Introduction to Research
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Lecture - 22
Creativity in Research - Part 2

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Thinking styles - creative people often question conventional wisdom, assumptions, and rules okay.

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Because of this, creative people get into conflicts with the society around them. I am not suggesting it you that you should start fighting with your friends and all that, but generally these are the characteristics of creative people.

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So, to be creative one needs to be persistent; you should be at it; you should not give up okay; that is why you have to be tenacious. You have to be uncompromising. You have to be stubborn. You have to believe that it will work and keep on working at it. Arrogant - I put question mark. There is a thin dividing line between arrogance and self-confidence. So, you

can be arrogant in homeopathic dose, but not in allopathic dose okay.

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Hard work okay. Hard work is very, very important. There's something called the 10,000 hour rule, which was first proposed by Herbert Simon, who is a Nobel Laureate, who says, who said that it takes 10,000 hours of extensive training to excel in anything. Bharatanatyam, cricket, tennis whatever, you have to put in 10,000 hours of quality time before you can make a mark okay. So, the reassuring thing in this is, contrary to popular perception it is not innate talent or genius that alone matters. If you are having above average intelligence, then if you put in this 10,000 hours anybody can become an expert. All these great people you are thinking right - Mozart, A.R. Rahman, Viswanathan Anand, Bill Gates - all these people put in 10,000 hours in their respective fields before they became famous. Rahman started learning key board at the age of 3 right. So, it actually debunks this so-called Genius Theory. Lot of it is only perspiration; just hard work okay. So, the most reassuring, I come again is, hard work alone matters, which means any one can do it. Basically, do you have the tenacity? Do you have the tenacity? Okay are you ready to run this marathon, steadily without giving up okay? If you put in these 10,000 hours, you can be a master in any field okay.

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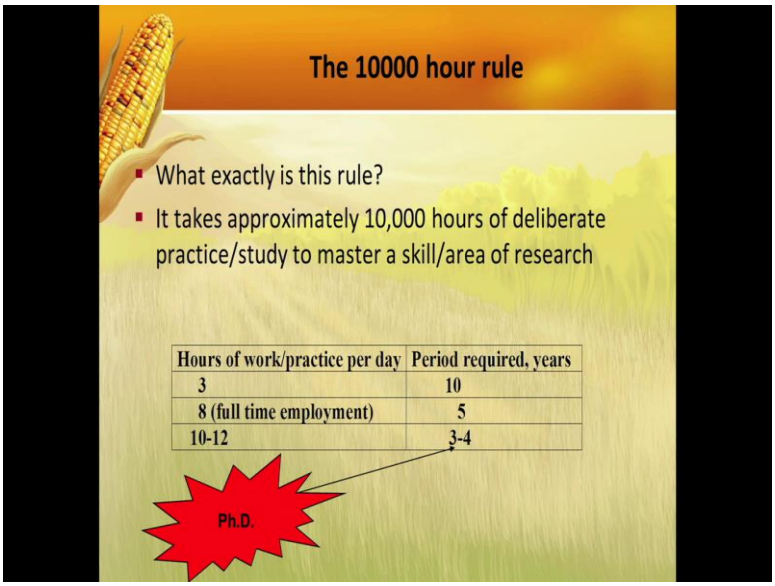

What exactly is this rule okay? It's so simple. It takes approximately 10,000 hours of deliberate practice/study to master a skill or area of research okay. So, if you practice tennis for three hours a day, it will take about ten years for you to become a champion in school or district or whatever it may be. The same is the case with karate, Bharatanatyam, whatever, okay violin or any instrument or whatever.

Full time employment. We spend 8 hours, so that it takes about approximately 5 years. That's why they say to become Associate Professor you have to Assistant Professor for 5 years. 5 years is also the time people get their Master's degree - M.Sc., MA. So, in 5 years you would have put in some 10,000 hours in that field. Now, many of you research students, put this 10,000-hour rule. If you spend 10 to 12 hours a day, 6 days a week, leave the Sunday for your personal things you want to do - sport or you want to watch movie whatever or you want to just sleep off in the afternoon - if you spend about 60 hours a week, it takes 3 to 4 hours, 3 to 4 years before we get that vision - that dharshan - and you say, that yes, I am completely confident about what I am doing. I need my Ph.D. now okay. And the guide also says, ok, you are ready, now please go out and conquer the world okay. You just get past your guide in that field and then you talk more confidently. So, I say Ph.D. is also about this angle. Initially, you will say good morning Sir, then till compri it is like this; then, slowly it will become like this; then, first paper it is like this; when you are finishing, it is like this okay. So, that angle, the theta, Ph.D. is all about the theta okay.

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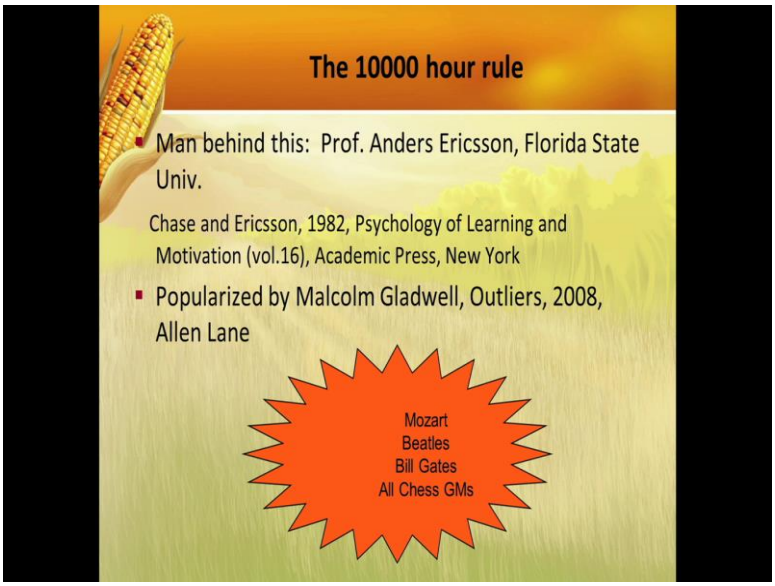

Okay Professor Anders Ericsson of Florida State University has also done lot of work on this, subsequent to this Hebert Simon's proposal. There's a good chapter on Psychology of Learning and Motivation in Academic Press Volume Sixteen; you can take a look at this. And a very popular book on this is by Malcolm Gladwell; his book, the title of the book is Outliers; he published it in the year 2008, and he looks, and he looks at the success of Mozart, Beatles, Bill Gates, all Chess Grand Masters; he has conclusively established that all these people have spent 10,000 hours before they became famous.

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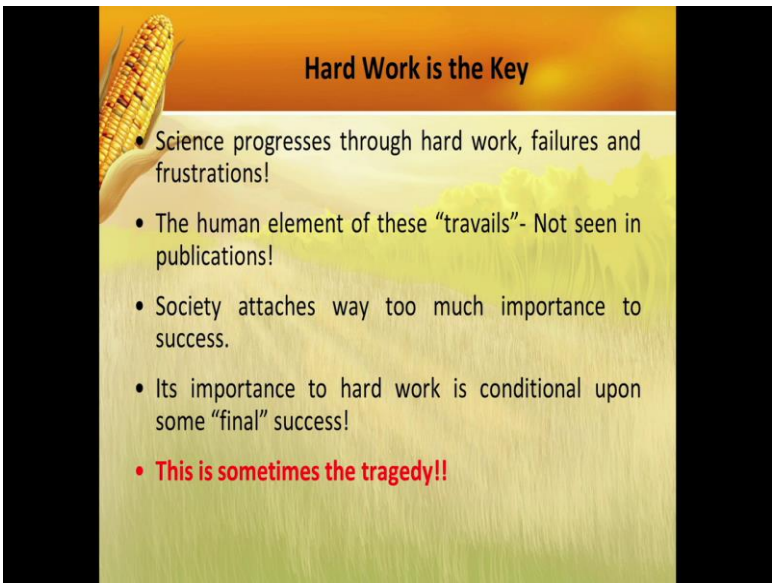

So, therefore, hard work is the key. First you have to acquire knowledge then hard work is the key okay.

Actually, if you look at the progress of science, science has progressed through hard work, failures, and frustrations. First time when we are writing a computer program, if it works, I can give it in writing that you will get absurd results. First, first the program, you will not be able to compile; then, you will be able to compile, you will be able to run; when you are running, it gives garbage; then one stage will come, I have done everything, this stupid fellow he is not giving the correct answer; that peak of frustration, at that time you just take a break, and visit a temple or just take three four days break do something else; then, when you are taking bath or you may be reading a newspaper or you are watching a movie, ah! in line 542 I didn't put the square root instead of the… you will realize, you will come back, and then, it will start working okay. So nobody gets it right out.

If you look at a guide, some particular X professor, 450 papers, what a great person he is. All people who have achieved this greatness also, those people also have rejections. You have to talk to them, but the thing is even after this rejection and all that, they are not giving up; you should continue. See when you write, I have said this in my Joy of Research, Joy of Research book, when you write ten papers, one or two papers will get rejected, because it is statistical. What is the probability of acceptance? For example, I am a reviewer; if I get to review ten papers, I reject 2 or 3 statistically. So, my probability of rejection is 0.3 okay. Some other process may be 0.4. So if your paper is reviewed by three professors, find out the joint probability of acceptance. For the first reviewer, for him to accept it is 0.7 and, second reviewer is 0.7, say third is 0.7. So, your joint probability is 0.7 into 0.7 into 0.7 which is a low quantity. And then, when we write more and more papers, from our group some paper will get rejected; you should not worry. So long as it is original, you have done the experiment, you have got correct results, then the contribution is something very subjective; different people will… it is just that the set of two or three people viewed your paper differently. So, you try in some other vehicle.

So, if you are confident that it is original, it is not copied, there is no plagiarism, you have put in your hard work, then finding the right vehicle for your this thing is so easy now, because you have got so many journals okay. So just like a mother giving birth to a child, the most important thing is you have done your part and that baby has come out - the paper has come out - then we will find out something, we will find out some mechanism. So, that joy, that

thrill is already there; you have already done it; you feel, yes, it's good; you feel, yes, it's good; my hard work everything is there; we will find, we will find a journal to accept it okay.

So, the human element of these frustrations, how many times the guide corrected, how long it has taken, how many test tubes are broken, how many this thing volt meters went off okay, how many times program cupped all these things are not seen, because there is no time for the reviewer or there is no time for reviewer or the editor or the reader to look at all this. Why? The society attaches too much importance only to success okay. So, if you want to know how science has progressed, you have to look at the biographies of scientists. Benjamin Franklin, you will get an idea of what… or Thomas Alva Edison, you have to read; then you will understand the trails, the tribulations, and then the failures, which they went through before they could turn into success.

Therefore we often correlate hard work with success. If it is not successful, there is no hard work, but this is a dangerous correlation. If somebody has not scored marks, we automatically conclude that he has not studied well; there may be many other reasons okay. So, this is sometimes the tragedy, but we have to live with this, because it is a part of us, we are part of this system, we have to live in the society okay.

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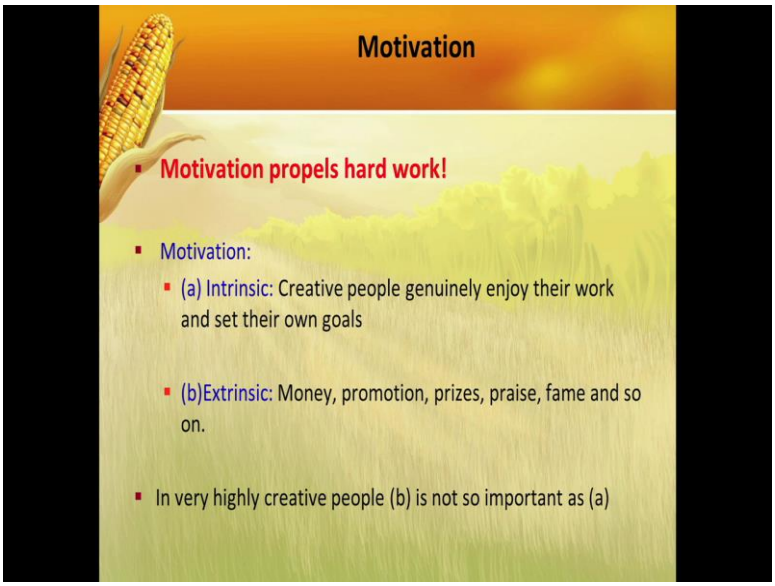

Let's now discuss about motivation. Motivation, sometimes, can be a big problem, particularly for research students, because we go through phases where sometimes the motivation is very high, sometimes the motivation is moderate, sometimes the motivation is

very low okay. Whenever the motivation is very low only during those periods you require something, so that it gets back to normalcy, and then, because you have to be motivated constantly, and you have to get… you have to be self-motivated, because motivation propels hard work okay. So, how to stay motivated is very, very important; motivation propels hard work. There are two kinds of motivation: first is extrinsic okay. So, you want a reward, you want money you want praise, you want promotion, you want prizes, fame - all these extrinsic motivators. If you get that then you will work more, you will work more. That is ok. These are all called – extrinsic; extrinsic motivators okay.

The most difficult, and the most, and the more important of the two is basically the intrinsic motivation, where you set your own goals, achieve your goals, and then don't stop there, and then don't stop there; set new goals, achieve; set new goals and achieve; and constantly, you are propelling forward; this is intrinsic motivation. In highly creative people the intrinsic motivation is very high; therefore, you constantly… you enjoy what you do; the sheer joy of solving an unknown riddle; when you are in ninth standard you want to solve a unknown riddle, there is no prize, there is no motivation, and you are struggling with that for two hours; you are struggling with it, it doesn't come; then, finally, when you get it; finally, when you get it okay, then you, say, put this is theta, that is theta by 2, sin theta cos theta two sin theta, cos theta secant theta divided by multiply by sin theta divide by sin theta…; finally, L.H.S is equal to R.H.S proved okay; then you get the Eureka feeling okay; that Eureka feeling is not related to money, is not related to degree, it is not related to prize, that is your own feeling; at that time your mother might have kept Bournvita, all that you forgot, all that, even food was not important, sleep was not important. You, in fact, you were not conscious about your body also; you were just in, you were just freaking out, it is just your mind which was working at that time; that means, you are at the peak of your intellectual abilities okay. So, the challenge, the challenge and the skill got balanced, and a sense of timelessness set in your activity; you really don't…. the time become infinite, at that point in time you are not looking, you are not looking at even the watch okay.

So, if you are intrinsically motivated, in many of your activities, you can reach that peak levels of achievement. In very highly creative people b is not so important as a, but initially you will start with, initially you will start with extrinsic motivator. The same thing with prayer; when you go to a temple, what do you ask? Initially, I want this, I want that, I want that; whether God will give or not give is not our this thing okay; that is another point. If you

really believe so deeply, then at some stage you will understand what is it you will not give which I deserve if you don't ask, even if you don't ask, if it has to come to me it will come to me. So, you will… so, your own ideas about prayer may change right. So, I will just come, I want to see you. Oh! today is advance heat transfer; so many coconuts I will break. So, it is not an insurance policy, you know. Why he should solve your advance heat transfer? You study your conventional and conduction properly.

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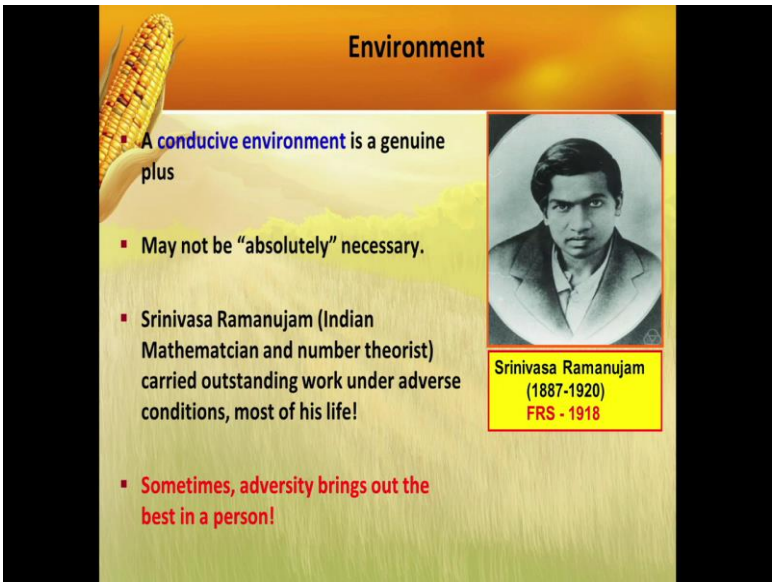

Environment. A conducive environment is a genuine plus okay, but it is not absolutely necessary. Srinivasa Ramanujam FRS, you know, one of the India's great mathematicians. So, he was born in Kumbakonam and most of his life he went through lot of struggle. He did not have access to journals and this right, and then, he was not in a big city and all that, but still under this adverse conditions the best science came out of him, you know, the best mathematics came out of him okay. So sometimes adversity brings out the best in a person okay. You should not say I will put these kind of conditions; I want a beta flop machine; I want so many these things; I want such a big RAM; only with all these things I will work okay. Even if you don't have this, what are the other alternate ways, what are the other ways of seeking solutions to these problems? Then it will make you more and more creative okay.

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Role of stress in research. The first thing is you should be somewhat unhappy about your current state. If you are too unhappy, then you will sit in the hostel room and you will not come out, that is the extreme case; but you should have some this thing, oh! it is not good, it is not good okay; there should be some optimal unhappiness with your current state which will propel you to improve and move forward okay. So, hence, progress is all about optimal disenchantment okay, optimal unhappiness, and channelizing this disenchantment. So, achievement is all about, achievement is all about optimal nervousness; I mean you should be optimally nervous, you should be optimally stressed, and then, with that, this propels you to work harder okay. Eustress is required for bringing out the best in us; u plus stress is good. So, there is also something called good stress; for some of you this may be news; you also have, you have good stress and bad stress. So, stress by itself is not stressful until it becomes distress. I have confused you enough okay? Stress it is not stressful until the stress becomes a distress. So, there's some… So, a little amount of pressure, a little amount of stress will make us work better okay.

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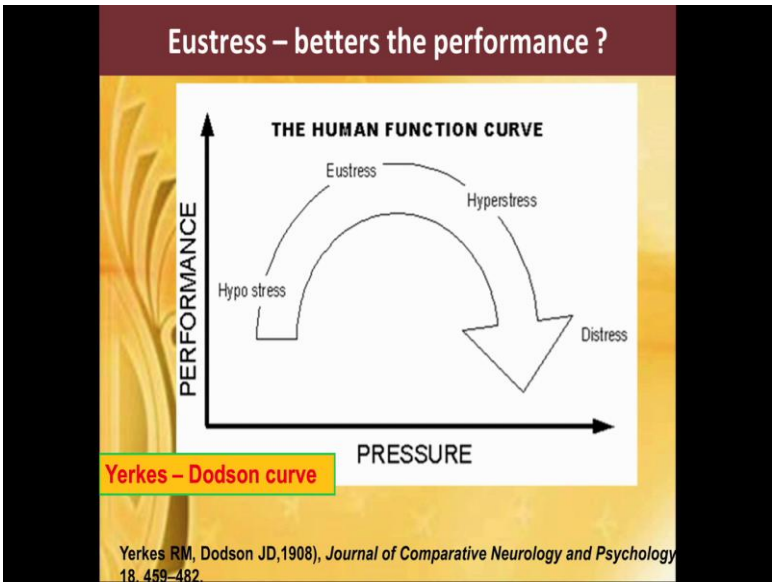

So, this is a human function curve. This is called Yerkes-Dodson curve. This is Journal of Comparative Neurology and Psychology, published in 1908, where they did studies on rats, and then they give electric shocks to rats, and ask the rats to do some activity. So, rats were asked to do some activity or exercise or whatever. So, that was the target. I mean, there is some sort of a activity and this was benchmark, and now they figured out that if they are not stressed at all, if they are in hypo stress, then the performance is very low; the y-axis is performance, the x-axis is pressure; when they are in eustress, when they are reasonably stressed, they did very well okay. And then, once they are over stressed - too much of electric shock - again the performance goes down; then finally, distress, and finally, it will even lead to death and so on.

So, this has been mapped on to a human performance curve and they say human performance curve also resembles this. So, if you are extremely stressed, at the same time you are not stressed - under both these cases the performance will be very less. You should be reasonably stressed; you should be in the eustress to bring out the best in you. What is the eustress for you is something which will you have to introspect and figure out. This depends on different people, how many activities you can take at the same time okay, how much time you want to sleep, how much time you want for leisure, how much time you will devote for research, how much time you will devote for family, whatever. So, you will have to figure out your eustress point okay.

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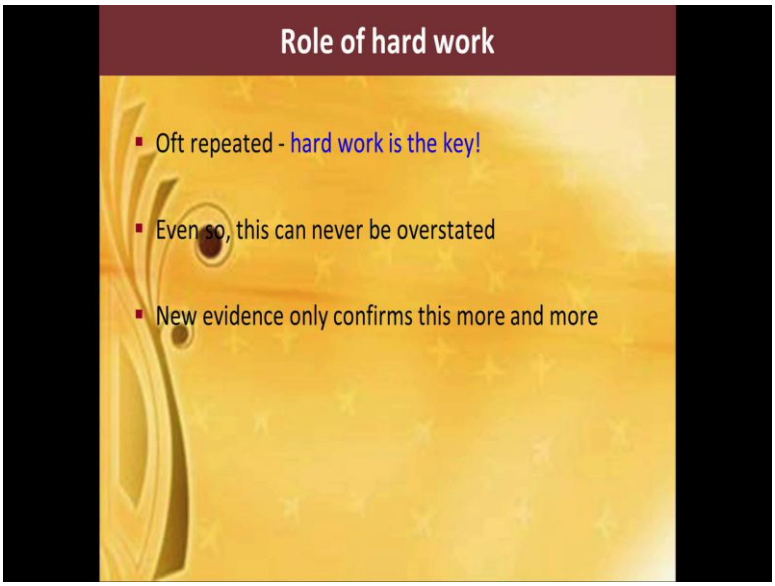

Role of hard work -we have already seen. Oft repeated hard work is the key. Even so, this can never be overstated. Even if you say hundred times, we cannot say that it is over stated, because new evidence only confirms this more and more okay.

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Now, how does creativity occur? The conception of a new idea often occurs in a… often occurs in intuitive flash of insights; suddenly, some insight comes that I have found the answer to this problem. Sometime it comes, it can come when you are not in the lab; it can come when you are not in the experimental setup; it can come in somewhere when you are

jogging or it can come when you are watching a movie or even in your bus or something, where more or less the complete idea is revealed to you, but it doesn't mean that mathematically you can prove it or when you do an experiment you can get this, but sometimes that intuition tells you where more or less the idea is completely… in which more or less the complete idea is revealed – it's not related - the complete idea is revealed okay.

Scriptures we called it as Dharshana or we call it as Dharshana. Dharshan which is, say, in a temple; dharshan means you have that vision; the vision of that heat transferring something fluid flow or something, you have a complete idea of what that. After that, you have to note down and jot down, and then, you will have to work hard to do this thing.

See, Max Planck got this in 1901 okay. i b lamda, the black body distribution - the spectral black body radiation into the c 1 lamda to the power of minus 5 divided by e to the power of c 2 by lamda t minus 1. Some people already figured out c 1 lamda to the power of minus 5 by e to the power of c to lamda t. Max Planck figured out that e to the power of c 2 by lamda d 5, if I put minus 1, then exactly that theory was matching with experiment. So, he got that dharshana - that is the correct black body distribution. He published that paper; it was accepted, but that bothered him - why that minus 1 is coming? From where that minus 1 came? Then, he figured out if he has to go back to minus, how to get that minus 1? He has find out that e is equal to n h mu, e is equal to h mu, e is equal to n h mu or s equal to n h mu; energy transfer can take place in finite multiples of h mu only, it should be n h mu where n can be an integer. Therefore, h is a fundamental constant of nature, which cannot asymptotically approach zero; it is 6.627 into 10 to the power of minus 34 joules second. So, this announced the birth of quantum mechanics, but first he got the idea - it was just a curve fitting idea; he just got this dharshana, oh! I put minus 1. So, that minus 1 got him the Nobel prize, but it took 17 years for him. 1901 was this thing, and then, he worked, and then he proved, and then 1918 Quantum Statistics was his Nobel prize okay. So, then Einstein, other people have worked together, and then, you know now, this can also be used for splitting the atom; e is equal to m c square and all that right.

So, when you are doing your research, when the dharshana comes, take a note book and write down this idea. Suddenly in your heat pipe, you get a brilliant, you will get a brain wave; then you write it down, then you have to logically follow it up it; it may cup also; doesn't matter okay. Then, what is the lesson you have to learn? If some brilliant idea is coming, and you work on it, and it doesn't work, then slowly what do you learn is, far many times brilliant

idea will come, but which brilliant, which of these brilliant ideas I have to pursue is something you will have to figure out. So, you say the next two three weeks I will work, if it is not coming out, I will discard. So, you will have a mechanism by which you will judge, this is the path I will take, I will spend one month; if it's not coming, I will go to some other path. You should have your own back up, multiple backups, second line of defense, third line of defense, you should internally evolve all this alright.

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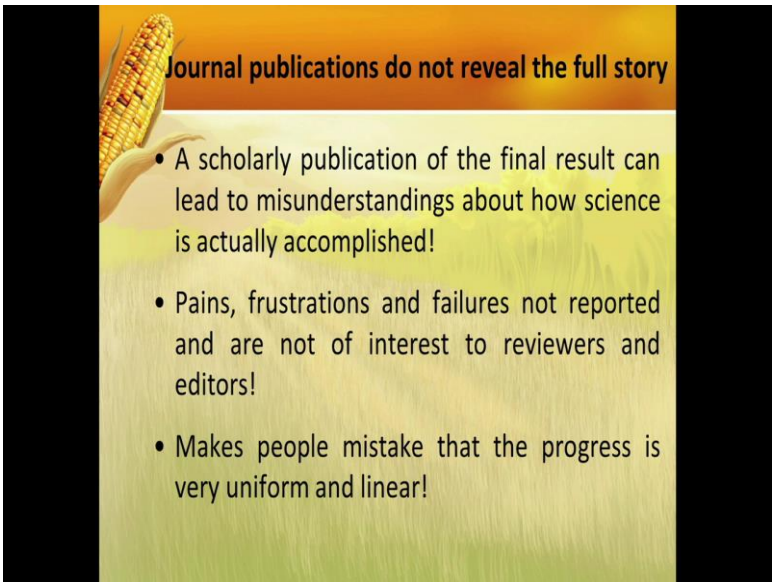

Journal publications do not reveal the full story. A scholarly publication of the final result can lead to misunderstandings about how science is actually accomplished: abstract, introduction, literature survey, experimental methodology, results and discussion, conclusion, references, in between nomenclature; how nicely he got it, but how much suffering the authors went through to get that paper, that we don't know, because that is a way, because everywhere that is people don't have time, reviewers don't have time, people don't have… I mean it costs a lot of money to write your own story and all that right. The pain, frustrations, and failures, are not reported okay. So, it makes people feel that progress is very uniform and linear; it is not the case.

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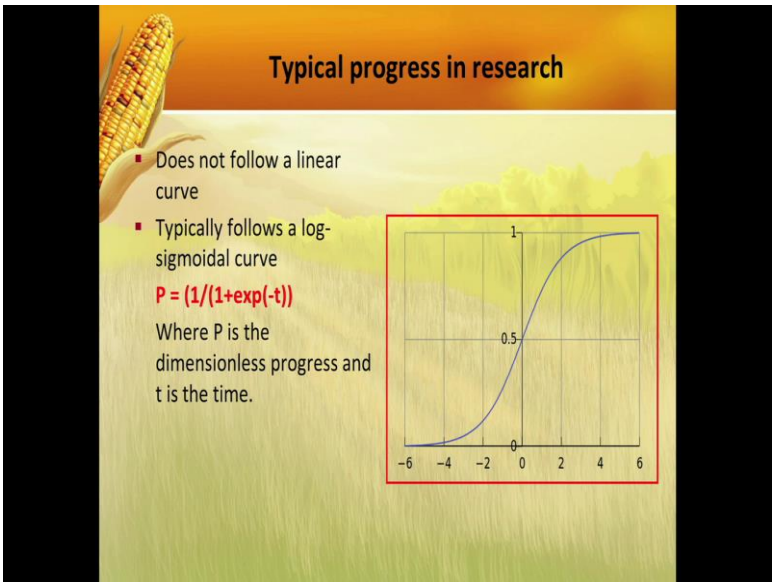

Okay let us look at this. Typical progress in research follows what is called a log sigmoidal curve okay. In the initial years, your progress will be very less, you should have patience, then suddenly the graph takes a turn; isn't it ? The graph takes a turn okay where you get a rapid progress, then afterwards if you keep on spending more time, again, the progress is very less; therefore, initially, one, two, one, two, three years whatever, you are learning the science, you are learning your field, you are going through your qualifiers and all that. And you are trying to write a program or you are trying to develop a setup, it is not working; some joy is not there or some workshops something is not there or something is not moving or somebody is not signing; I mean so, many things are, but after sometime suddenly the flood gates will get open; one day to your surprise, you will see the experiment is actually working, and it is giving good results. The program is actually working; then you should capitalize on that, and try to extract maximum, and after that, again milking it dry is not a good idea. I will write the fourth paper, fifth paper, sixth paper, then the reviewer will say I don't want any more paper on this. So, this is the right... So, initially if it's not working, don't worry, give it some time.

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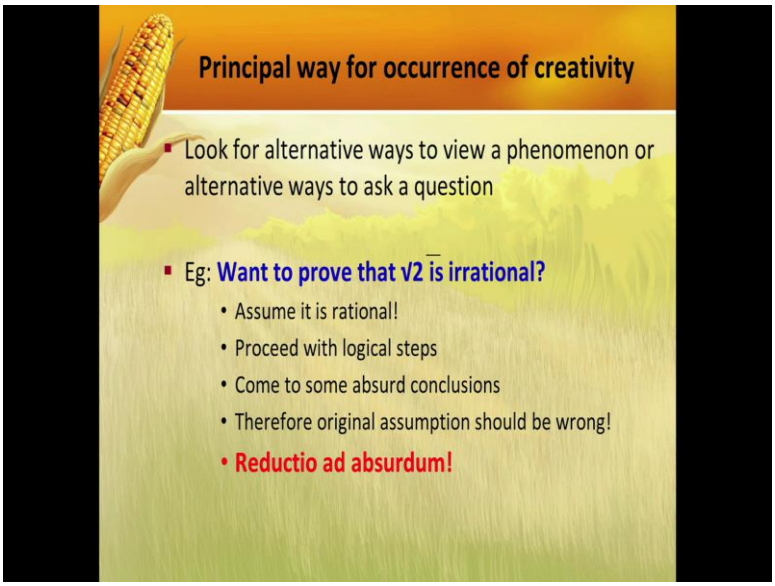

What is the principle way for occurrence of creativity? I mean, we should also look for alternate ways, alternate ways in which you view a phenomenon okay or how do you rephrase a question okay. For example, you know that you want to prove root 2 is irrational. How did you do it in mathematics? If you want to prove that root 2 is irrational, we assume that root 2 is rational, that is root 2 can be represented as p by q okay, where p and q are integers; then you start working various operation; finally, it will lead, it will lead to some observed conclusions, which you believe is not correct; therefore, if this is not correct, you go back and find out where you make the mistake; you figure out all the steps are correct. So, what is wrong? To assume that root 2 is equal to p by q and is rational was wrong; therefore, root 2 is irrational. This is a way of proving; this called reductio ad absurdum, reducing to absurdity. So, used by ancient Greeks; this is an exercise in logic okay. So, in your this thing also, you have a multi objective optimization problem how are, what is the, what are the different ways in which you propose, in which you can impose the problem or you want you want a figure of metric for the performance of your device; it could be your solar collector, it could be a heat pipe or it could be a jet impinging jet whatever, can we think of some other this.

Traditionally, so many things are used. Can you deviate and come out with a new performance metric? Think about it okay. And then, literature, everybody knows Reynold's number, you keep plotting Reynold's number. As Reynold's number increases, Russelt number increases; what else it will do? What a brilliant conclusion. So, we should not restate

the obvious; it is already known; it is already known. Okay we should say something, so that's what we say know, dog bites man; what is news? Man bites dog; that is news; how your results and discussion and conclusion will be man bites dog.

Contrary to popular belief as I reduce a tube diameter, though the pressure drop increases, the heat transfer is increasing significantly. Therefore, heat transferred to pressure drop is increasing; therefore, it is more advantageous to use a smaller tube diameter, and yes, then people will say, what he is saying, what he is saying, what he is saying, surprise; unsettle all the people who read your work; do not allow people to read your things in peace; that should be your goal okay - reductio ad absurdum is clear right.

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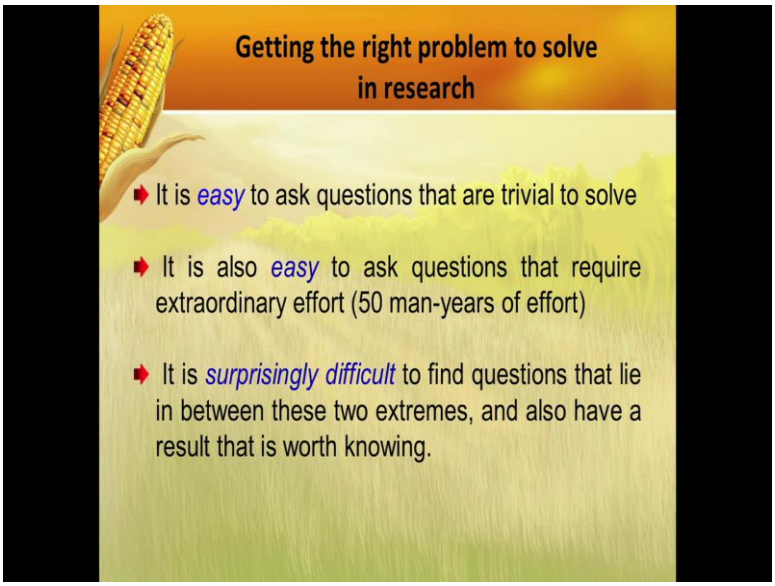

Getting the right problem to solve in research. So, the happiness comes out of creativity, because it gives you a sense of achievement or accomplishment that you are able to do something that it is your contribution. You are contributing something or you are able to find out something which was not there; it comes out of that; you don't even want that; what is it? where do you want to get happiness from otherwise? You tell me.

Student: The joy is intrinsic, you are doing.

Yes, yes, the joy intrinsic means because you have improved, you have improved over what you are thinking you can achieve; you have improved compared to your present level. So far, you are not able to solve this unknown rider. So, far you are not able to… you are improving,

you are improving, you are improving; through this thing, other things may also improve; that we don't know now, but you get some sheer joy out of finding the unknown; darkness to light Asathoma sadgamaya , thamasoma jyothirgamaya, I mean it's light, from darkness it is light. When you are finding something new, it's like thousand watt bulb; isn't it?

Getting the right problem to solve in research okay. It is easy to ask questions that are trivial to solve. Find the inverse of a three by three matrix; everybody will solve; that is not a Ph.D. problem. It is also easy to ask questions that are extremely difficult to solve; Ph.D. problem using thermodynamic arguments, using thermodynamic arguments prove that God does not exist - can that be given as a Ph.D. problem in thermodynamics or radiative heat transfer? Or I will develop a new theory for the evolution; high risk problem okay. It's surprisingly difficult to find the questions that lie in between these two extremes. You ask the right question, you solve, you work on this question for three to five years, you get a good answer, you get a couple of publications, you get your Ph.D.; that is the right problem for research; are you getting the point? And it surprisingly… and if you are an academic, a full-time scientist or a professor later on, how to constantly generate these questions which are neither easy to solve nor difficult to solve, but are worth solving. So, it's a challenge okay.

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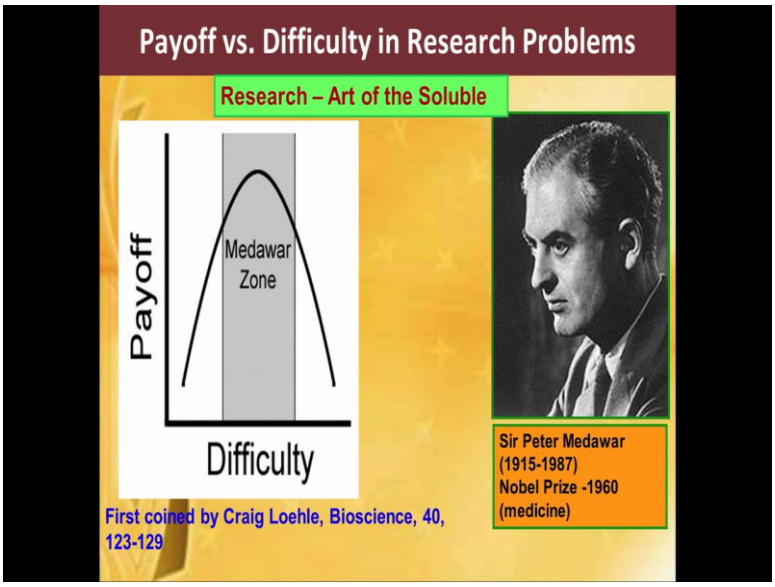

So, this Sir Peter Medawar; he got the Nobel prize in 1960. So, he talks about the return in investment on working on a research problem; that is payoff y-axis, and the x-axis, the difficulty level. If the difficulty level is very low, the return is very low; if the difficulty level

is very high, the return is also very low, because you may not be able to solve it, but if it has the right difficulty level, then you have the return is very high; that is indicated in the grey area that is called the Medawar zone. So, what is your Medawar zone in your field of research you will have to figure out.

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