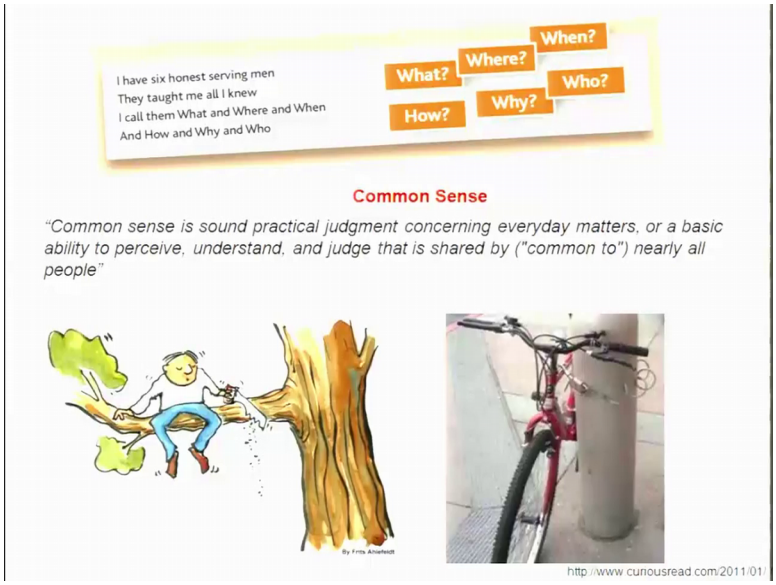
Introduction to Professional Scientific Communication
Prof. S. Ganesh
Department of Biological Sciences & Bioengineering
Indian Institute of Technology, Kanpur

Lecture – 04
Scientific Hypothesis

Welcome to this week two lectures of the course, introduction to professional scientific communication. So, in the previous week we looked into a number of concepts with regard to why it is important to develop hypothesis. Today will extend some of these concepts and see why indeed it is important to develop hypothesis; when you talk about any scientific research projects.

So, just recall our discussions we said that we should for any research project or whether it is innovation discovery, we need to ask questions.

(Refer Slide Time: 00:59)



The questions could be what, where, when, how, why not this is the questions really help you to think and come up with solutions or answers or possible explanations for the natural phenomena or based on these principles you come up with certain devices technologies, which could be of benefit to the society. Therefore, you know every research project whether it is discovery or innovation are driven by curiosity. So, when I say curiosity it means basically common sense.

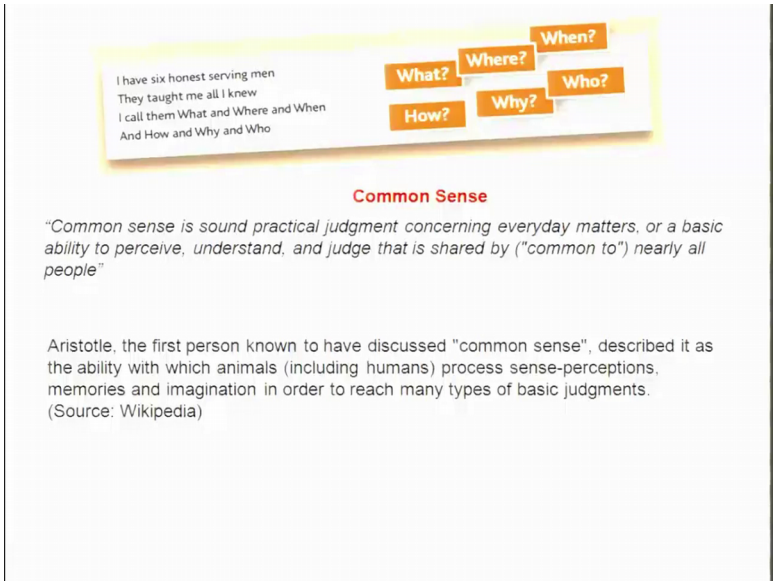
Common sense sounds like you know it is a its something that all of us are aware of and we have we do have the ability to look at ask questions and come up with certain suggestions or solutions, but there any is many of us take it granted, we really do not put our brain to do what the best it can do. So, in other words when you say common sense we do look at many things around us, we take it that this is how it is we really do not help in changing the system therefore, it can get better whether it is the way for example, certain buildings are designed or the way the people move around roads or the way the vehicles or design, each one of these are looked into in several aspect and people come up with certain solutions, which make it easy for all of us to leave.

So, just to define what is common sense; common sense is sound practical judgment, concerning everyday matters it is nothing scientific here it is day to day living or a basic ability to pursue understand and judged that is shared by all of us, right. So, if you look into the cartoon that is shown here in the slide on the left side is somebody is sitting on a branch and cutting the branch, you know if we cuts through the you are going to fall down that shows that he does not have a common sense.

What is doing is right that is using a tool to cut the branch, but exactly he is sitting on the other side of where is going to make the cut it does not make him to be in a safer zone. So, that is what called as not having a common sense.

Look at this structure give me a find this is perfectly all right because a bicycle is tied with a pillar with a very good rope and which has got a number lock pattern lock, you need a key to open it. But if you look more carefully you will find that this method of you know roping the bicycle with the pillar does not really help because one can lift, the bicycle such that true put come out of the pillar therefore, he did not really use a tool in the best possible way to secure your bicycle. So, this is what called as common sense you have to apply your brain when you do anything therefore, what you do is exactly what it is meant for otherwise you do things that really does not make much sense that which called as not having a common sense.

(Refer Slide Time: 04:10)



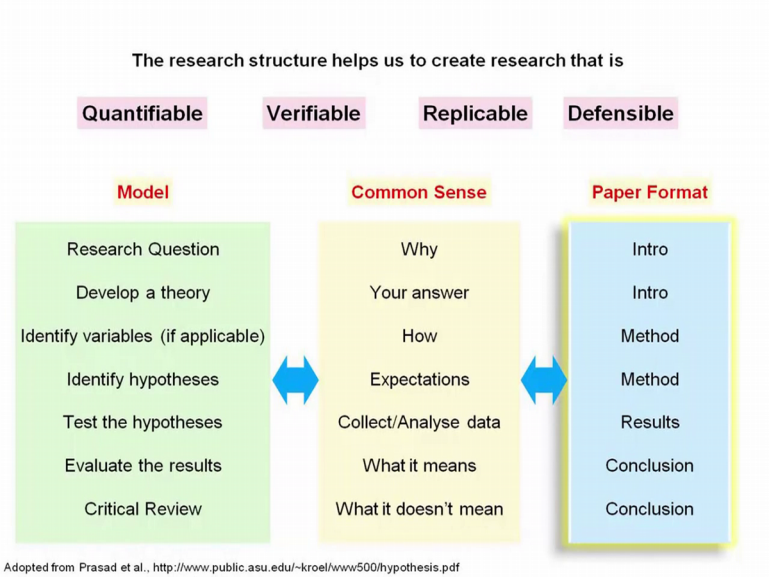
The first person possible in the literature that is what the western literature says, he is at Aristotle, he is the first person known to have discussed what is called as common sense. He described it as the ability with which animals not only humans, but all other animals possibly the mammals process sense perception because you do that information perceived through your eye or ear or you know text sound whatever it is these are the sense perception and memories because you also recall previous incidences or someone mentioned about certain events that is the memories and imagination that is extremely important when you talk about science because you have to imagine and this together you know help to reach many types of basic judgement the very basic concept of learning when you are able to you know learn how to ride bicycle and many other things is also you know you learn quickly, possibly which uses some other common sense as per.

So, this is something that report at least in the western literature about the common sense we know that it is indeed true. So, what is important here is sense perception. So, have to be open to observe things, if you translate this thing. So, scientific research you have to be open to observe you have to observe patterns, and memories is not just that particular day what you say, but you should have had documentation that is what you can translate into memory. You have had documentation you can go back and forth analyze and arrive at whether they all represent same pattern and then imagination because these are like snapshots and when you talk about for example, it detective or the other types of

reasoning you need to look at snapshots, and try to connect them and tell perhaps this is what happening right.

So, this is called as imagination. So, you have to get all these three together that is exactly takes us to science right. To the common sense is nothing, but asking questions right when you look at things and toy ask questions and try to get some answers.

(Refer Slide Time: 06:16)



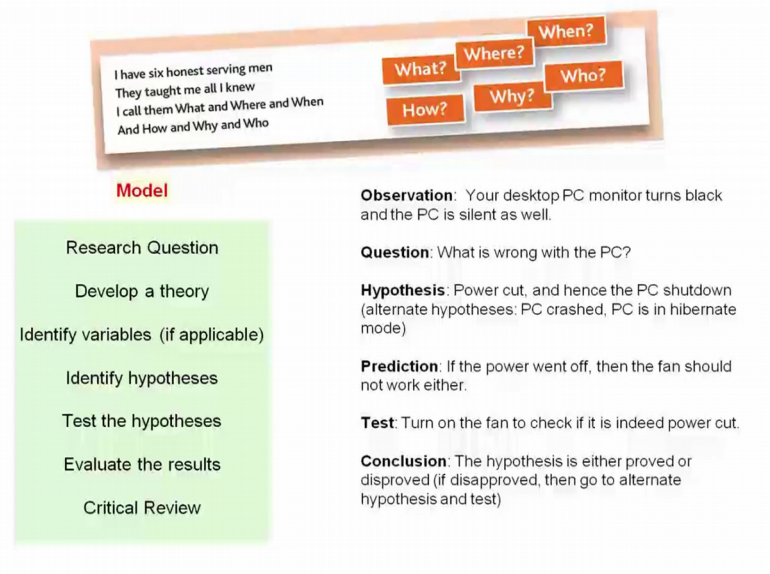
It could be y for example, you get some an answer when you ask questions why and how and also the expectations, you know and then you look at the data and analyze and see what are the data, which possibly tell you what it means and then what does not it mean both are important. So, you need to know the limitations of your data set what it can explain, what it cannot explain. So, that is what translated in terms of what you call as model. So, you do have what is called as research questions, which are in common sense the very simple question that you ask why. And then based on the research questions you do a literature survey and develop a theory and then identify variables, at times that could be because your data set or your stamping points could be limited to certain condition therefore, you should know variable.

And then based on that you develop an hypothesis which sort of gives you a theoretical answers to question, that you have had right. Now this is after all an hypothesis when you need to test them further you do experiments or do one or the other analysis, and then you obtain certain observations and then you extrapolate. So, that is the scientific

model you used which is not very different from common sense, except that you do have certain clear well defined methodology which we will talk about in a while from now.

So, what are these, what is an observation, what is an hypothesis, what is conclusion, just I will give you some examples from our day today leaving for example, an observation.

(Refer Slide Time: 07:54)



Now, observation is the PC the desktop that you have been using you know the monitor turns black absolutely blank you do not see anything and you know looked at the CPU or the PC unit itself and then you find it is absolutely silent all right.

So, the question that you ask is what happened to my PC have been working until the last minute and all of a sudden it is silent it is blank. The question then with this question you have to now hypothesize why the monitor is black, and why the computer is silent now when the hypothesis could be power cut all of a sudden power gone, you do not have a backup system therefore, the computer shutdown all right. But the other possibilities as per for example, the PC crashed are you have hit some you know button there in the keyboard therefore, the computer gone into hibernation mode. So, these are the other possibilities, but you are sure that the computer is new. So, absolutely should not be a problem that it crashed out. So, quick.

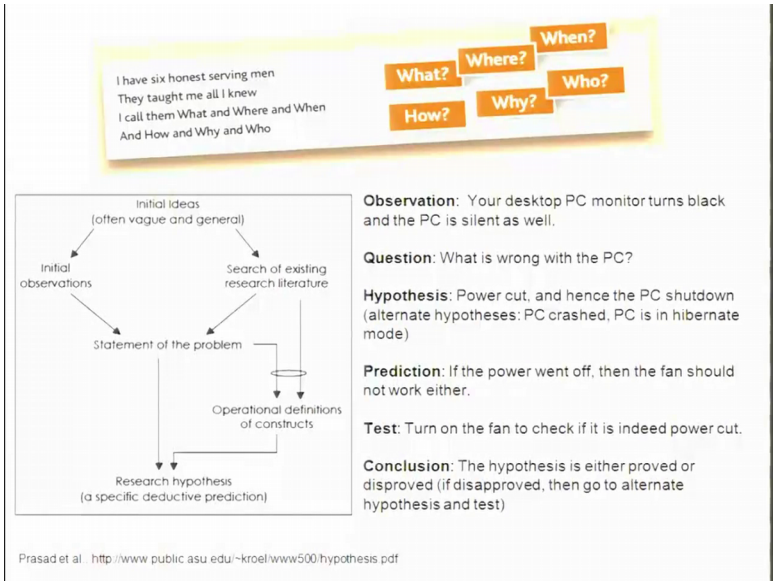
And then then you did not do anything, because when you left the computer was on therefore, you think that hibernation is not the possible reason. So, you think power cut

could be the reason. So, what you do you have to test your hypothesis that the PC is down because of the power cut what will you do you have to do, a prediction you have to test it. So, if my hypothesis correct, that there is a power shutdown then the other electronic device in or electrical device at my room should also not function. So, I turn on the fan I see that it is not running or turn on the light it is not on, which tells me there is no power all right. So, that is how you come predictive you know develop certain method to test your hypothesis, and then you do that certainly you turn on and then see that it is indeed power cut.

The conclusion is based on the observation; say suppose you turned on the fan and start you know rotating that means, power is there. So, it should be a problem either it is there is no power cut, but it is a problem either the computer crashed or it is inhabited put. So, then you have to come up with another word like how do you can you try to restart, if it could start then you know that what could be the problem and so on. So, you basically you test the hypothesis that using certain tools and then you prove the hypothesis or you disapprove the hypothesis equally important the second one, because if it is conclusion our hypothesis disproved when you have to go back to hypothesis number two, the alternate hypothesis if you do not have then your clueless. So, that is how you need to go back and do.

So, that is this where is generic simple you know example to explain, what is an observation, what is the question that you are asking and how do you develop an hypothesis which can be tested and how do you predict because you carry out an experiment then there would be certain outcome. So, is it having any predictive value and then finally, you control. So, this is how you do. So, in real time you look into the research, can you do have a cartoon that is a schematic.

(Refer Slide Time: 11:13)



That is shown in the screen on the left side is that you have initial ideas, based on your own observations are from the literature and then you do lot of (Refer Time: 11:24) discuss with people and then you arrive at their problem right to make a statement about the problem and then you develop an hypothesis, which can be tested that is what you call it as research project.

So, that is how normally you know a research project is executed. So, that is you know as what I am explaining again is that you have common sense and the model research model that we dis you know just now described, talks about how do you identify or arrive at an hypothesis and then go over doing where experiment.

So, when you do all these things. So, when you have you know did a define the question developed an hypothesis and you have develop tools to test the hypothesis you are had observations, you analyze and then you conclude and this is your research project and that needs to be put into certain format. So, that is called as a report or paper format which is shown on the right side.

So, you would have what is called as introduction, which pretty much explains the overall research area and why you wanted to ask this questions including the hypothesis and then you talks about methods right and then it talks about the approach that you use that method, and the observation you call as results and then you have conclusions which translates into the interpretations of the results all right. So, this is how you convert this,

your observations based on the project into a research document which could be a report thesis a paper and so on.

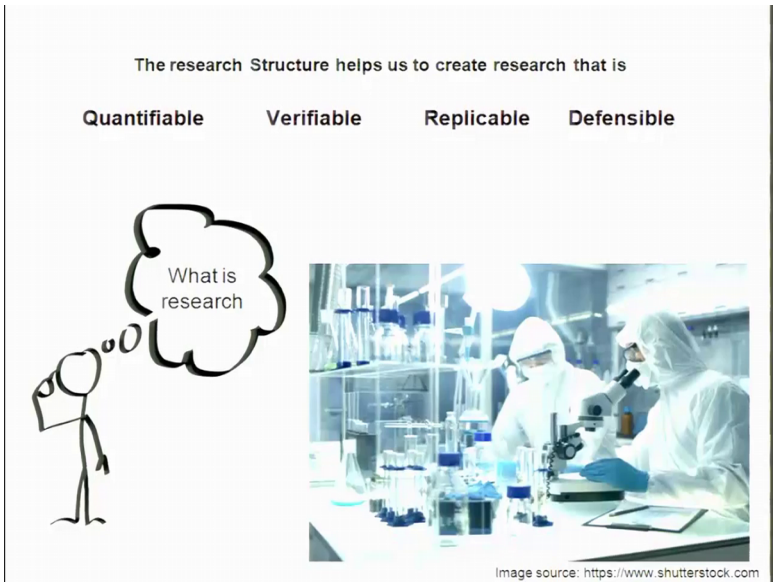
The question is why should I develop a report all right you do develop a report, because you know the research is considered scientific research helps us to validate whether whatever you are saying is accurate or not. In other words the research structure what we this just now discussed whether in terms of model or execution or when you document that in terms of a paper, helps us to help us meaning the other person not who anyone else who reads your report to test and validate and accept and you know further elaborate or improve upon what you form.

So, your observation should be such that, it is quantifiable you should have told that how many times you are done the experiments what are your sample numbers what are the different kinds of reagents you have used. So, it is quantifiable and verifiable meaning if I use a methodology, I should be able to get the same kind of you know results therefore, I look into your methods, I look into the research I do agree with you that your statements are correct that is verifiable replicable meaning, I can redo the experiments exact the way you are done because you are documented exactly we are done.

And defensible meaning you are able to go and present your data or someone else can read your report and say what he has done, what she has done is commendable job and everything is in place, whatever conclusion this person makes is you know very logical and I agree with that. So, that is what the experts or people in your research domain would be able to tell, all these are doable only when you are able to document your results.

And the documents you know helps you to defend your research, because you have used the appropriate methodology. You have used appropriate methodology because you have ask the correct questions, you have ask the correct question because you have a very valid hypothesis. So, everything starts with hypothesis if your hypothesis is not correct, I can assure you nothing is going to be you know appreciable way to move. So, you are going to have problem everywhere because you end up wasting time.

(Refer Slide Time: 15:39)



So, when you talk about research what it comes to mind? So, when you go and talk to your friends and say that I am going to do research right and ask them to close your eyes and think about how you would be when you become a researcher you ask anybody or you ask yourself, if you are not started research as at right. Most often people you know think this kind of a scenario where you have a lab coat, it is a lab which has an equipments and you are very serious sitting on desk working on something, this is the imagination comes because most of the experiments that at least in biomedical field or in chemistry and other such areas, it is done indoor inside the lab ok.

So, there are certain guidelines as to how do you do right research. So, there is a typical concept that you know the lab is secured, we have lots of glass bottles the reagents of different colour and you sit and do research right. This is a second of imagination and let us have a look at it I am going to show you some snapshots and then I am going to ask you at the end of the snapshots few questions, and then we will revisit this as to why I am asking this question. The first one I am going show you is a few snapshots of in advertisement that comes commercials either in TV or newspaper about Horlicks you must have seen these adds right.

(Refer Slide Time: 17:01)

And then you also have advertisement for example, Colgate again you have an add here and it could be even for hair oil again you see an advertisement coming and for example, a detergent, which used to wash clothes or it could be a soap that you use either for hand wash (Refer Time: 17:24) and so on. Now the question is what is common amongst all these adds if you think about very carefully in every add or most of the add, you find one individual who is wearing a white colour lab coat what is the reason? The reason is these companies's try to tell you that our product has been tested by a research lab. So, it is certified it is going to do exactly what we are saying, which makes you to believe this is undergone a scientific scrutiny exactly the way you are imagine that you are in a lab with a lab coat and so on.

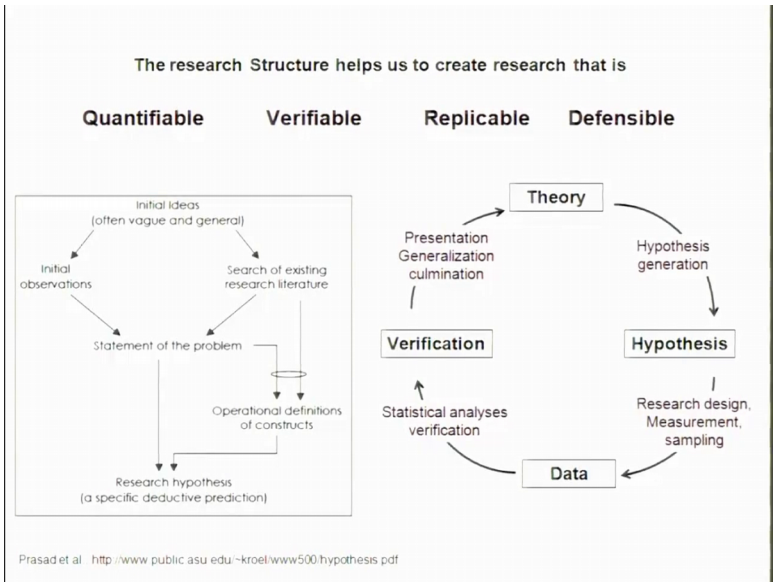
So, that is the credibility of science; the sciences that is quantifiable you can repeat if you know you can you know verifiable.

(Refer Slide Time: 18:14)

You can go back and look into my all the records and you would say that I have done all the experiment that is required in the best possible way, the results do not lie replicable you yourself can do this and differentiable I can defend my work and say that what they I have done is correct. Therefore, it is you know that is the basis of research that whatever you show is based on the facts and nothing is fabricated, nothing is falsified. And that is perhaps one of the reasons why you know most of these products which are in the healthcare domain come with certain individuals having a white lab coat to sort of tell even the lay public that is a tested and proven and so on whether indeed that is the case I do not know I am not saying that these products are good, but that is what being used as a standard to launch that product right. So, that is the power of science.

That is it cannot be falsified therefore, you know there are ways by which science is done, and there are ways by which science is documented, their ways by which the science is presented and these are universal you know kind of a guidelines because the entire word uses it therefore, important you know each one of us who practice science, should learn to you know use these guidelines therefore, others can understand and appreciate what you are done as a researcher.

(Refer Slide Time: 19:41)



Let us go back to the same concept, the concept is that how do you arrive at ideas or hypothesis. So, this is something have been repeating because it is extremely important that you develop a very very good hypothesis therefore, your project can really quick start. So, the way it is shown on the left side is that you have initial ideas and then I go and then do a literature research discuss, and come up with the research hypothesis.

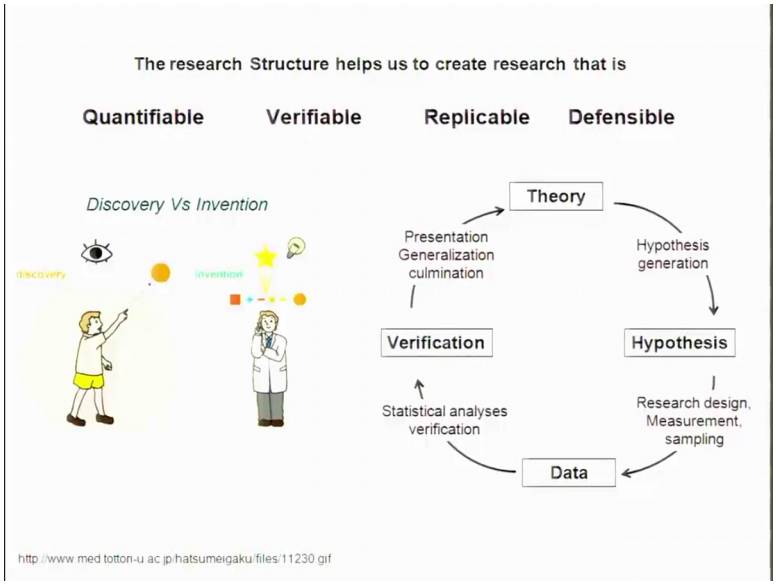
This is not unidirectional this is something that we discussed earlier as well. So, you have certain hypothesis based on certain theory, it could be the preliminary result that you have or published work of someone else, and then based on that you develop your own hypothesis and then you test and generate data, the data you have and then you sort of you know interpret that validate it and then you again come up and say something new. In addition to proving your hypothesis, you further make certain you know theories which again can be tested again by you or someone else and so on.

So, this is a cyclic process therefore, you know for anyone else to follow up your work and look at your data and even have a very different kind of interpretation, you need to present the data in the best possible way therefore, every else can look into and get the benefit out of the research that you have done. So, that is what called as you know once you have hypothesis, you have made a research design, we have done measurements, we have done whatever experiment you have done and you generate data and then you use the data to analyze which could be verification statistical analysis and so on.

And then you present you know kind of a generalized you know a kind of synthesize a particular outcome or philosophy or theory, you know which is a culmination of everything; your hypothesis your data the others who are published you know results in the similar domain their thoughts, everything culminating to what is called as a theory which is you know extension of your hypothesis you have mans possibly proven the hypothesis or tested it and then validated it.

And now you are giving something new. Now this again can lead to you know another hypothesis and then again it goes on. That is how what you call as resets always is incremental because what you do is going to help others as per therefore, it is important that you communicate in the best possible way. Often there is discussion that you know the discoveries are very different from inventions or inventions are vary from different form discoveries.

(Refer Slide Time: 22:24)



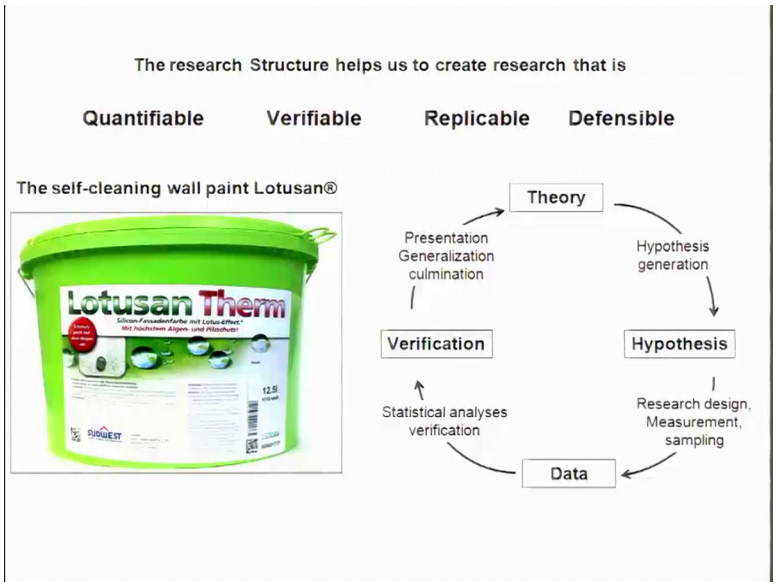
And they say that for discovery like what you do in basic biology or basic chemistry, physics, maths and so on here it is you know you have somebody has done something, and you read and then you sort of you do something more and try to understand the complexity that is otherwise happening you take about our own body right.

How our brain works is still a million dollar question. So, you do not know exactly how the brain works. There are a large number of lapse research group work on it everyone talk about a particular process they study, and they say that this is how the memory is

coded this is how you are able to retrieve, the memory this is how your brain is able to think and so on, but still you have not solved as to how the brain functions. So, this is discovery, but the question is can you when you when you talk about inventions is it very different from discoveries do you need an hypothesis for any inventions right.

So, these are debates that goes on people say that you know inventions are not like I can make something from nowhere. I do not really need to have an hypothesis and so on, but I will give you some examples nothing comes out from just nowhere for everything you need to have certain observations based on that you are going to think something and then you develop an hypothesis even for an invention. So, I am going to give you one such example, there could be hundreds of examples that is something that you may wish to go and study yourself.

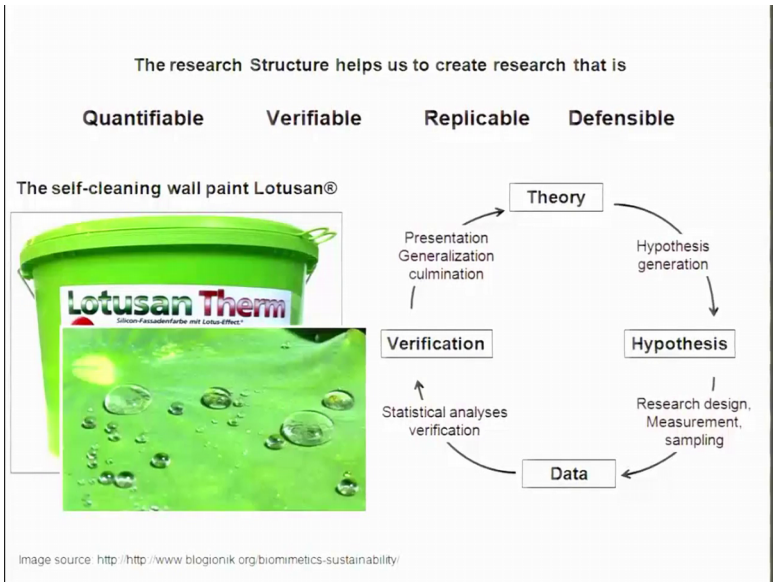
(Refer Slide Time: 23:57)



So, what is shown a on the left is considered to be a wonder wall paint. So, it is called as self-cleaning wall paint Lotusan. So, the idea it is being marketed in the Europe probably it has come even in India they say that this paint is something that would not allow the dust is settle on the wall. So, the settled there is a rain or just you have a pipe with you know water with force, and that is just wash it all the dust will go. So, you do not need to really clean it you know it is fantastic.

But this is not something you know came out from nowhere, this is not something invention that did not have any observation. This is based on very simple process that you find if you are in the rural area if you look into the lotus the leaf.

(Refer Slide Time: 24:46)



Now, if you sprinkle some water droplets, you will find that they do not really you know adhere to the surface they become bubble like the way you must have seen mercury, they go around and then they do not stick to the live at all. It is because the surface is so rough. So, does not allow any contact points therefore, when you have water which is rolling over subsurface it will carry we all the dust that are there and in fact, with a very similar principal they have used to develop a pain, which now you know when you paint on the wall now water droplets can carry the dust from your beautiful home. So, again these are called as biomimetics which is again based on natural principles.

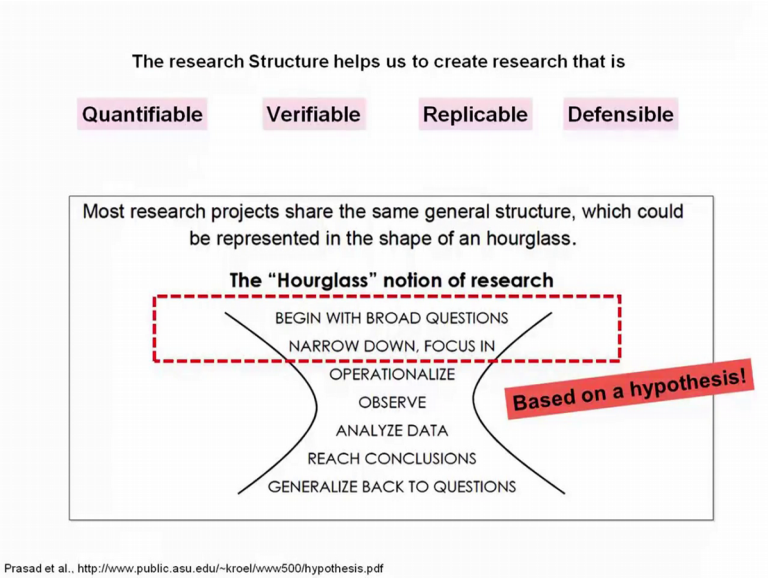
So, everything weather is a design of a submarine, whether is a design of missile, whether is a design of you know aeroplane all these are based on certain concept that you can see whether it is a bird, whether it is a dolphin and so on we can learn a lot from the nature which tells you what is the time tested design that can work. In fact, if you asks then you are yet to make a vehicle or a helicopter or aeroplane, which can mimic the kind of a manure that the dragonfly can fly right as you are yet to understand.

So, these are the challenges. So, the inventions as well do not come from nowhere. So, have to observe, you have to understand, and develop an hypothesis therefore, how you

can even design certain machines which can do at least a few of the beautiful things that our body does or the animals to or plants too and so on.

So, that is the challenge therefore, you know hypothesis is extremely important, for even in the in terms of concept design hypothesis help for example, if you are designing a motorbike, if you are designing a car it is not that you are designing something that you like.

(Refer Slide Time: 26:45)



Because these are products that should be sold out therefore, you need to understand what is the design that people might like, and if you are targeting a particular age group you need to go and sort of interact with them as to what design they might like, what feature they might like and you want to embed them to make it as a profitable product.

So, everywhere you need to have an hypothesis and then you have to go and test, and then kill the hypothesis are revive and come up with the alternate hypothesis and finally, implement. So, hypothesis is everywhere whether it is basic science or when you do any innovative research. So, therefore, you know the documentation reports are extremely important that is the point that we are talking about.

And normally most of the projects have the same you know structure, when you talk about science projects which could be represented in the shape of hourglass, you must have seen the hourglass you have a sand on the upper chamber, it would take about 60

minutes for all the sand to come back to the come to the lower chamber that is called as hourglass then you invert it.

So, you have a narrow construction there. So, that is exactly a kind of a structure that is you know proposed for most of the research projects; that is to begin with broad question. So, you have a larger context and then you cannot until the everything right you have to define you know an focus and if take a few question that you can address practically possible, and then you operationalize meaning you implement or execute certain experiments to question to get an answer to this questions, and then you get certain data that is you observe.

And then the data points you analyze, and then you have certain conclusions and the conclusions are used to extrapolate and give a generic response. So, if you open any text book for example, g or molecular cell biology, these are you know having these books have a number of chapters right from biomolecules to cell signaling to, cell divisions to, aging, they cover wide variety of topic all these text book material that you read you know they talk about how the genes are regulated or they talk about how cells communicate with one another. Now they talk about all the signaling process everything these are very generic statement without really telling in which system such kind of communication happens.

Reason being that there are very few systems that is being studied; most of the cell function that we know how come from the studies that are done in eukaryotic for example, east or in mammalian cells then you would try to implicate that perhaps this is what happening everywhere is a kind of universal rule, which maybe or may not be correct, but that is the understanding we have. So, that is how normally the interpretations or you know you make generic conclusions, and later one can go back and then study other system and show that indeed, it is not universal and there are exceptions and you study more you will find that the exceptions are not that exceptions, but there are quite a large number of organisms or plants, do follow certain exception therefore, they are no longer exceptions.

So, this is how science evolves right, here the point is that regardless further it is discovery or invention you need to have a very good observational capacity you should look into the natural phenomena, develop an hypothesis and come up with certain even

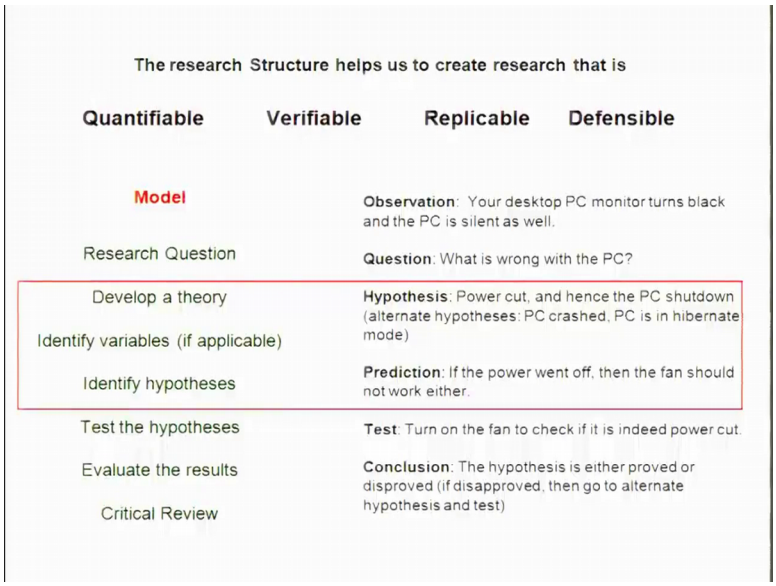
novel technologies or devices that could be of great help to the mankind. So, when you look into the research project, the way the most of the research projects are structured, they are structured in certain guidelines. The very reason that there are certain guidelines as to how you should carry out research is important because you know whatever outcome of your research project is going to be looked at, is going to be read carefully by other researchers in the field therefore, they can learn a bit from your findings, and they can also develop their own hypothesis based on your results and observations.

Therefore the methodology is or the approach for research is very very similar across the globe, and it is also called as the hourglass notion of research. It is a kind of a generic structure for most of the projects, it is called hourglass because now you have a broad understanding generic ideas and there are broad questions, and from these questions you ask very pointed objectives that is what you call at that you develop these objectives has to focus has exactly what you will be looking at in your research project.

And when you execute this plan in terms of methodology, in terms of approach using tools appropriate tools and then you get data, which is what you call as you observe the outcome of your experiments and finally, you analyze the data and then you reach conclusions based on the data, and then you again general I and sort of explain whole lot of thing.

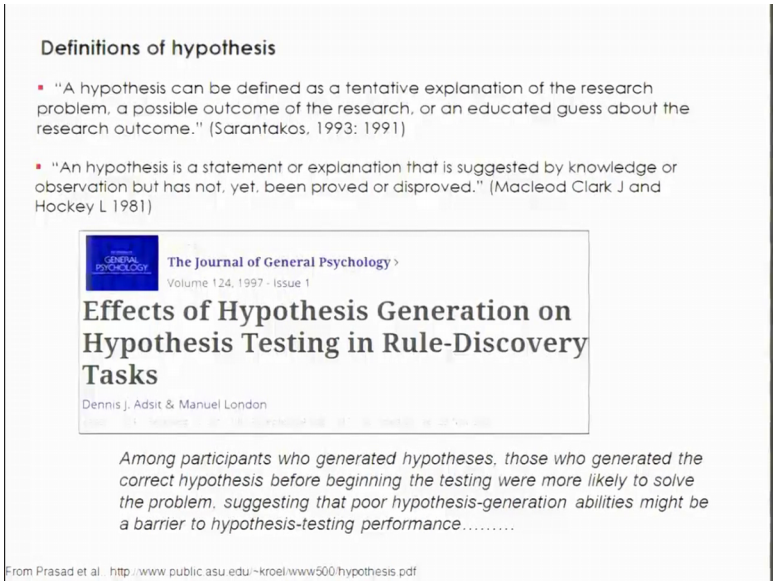
So, this very approach is based on the hypothesis that you develop therefore, hypothesis is as important as any other you know aspects of the research. In fact, hypothesis is very very important because if your hypothesis is not correct, the rest of the thing that they are going to you are going to do in the project he is not going to really sustain, because it will not be yield the kind of results or progress that you wanted.

(Refer Slide Time: 32:25)



So, to explain you know what hypothesis mean, I have already introduce a topic that is the how the for example, your PC all of a sudden stopped you have an hypothesis that the monitor and the PC is not working, because this is power cut and then you have predicted if I for example, you know if indeed that he is a cause that is power is a cause for my PC not a function, then any other electrical equipment that is that is there in the room if I turn on they should not be functional because there is a power cut that is how root of you know test that is called as a predictive model, and the you will certainly test and then you have an outcome. So, this is very important.

(Refer Slide Time: 33:16)



So, therefore, you know hypothesis is something that you can based on the hypothesis we can predict therefore, we can test then you go and get data, which would either support your hypothesis or would say the hypothesis not correct. So, to define the hypothesis, a hypothesis can be defined as a tentative explanation on the research problem a possible outcome of the research for and educated guess about the research outcome.

In other words, you have certain questions for which you know you are looked at the literature you did something reserves and then you come up with certain explanation, suggesting this is what happening and if I do something this is what I expected this is the hypothesis, right. And, hypothesis is a statement of explain or explanation that is suggested by knowledge or observation, but not at improved or disproved as long as it is not proved or disproved determines hypothesis. Once it is disproved this is no longer hypothesis if it is proven, then it is you know this is what happening therefore, easiest to become an hypothesis, right.

So, therefore, hypothesis is a first step to you know to your major project. In this regard I would like to highlight one research paper that are come in a journal called journal of general psychology, where the authors have really looked at various aspects of you know science students in terms of you know how do we develop hypothesis, how many hypothesis they develop, how fast they develop hypothesis and so on.

So, there are various aspects for this particular study, but what I would like to point out outcome is one particular outcome. The outcome is as it is vibrating copied from the abstract of this paper, it states that among the participants who generate a hypothesis, those who generated the correct hypothesis before beginning the testing were more likely to solve the problem, suggesting that poor hypothesis generation abilities might be a barrier to hypothesis testing performance.

In other words if you are unable to generate hypothesis, which is you know close to what you would expect at the end of the results, which is most likely to be proven correct then you know your ability to see when solve the problem is not as that good. So in fact, therefore, you need to understand as to how to develop hypothesis the correct hypothesis therefore, you can succeed in your research project its extremely important that is why I

am spending lot of time in saying what is an hypothesis and how to develop an hypothesis.