talking about. So, if you are talking about, say, a specific failure mechanism, let us say, you know, mechanical failure, you have done some test

on, you know, if the battery – that rechargeable battery - is subject to some mechanical failure. How does it survive the mechanical failure? So, you have to talk about the failure mechanism; you have to say, you know, mechanical failure of a particular version of a rechargeable battery; then that will be something that both identifies the area of research and also highlights what's new about it. So, what is new in that area that you have been working on which is what your paper is about okay. So, a title should immediately convey that to the reader, so that is the thing.

Now, the next point here is the abstract. So, normally if you take a journal paper, on top is the title, and then, immediate next section is an abstract. You can pick any journal paper; you can see it; this is just an example here. So, it doesn't matter if you cannot really read the text that you see here. You see a tile, and then, you see an abstract, and then, you will see an introduction; the immediate next section will be the introduction. So, those are the three that we are talking of here okay. Now, the important thing about an abstract which is where most students have the greatest difficulty is that in an abstract you have to sort of give away all the important research. So, in an abstract, you have to give it all away. So, that's the important thing of an abstract.

So, you will be very surprised to note that in any journal paper that you take, the abstract that you see here, right below the title, contains all the major findings of your work, will be there okay. So, an abstract gives it all away okay, but there is some catch there; it is aimed at an reader who has not read the rest of your paper. So, you cannot assume certain things about the terminology that they may be aware of etcetera, but still it gives all the results away. This is where most of the students have great difficulty, because almost any other form of literature that you read, does not give away all the important results right at the beginning okay, particularly a novel. If you read, if you have been enjoying good stories, the thrill in the story is that the most important result or the most important point of the story is hidden from you. So, only towards the end of the story you get that important point. Here, in a journal paper, the exact opposite is true; right at the beginning you give the most important result away. You don't try to hide anything; in a journal paper, you do not follow the style of hiding your result, and then all the way to the end of the paper, and then suddenly springing the result towards the conclusion. So, what you have thought as a very good style of writing is exactly the thing that is not

acceptable in journal writing okay. So, you have to give your result away. And this point has got to do with it - completely and entirely to do with this; specific word that I highlighted earlier, that the purpose of technical writing is to convey your work efficiently. So, this is the most efficient way of conveying your work. Right at the top of the document you give away your best result.

Now, students typically become very apprehensive that, you know, if I publish a paper, and then write at the top of the paper I have given my best result away, why will anyone else want to read the rest of your paper? So, this a concern that students have, so they become very uncomfortable with this idea that you should give your best results away. If I give it right away on top, then why will anyone read the rest of the paper. This is where again the purpose of technical writing differs from other forms of writing. The purpose of technical writing is not to make people read the entire paper; that is not the purpose of technical writing. The purpose of technical writing is to give information of your work efficiently. Only if a person is interested in more details they will read the rest of your paper, and that is something they accept, we also accept.

So, when I pick up a paper published by somebody else, that's exactly what I am looking forward to in that paper. If somebody else picks up that paper published by me, that is exactly what they are looking forward to in that paper. They want to see the important result at the beginning. If they are also working in that area, if they want to do an experiment which is along the lines of what I have done or want to improve on an experiment that I have done, then they may read more details of it in the paper, but the purpose is not for me to somehow force them to read the rest of the paper. So, up front, when you accept this idea that, that is the way in which technical document is written, it becomes much easier for you; you breathe easy knowing fully well that your best result is out there. If somebody just wants to read the abstract, and move on, and do something else, that's fine. We have no problems with that; we should be happy with that okay. So, that's what an abstract is. So, you give away all your important results here; you give it all away in your abstract.

An introduction talks about what is your work, you also talk about why is it important, you may say something about what is required to understand your work etcetera okay.

So, what is your work. So, you will give some background, you know, I am working on, say as I mentioned, rechargeable batteries. And, why is it important? I mean there are lot of people who are interested in having rechargeable power sources for portable applications and so on. And you also want to indicate what is required to understand your work; meaning, if there is some background information that people need to be aware of. Let's say you are looking at a particular kind of model for rechargeable batteries, and you are using that model to assess your data, then you mention that saying that, saying that, in this paper we are using this particular model. So, that alerts the reader that if they want to understand your paper, they should be familiar with that model. They may need to go on look up some other paper or may need to look up some other book to make sure that they know what that model is. So, that they can understand your work.

And also, when you talk about, why is it important, this is another specific place where you draw the attention of the reader to other published literature papers, other technical papers in that area, saying that you know, so and so researcher x has done the following work, researcher y has done the following work, and researcher z has done the following work, and then your work. In between all of the important work that other people have done, a particular aspect has been neglected; somehow, they have not looked at a particular aspect for which you have now created some new nice experiment and that is why your work is in that area. So, that is where you compare your work with other journal articles okay.

As I mentioned, in journals that is the process. To publish, you have to first of all convince yourselves and convince the reviewers that you have done something new. So, this is a important. Why is it important is the location where you try to highlight that – that how is it that your work is new? You compare it with what is already in the literature, you put it down there in your paper itself, and then, in that process you convey that you know you have done something new.

In the end of the paper, at the back of the paper, you will have a list of references. So, typically, if you take the last page of a journal paper, journal article, there will be references. So, those are all articles that you are referring to in your introduction, in your

experimental details, etcetera. You are referring to those articles, so that you can convey what this idea; so, that's how you link up with other work that is done. So, this is the beginning of the document; this is the title; the abstract that gives everything away; and then, the introduction which mentions – what's your work? Why is it important? And then, what is required to understand your work.

And then, you get to the middle of the document. The middle of the document, basically, normally much of the work that we do, if it is experimental work, it will consist of..It will have your experimental results. It will have experimental details, it will have results, and it will have discussion.

You may have a modelling kind of work, so in which case you will talk something about the theory behind that model. How you have gone about setting up the model? How have we implemented the model? And so on, I have put down something here which relates more to experimental work, but you can correspondingly think of some parameters, which would be relevant to modelling. So, normally, many of the experimental papers will have, you know, experimental details. So, that they will simply talk of - what is the experimental set up they had, what are the different standard techniques that they have used, if those techniques had particular parameters that had to be set at some particular values - they will mention all that. So, all of the details of how each experiment was conducted will be mentioned here. Again, the intention is to make it clear enough that somebody else who wants to learn your experiment should be able to look at your experimental details and run a similar experiment. So, you hide nothing here, you make every detail of your experiment clear okay; unless you are trying to patent something, in which case, you indicate that it is being patented and there are some details which you have withheld, but that has to be very clear. Normally, the experimental details are written clearly enough that somebody else can reproduce it.

Then you have results and then you have discussion. These are two separate points; lot of students actually don't understand this difference. A result is something that any technician operating an instrument can convey to you okay. For example, if you are looking at say, the hardness values of ten samples and with, say, decreasing grain size. So, if you find that, you know, the hardness is increasing as you decrease the grain size

then that's simply a result. Okay so, that's simply a factual statement of data. So, a result is simply a factual statement of data. So, you see a trend that is going up, you simply say that I see a trend that's going up; you see a trend that goes up and then comes down, you can mention that I see a maximum in that trend. So, these are all things that any person looking at the graph can mention, can immediately recognize. So, a result is typically a statement of fact okay, there is no judgment there. It's simply a statement of fact. So, strictly speaking, if you have written your result section correctly, there can be no controversy on the result. Meaning, if I look at your results and somebody else looks at the result, they cannot have two different conclusions because you have simply stated a fact and the facts are as straight forward as that as something is a straight line, something is a curve, something shows a maximum, and something shows a minimum. So, that's a result. So, that's is one thing.

A discussion is where you try to understand the implication of your result okay; so here you are making some argument about that result. When you say that you are seeing a maximum, you are making an argument as to why is it that you are seeing a maximum. You may say that there are two parameters and conflict, one parameter is causing something to go up, another parameter is causing the same thing to come down, and as a result when the second parameter takes precedence, it starts causing the curve to come down. And so, it will be something that you are analyzing, that you are using all your scientific background to analyze and come up with the answer. So that is a discussion. And, in general, the idea is that result is something that nobody can argue with you about, discussion is something where different people can have different opinions. So, a discussion is to some degree an opinion. It is not some arbitrary opinion; it is based on some scientific background and some scientific analysis. So, you are going to apply thought in coming up with your discussion, but in general, it is something where you have much more freedom in what you are doing okay.

So, normally, this is the middle of your document and you can actually adopt different strategies for this document. So, for example, one standard strategy that many people employ for a document is simply chronological, which simply means that I did first one particular experiment, then I did another experiment, then I did the third experiment, that is how you present your result – that's chronological. You can also say that, you know,

for example, you are discussing say something about a nuclear reactor. So you may want to start from in terms of temperature, the outermost shell of the reactor is at room temperature, where let's say something outside the nuclear reactor, all the way outside, is at room temperature. Inside you may end up seeing a temperature of several thousand degrees C or tens of thousands of degrees C, even million degrees C (may be there right inside)). So, you can follow temperature, you can go layer by layer, and you can follow temperature. You can follow a particular variable, and you can say, you can do a spatial approach, you can say, you know, outer most; it is going to be something all the parameters, materials, etcetera; outer most are going to be something. You go inside, inside, inside, the materials change, the conditions change, and the implications change. So, this is something that's spatial.

You can also look at something else like the variation of a particular variable. Let's say, you have some fluid flowing through some particular process. You can just simply look at, say, the viscosity of the fluid. May be the viscosity of the fluid changes based on the conditions that is experiencing at different locations in its path; so, you can follow that. So, you will have some schematic in which you follow that variable, and you put up the key values of the variable at various places, and you imply indicate what they are. So, my point is the middle of the document has a purpose that is the primary, you know, the greatest detail of your work is presented in the middle of the document, which is summarized in your abstract, but it's presented in the middle of your document. And you have different options available to you, how you can go about to the middle of the document. I mentioned about the spatial way, you can follow chronological way, you can follow the flow of an variable. Lot of different ways in which you can see it happen, when you pick up a journal paper you can also understand that is how they are doing it. So, that is the middle of the document okay.

And then, finally, you have the ending of a document okay the ending of the document, which is typically the conclusions. So, conclusion of your document, where, again, you conclude the major results of your work. So, now, in some ways, the ending and the abstract have similarities; both of them show the results of your work, they summarize the results of your work, but there is one difference. An abstract is aimed at an audience that has never seen your work before; so, therefore, some of the terms that you use.. you

have to be careful with what terms you use here. You have to be little bit more restrained on what terms you use here. You cannot use abbreviations which you have actually mentioned later in your work. It helps to keep it in a manner that any new person reading it will understand what's going on here. So, that is the thing that you have to remember that the reader has not read your work.

In an ending, it's different; you can assume that the reader has actually read through your paper you have greater of flexibility in presenting your work towards the ending, still you are going in a concised way, mention all the important results. And you can also give a future perspective. You can say that you know, for example, I mentioned that those two comparisons between two fuels and that one fuel is better; you can say that one of the additional aspects that needs to be looked at is the operating condition of the fuel. To see if the fuel that is better can be made even better based on the operating condition that you are working on. So, some future perspective which you don't necessarily throw in the abstract okay. So that's how the abstract differs from the ending. So, these are the major things associated with the technical document, and in all these cases, as I mentioned, the idea is to convey your work efficiently right. So, the idea is to convey it efficiently, so that's how in each part you will find that theme being repeated. We don't want to waste words and so on.

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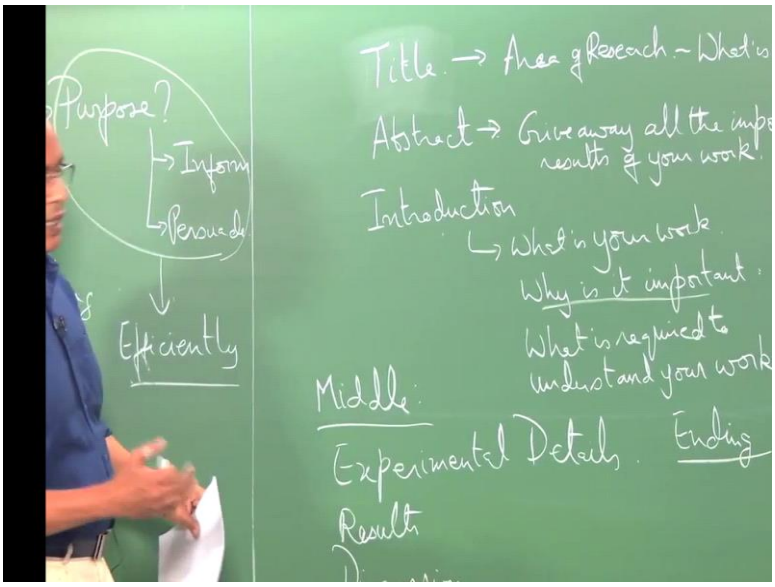

In the entire document, there are couple of things that show up which affect, you know, this idea of efficiency throughout your document. And those two are: language and illustration okay. So, language and illustration are two parameters that appear in various parts of your document; language and illustration are two parameters that appear in various parts of your document and they are very critical in this idea of efficiently conveying an idea. So, for example, with respect to language, again, in common literature that you read in, say, novels and other forms of literature, may be poetry you read, there is less emphasis on trying to write simple straight clear sentences. People would like to write some flowery language, etcetera, and so when you read that kind of literature, it's the wrong example to use for a technical paper.

In technical paper, you want to keep it very straight, straight forward, clear cut description of what work you are doing. Some of that common mistakes that people make are first of all, writing very long sentences. A simple gauge of whether a sentence is long or not is that when you read the sentence, you should not have to, when you reach the end of the sentence, you should not have forgotten the start of the sentence; it should not be that you read all the way to the end, and then, again, suddenly you are not sure how the sentence started, so you go back and read the sentence again.

Basically, if you write it such that the reader can read it efficiently, in a single reading they can go from sentence to sentence to sentence..So, they can keep doing that.

And other mistakes that people make are using phrases such as it is obvious. So, those are considered to be improper and arrogant ways of saying conveying some research. So, ideally, those are phrases that you should avoid. So, language is something that you have to pay attention to, which with experience you will gain as read papers on what kind of languages is acceptable, but basically you have to keep it simple. Keep it simple, keep it clean, so that a person reads a sentence, understands exactly what you are trying to say in the sentence, and moves on to their next sentence, and they are not forced to reread it again.

And then, there is illustration, illustration you have wide range of illustration available to you. You can have graphs, you can have schematics, you can have photographs, you can

have charts of different kinds, you can have micro graphs of different kinds, etcetera. So, you have to judiciously select - what is that form of illustration that best conveys the idea that you are trying to convey okay. Often, putting an illustration together is the place where you actually put in your creativity to come up with a very interesting and nice way of efficiently conveying the information. You have a large body of information of experiments conducted in various conditions, but if you make a very nice simple table which summarizes all of those experiments, so that when a reader just looks at that table, at a quick glance they get an idea of all the range of parameters that you have done, and what are the important points that you are trying to highlight, then that makes a big difference in the reader's ability to read the rest of your paper. You can keep referring to that, you know, table often; say in table, this table such and such, you have got a particular item highlighted and the description that follows in that paragraph is relative to that item. So, as they read the paper, they can use this table as a reference, and when they get done, this table will give them a very good way of summarizing that result, and also to agreeing with you. You know when you are trying to make some argument based on a wide range of results, this table helps them focus on your argument from your point of view okay. So, therefore, making that illustration is very important and you would also understand the level of complexity of the illustration.

So, for example, so sometimes you have to make a judgment. So, you would… let's say you are trying simply say that there is a solar panel. So, you have some satellite and associated with that there is a solar panel. If the only purpose of this schematic is to convey that a particular satellite has two solar panels, and they are deployed in this manner, then a schematic of this nature is sufficient, if that's all you are trying to do. On the other hand, if you actually put the photograph of the satellite, you may find a lot of wiring, etcetera; other details - you will have the reflective surface on top of this satellite, this will have some shade associated with it, some other shade associated with it, lot of other information will be there. There will be plenty information here which will then be very distracting okay. So, this may not even be uniform, it may be of some odd shape and so on. So, lot of other detail is there which when you see can be distracting. So, you have to decide what is the kind of illustration that very efficiently conveys that one information that you are trying convey to the reader.

So, that is the reason why you have to select whether a photograph makes sense or a schematic makeas sense, whether a table makes sense or a graph makes sense. These are all the ways in which you have to… because a table will give a whole range of numbers right. So, you have lot of different numbers here. So, if you have lot of different numbers in a table, sometimes that does not immediately convey the idea that you are trying to say. On the other hand, same table when if you have plotted it as some kind of a graph, you know, and it showed you this; this graph is in a much better position to convey the information that there is a maximum, than this table is in a position to. If you just have various x, y values here, a wide range of x, y values here, you know, you have a 4 by 4, 16 coordinates you have here. If I have put 16 coordinates down there, of x and y values, that does not immediately convey that there's a maximum; whereas, the same 16 points, if I plot here, if I have all those points plotted here, and I show a maximum, that's a very nice way of showing that there is a maximum. So, there is a choice, you have a choice and you have to intelligently use this choice okay.

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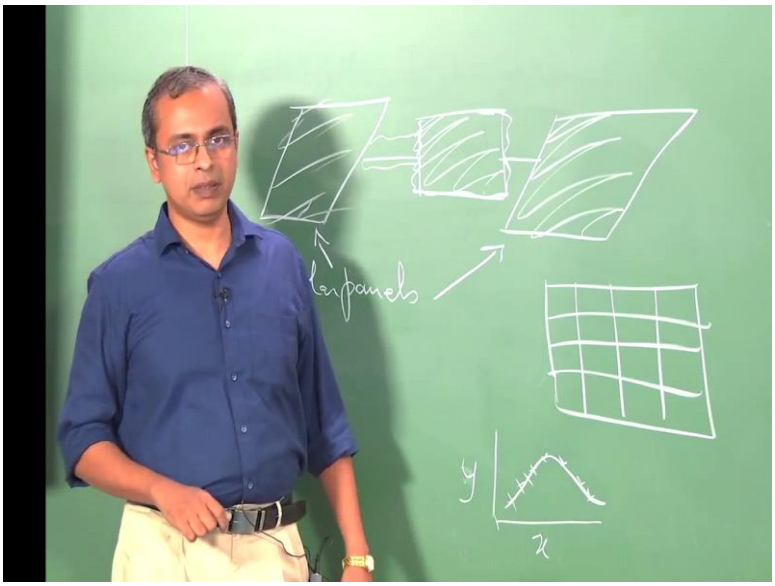

So I think to summarize, we have now spoken today about technical writing. I have compared technical writing with other forms of literature and writing that you may be familiar with. Tried to highlight what differences are there between these different forms. We have also walked through all the various parts of a technical document and you have

seen that there is a beginning, there is a middle, and there is a ending, and then there are certain things that are excepted out of each of these points. And your familiarity with what is excepted is what makes your writing better. If you become familiar, then when you write a technical document it becomes easier to make the document closer to what is expected okay.

So, I hope that this information will now help you become a more critical reader of technical documents and will also help to become a better writer of technical documents and so that you become happier that your drafts are much better and much closer to being the ones that are accepted okay.

Thank you.