Research Methodology
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Lecture - 01
What is Science? Part 01

Welcome to the course on Research Methodology. This is a course that will train you, give you the necessary inputs, in order to embark on the enterprise of research. You might ask, what is the necessity of such a course? What is the necessity of learning research methodology anew?

You have after all gone through various courses of science in school, college, university and through that have you not learnt science well enough, so that you can do research? No. Actually that is not a fact. That is because in school, college and university level, what we teachers have conveyed to you, are the things that we know for sure, that these are true, tested knowledge.

Only those things have been communicated to you, and your task throughout this educative process was to absorb what we convey—the things that mankind already knows—and to understand those things to solve problems and finally, when you are prepared, appear in the exam, reproduce the things that you have learned in the exams. And if you can successfully do that, we say you have learned the subject. Learned what? Learned what we already know.

So, this is this the education that you have so far gone through. But research is a completely different ball game. That is because here we have to find out things that we do not know. Not only *we* do not know, nobody knows. We have to embark on completely uncharted territory.

And in that, your prior knowledge, whatever you have learned so far will be useful only in the sense of supplying you the background information. But it will be of no use when you talk about what should I do in order to find things that I do not know. There is something that needs to be learned and that is what the content of this course is. How do we do research and what does it take? All that will be the subject matter of this course.

At the outset, it will be advisable for me to lay out what will be covered in this course. The course will be in the main divided into three modules.

In the first module we will concern the philosophy of science. But unlike what is understood by the term philosophy of science, these sometimes are very abstruse subjects which are difficult to understand. I will not go into that. I will go only to that extent of philosophy, which is necessary in order to understand the method of science.

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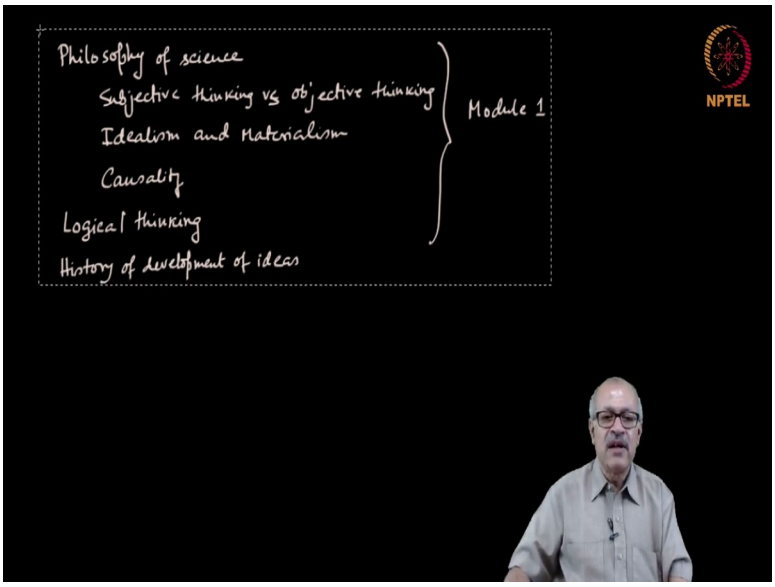

So, the first thing that I will talk about is the philosophy of science. Many of you might think that philosophy is an arts subject. In every university there is a philosophy department. Specific things are discussed in those departments and you might have the impression that this is not science. That is not quite so.

Whether one is aware or not, everybody harbors a philosophical outlook. Everybody has a philosophical outlook. Now, if that philosophical outlook is correct, then one has a higher probability of success in science, in research. But if the philosophical outlook is incorrect and unscientific, then there is very little probability of success in research. So, it is necessary for us to grasp the correct philosophy.

You have to realize that we obtain our philosophical outlook through interaction with the rest of the society, through interaction with our parents, through interaction with friends,

with other people whom we know, even through radio, TV, newspapers all these inputs come to us. And through those we form a philosophical outlook for ourselves.

Now, it so happens that much of these ideas, much of these philosophical outlooks that are prevalent in the society are not really scientific. That is why there is a high probability that we cull from the society an unscientific thought process. And the first thing that one has to do in embarking on the enterprise of scientific research, is to cleanse our mind of all unscientific shades of thinking and practice thinking scientifically.

And that is what comprises the philosophy of science. We will need to learn about for example, subjective thinking versus objective thinking. We have to learn about the philosophical currents like idealism and materialism. We have to learn about causality and then we have to learn about the methods of logical thinking.

So, this is one hallmark of science that we have to practice thinking logically. Logical bent of mind has to be developed. And this does not happen by common sense; we have to really learn and practice logical way of thinking. In this chapter we will learn about inductive logic, deductive logic, and various types of deductive logic including syllogistic logic and we will practice those things.

And then we will go through the history of development of ideas. Now, here I will not go through the entire history of science. What I will try to show through this particular part of the series of lectures is: How did various philosophical thoughts arise in society, and how have these influenced science, and how the development of science in its turn influenced the development of philosophical thoughts.

The focus will be that. So it will not be a chronological account of the development of science. Essentially I will talk about the development of ideas, scientific ideas, philosophical ideas, and the relationship between the philosophical ideas and science. So, that will be the module 1.

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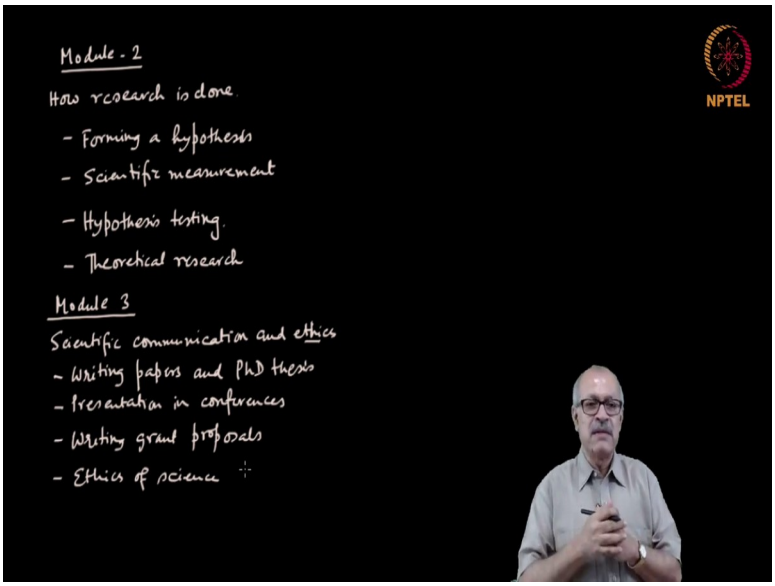

Then I will talk about module 2. Module 2 will tell you how research is actually done. So, in that chapter we will draw upon what we learned earlier in the module 1, because the philosophy of science will produce the backdrop of the method we follow in doing science. So, in this part, you will the learn the actual methodology of doing science, how research is actually done.

For example, you will learn how hypotheses are formed. In testing hypothesis the major thing that we do is measurement, some kind of a scientific measurement. So, we learn about scientific measurement. And each scientific measurement is different. A measurement for an earth scientist is not the same as the measurement for a physicist or a chemist. So here I will talk about the general ideas of scientific measurement. Not any particular measuring instrument, but in general the things that are involved in scientific measurement. And after that I will have to talk about actual testing of hypothesis. How hypotheses are tested.

This will include a bit of statistics because most hypothesis testing involve statistics. But I will not go to the extent that statistics books go because this is not a statistics course. So, I will just give a glimpse of the statistical methods that one has to follow in hypothesis testing and I will also talk about theoretical research.

So, in this module we will learn how research is actually conducted, the method of science. And then I will go to module 3. And this part will comprise scientific communication and ethics of science.

Obviously, scientific communication concerns a few things. First, we have to communicate our research results to the rest of the society; and normally this is done by means of scientific writing. So we have to learn writing papers—how to write effective papers. This part will include writing Ph.D. thesis. It will also include presentation in conferences. In order to do research in India we have to write project proposals, get grant money, and with that we do our research. So, it will include, writing grant proposals.

And finally, the 'ethics of science'. Very important part, because scientific malpractice has become quite prevalent unfortunately. And therefore, every student of science has to be aware of what is ethical practice in science and what is unethical. One has to have a very clear idea about what is ethical, what is unethical, so that even unknowingly one does not commit a violation of ethical practice.

This is more or less the content of the course. We will go through these step by step, in three modules.

So, with that brief introduction, let us come to the subject matter proper. What is the objective of science? The objective of science is to find out the character, properties and the laws governing the things we find in nature. So, that is essentially the objective of science. And the purpose of scientific research is to find out what we do not know yet. By conducting scientific research we produce a body of knowledge, which we know to be true. And based on that, we ask further questions, and try to find out things that we do not know yet. So, research concerns our attempt to find out things that we do not know.

That quest has been continuing ever since antiquity. That means, since very old time people have been trying to find out what we do not know. And naturally through that, our knowledge has been accumulating. But in the past various approaches have been used in order to try to know what we do not know.

We have questions; we try to find their answers. How should we try to find the answers, that method has changed over the past millennia. People have tried various ways. Some of these have proven to be fruitful, some of these have not proven to be fruitful, have led

people astray, lives have been lost... and finally, through many trials and errors, through years of hits and misses, through millennia of human experience, ultimately we have understood how to look for answers to the questions whose answers we do not know yet. How to do that? Thus a methodology of science has developed. And much of the course will be concerned with conveying to you that method of science.

As I said, it concerns philosophical outlook. If the philosophical outlook is wrong, then you have very little chance of success in research. If the philosophical outlook is correct you do have, but that does not guarantee success, because it depends on many other things, including your enterprise, your questioning mind, your thinking out of the box—many things.

But the primary thing is that your logical faculty should be developed, and your world outlook should be a scientific outlook; that is what concerns the philosophy of science. Effectively, when we have some idea we have to check whether the idea is correct or not, and thus a body of knowledge has developed which is called the theory of knowledge. How do we know, what we know? How do we learn, what we learn? And I will try to convey that to you in the next few lectures.

So, science is mankind's attempt to find the truth about nature. Through our 5 senses, we get to know about the natural world around us, and we ask questions, and we try to find out answers to that questions. The questions of the type: "How did it happen?" "Why does it happen?" "How does it happen?"

Every question starts with 'which', 'how', 'why': the question words. And then we try to find out answers to the question. And science is a systematic way of looking for the answers to the question that we have. But questioning is the starting point of all science. We have to have a question in mind and in order to answer that question we do science. So, a question is the starting point.

But it is not true that only modern people in the modern age have questions, and they try to find out answers to the questions in a scientific way. The ancient people also had questions in their mind. Those questions might be grand questions. Where do we all come from? How did the universe get created? What is the meaning of life? The ancients had that kind of grand questions, but they did have questions.

And also questions like why is the sky blue? Why is the leaf green? So, questions like that must have occurred to the people of antiquity. But in their time the methodology was different; I will come to that later. And over millennia we have developed a methodology of answering those questions.

Science starts with experiences that we have. We have experienced something and then we ask question about it. We have experienced the blue sky, we ask question about it. We experienced the green leaf, we ask question about it. So, everything starts with our experience.

But can an individual's experience become subject matter of scientific investigation? What I have experienced, what I have seen? No, because in various ways our minds play tricks with us. People often believe in things, and then report that they have seen those things. Many people will report that they have seen ghosts. But the investigation on the character, property, dynamics of ghosts have never become subject matter of scientific investigation.

This is because, in the 10,000 years of human history, it has never happened that two people have sighted the same ghost at the same time. And so, we now understand that sighting of ghosts happens when mind plays trick with us. The people who believe in ghosts are likely to see ghosts in odd situations and these are situations of personal hallucinations. And so we do not trust anything that is a personal experience.

So, a personal experience: "I have seen this, I have experienced this, I have felt this", can never become the subject matters of scientific investigation. Then what can? Collective experience, experience that is shared by many people. All people in the world will agree that the sky is blue. It is a shared experience, collective experience. So we do ask the question: why is the sky blue? Everybody agrees that leaves are green and everybody's experiences match and therefore, we do ask the question: why is the leaf green?

So, what can become the starting point of science will be experience, but collective experience. And then on the basis of such collective experience we ask questions and we look for answers to those questions. Now through that, by obtaining the answers, we create a body of knowledge.

So, science is a body of knowledge about how nature functions. We created the body of knowledge; science is that body of knowledge. How that body of knowledge is created? I will come to the methodology part later. But science has created a body of knowledge tested to be true and therefore we trust this body of knowledge.

The creation of knowledge is, therefore, a collective and cumulative pursuit. Collective, because many people work together to create that knowledge. And cumulative, because one generation creates a body of knowledge and on the basis of that the next generation asks new questions; find out the answers to those questions. That then becomes included in the body of knowledge, and cumulatively the body of knowledge increases. It's a cumulative process.

As I said that individual experiences, personal experiences do not matter in science. Only when the our personal experiences transcend the personal boundaries and are shared by many people; then that forms the backdrop of creating science. "Transpersonalization of experience" you can say.

And when you have that situation, an experience shared by a collective of people that produces the basis of our asking questions, collective perception can lead to conception and conception to knowledge. So, that is how we proceed. We have some perception about things around us. When that perception is shared, it becomes collective perception; that forms the backdrop of creating a conception, then on to creating knowledge.

Such knowledge that is created through these kind of collective experience and attempt to find out answer to our questions, needs to be organized. Just having a mass of data is not knowledge; that data has to be organized, crystallized, systematized and then only that can lead to knowledge.

So, that is also a purpose of science. Organization, crystallization, systematization of the information and data that we collect. After having collected information, after having systematized, organized that information, then science goes through a series of abstractions. Often through recourse to mathematics, a series of abstractions through which we try to extract the laws governing material phenomena. So, we find out the laws and principles that are general in nature, not specific to something. The laws of nature—that is what we try to find out.

And in trying to find out the laws, we formulate what are known as postulates. And then we try to test, those postulates.

In trying to find out answers to questions like: “How did it happen?”, “When did it happen?”, “How does it happen?”, we often formulate hypothesis and then test the hypothesis. I will come to that later, exactly what these terms mean. But these are the activities that we do in science.

But, I must tell you that the subjects that are typically considered to be arts subjects, like history, like archaeology, like linguistics, psychology and subjects like that, these are normally treated as arts subjects in the universities, these also follow exactly the same method to know what is not yet known. Exactly the same method as science uses and in that sense, these are also science, social science.

That is why social science is also science, as much science as physics, chemistry or other sciences. The only difference that might be pointed out happens in subjects like literature, music, etc., where there is an emphasis on romanticization, emphasis on value judgment. Is it good? Is it bad? Is it beautiful? Is it not beautiful? Sensitizing the mind of readers or listeners of music to beautiful music, beautiful things, beauty. That is often the purpose of literature, music and such areas of human pursuit. That means, in general, value judgment. While the pursuit of science is only one thing: truth judgment. Is it true or is it false?

And in that, there is a bit of difference between some areas of the arts and the sciences. But otherwise, I was trying to point out, the social sciences are as much science as any other branch of science. But in this course, I will primarily concern myself with the natural sciences.

Why? That is because in the social sciences certain tools and techniques are used, which will not be possible for me to cover in this course; simply because paucity of time. And so for those things, you will have to consult other material. I will concern myself with natural sciences.

But I will not focus on a particular branch of natural science, like biology, physics, chemistry. This course will be general in nature. And irrespective of the background you come from it will be accessible to you. That much I can guarantee.