Strategies for Sustainable Design
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Lecture 34
D4S with Inspiration from Nature

Hello everyone, in this lecture we will discuss about Design for Sustainability with Inspiration from Nature.

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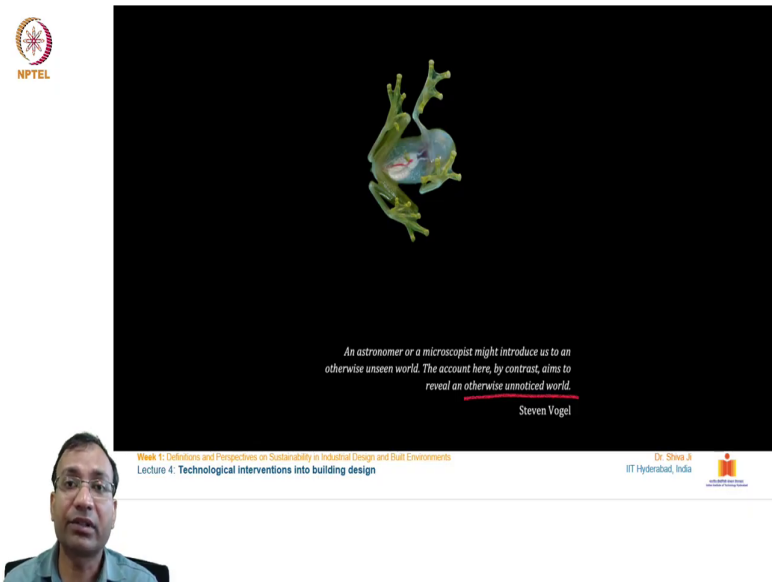

So, let us see like, what nature has to offer to us in terms of like design inspirations. So, there is one actually saying from Steven Vogel, he says an astronomer or microscopist might introduce us to an otherwise unseen world, the account here by contrast aims to reveal an otherwise unnoticed world.

Well, there is a lot many things, there are like innumerable, unaccountable instances where we can learn from the nature, there are several examples in our life, like how humans have actually drawn inspiration from like a nature and whether it is direct or indirect in like a several other ways, but there are always a baring in our designs, which has like a some inspiration from the nature.

Well, nature has its own ways of working, nature has its own like a ways of actually conducting the functions of the nature, whether it is like living beings of all types, whether it is flora and fauna, whether it is like a big animal, smaller animals, insects, even the human body parts also if you see. Like a how the human body works, how the mechanism works, how the form works, what are the actual kind of learnings we can take from. So, there are

innumerable, instances from which we can learn. So, we will see, like how this can actually work out.

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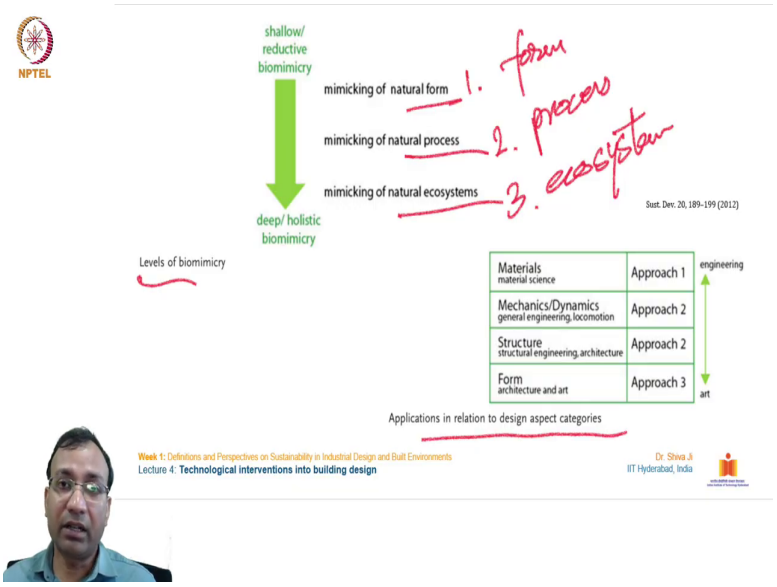

You see this slide, it talks about the levels of biomimicry, well what is biomimicry? Bio comes from like a nature, mimicry means like a mimicking it or replicating it. So, there are like, this mimicking is possible at different levels. First and foremost comes like drawing the natural form, for example, if a fish is there and I am trying to draw and trying to evolve the (())(2:10) form of that fish into like a certain like a form which resembles that frame or which functions like frame.

So, the moment it, when we talk about like the functionality of part of it, it goes to the natural processes. So, the process is the like the second level of like, bringing biomimicry in our like designs and the third and topmost level is the drawing from like a or mimicking the natural ecosystem, like ecosystem means the entire like mechanism, form functionality in several ways in like much detail than like the previous two.

So, we see this mimicking is at three levels one is at the surface level, the second is at a little deeper and the third one like completely going like a replicating or completely like a mimicking it into like with a much deeper understanding and mechanism. So, like a form process and ecosystem.

On the applications in relation to like a design aspect categories, well, there are some variations we can see there are like multiple approaches, from like arts and aesthetic side towards like engineering side. So, the art side goes like a for the like a form applications for

example uses in the like architecture and art, then comes like approach 2 for like a mimicking like a mechanics dynamics and the structural system of it.

So, it finds actually usability in general engineering locomotion, other like structural engineering even like architectural like functioning etc and in the third level which is much deeper understanding at engineering level, it goes for like material explorations from like material science, like examples.

For example, like the surfaces which are like a dust free or they are dust repellent. For example, mimicking actually the surface of the like a lotus leaves. So, that comes under like material exploration and if you want to evolve maybe a dynamic actually form for like a aerodynamics or fluid dynamics or something. So, well that comes onto like a form studies and majorly into the form studies. So, these are actually some variations like how this mimicking can be actually carried out. So, we saw and in the coming slides, we will see some examples.

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So, you see this slide, this one talks about creation of maximum strength with minimal input material, well this is one of the best examples of like bones, like our skeleton system. So, if we like a take like an each of these like pieces of like bones, depending upon the application and the usability of that organ, from wherever we are referring to that actually piece of bone is an excellent actually piece of engineering and there are several ways you can see the example given over here like nature employs a relatively small amount of material in its assemblies as compared to human constructions.

However, through unique configuration of these simple materials, nature is able to create structure that outperform many manmade structures. For example, bones in natural organisms shows variation in their cross section all over their length, to deposit the material where it is needed most. In addition, cross linking of the fibres in bone contribute to the increase in strength without a corresponding increase in weight of the material.

So, you see like wherever the maximum strength is required, the concentration of the material, the volume of the of the material will be their like a more and wherever it is not needed that much, there will be like a reduction of the material from that portion that segment and for example, like our femur bone is one of the most longest actually a bone the longest actually bone in like a human body is the femur.

So, the femur if you see the joints of a from where it gets joined with the knee or it goes into the pelvic bone area, so that actually portion is shown over here with this image. So, that is always like a broader with the for with the mechanisms so that it gets inserted into the pelvic bone area efficiently, while allowing the required moment in the like a body parts.

So, this is one of the best examples of like, how material optimization is used in the like natural systems. So, when we see like our structural system for example, beams and columns, they carry the almost same cross section in the their entire length and width, well if we study the structural actually and if you do the association analysis of that, so there may be some portions where even the lesser amount of material would do. But we generally do not actually get there do that. So, as a result actually, it may be like a possible that we are wasting a lot of material which is unsustainable.

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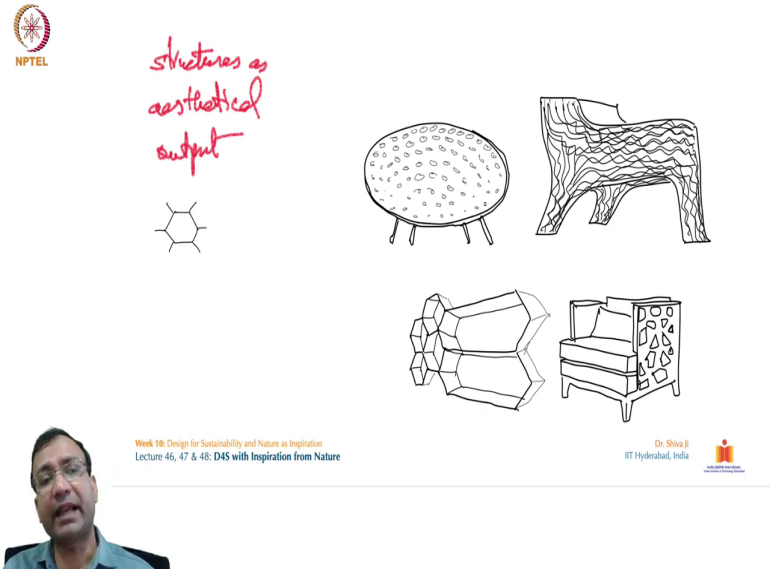

So, further if you see, like how structures of any material can be utilized as the like aesthetical appeal also, so you can see some images over here. So, these are the some actually, like a furniture, pictures of the furniture how this entire actually furniture is made out of this like this structure and how is it likely that this is going to provide, a cushioning effect while sitting on it and in this one, if you see these small corrugations, honeycomb sort of like a corrugations, they are very thinner in their own like thicknesses, but they are going to, with a with a group of like these a high concentration of these actually members, they are going to provide very like comfortable actually seating actually for the person who is going to sit on here.

And similarly, in this actually chair if you see, in this year this these actually honeycomb structures they are used for actually strengthening the side of this wall of this actually chair and in here if you see, on this like a wall in a shop. So, this actually structure is used for creating like a (())(08:22) species utilizing and creating a focus on the like a product which are being displayed over here, creating like interesting lighting, actually atmosphere lighting, like a experience inside these actually curve.

So, there are several actually interpretations of like utilizing a form of any like a like example from the nature in this case, like a honeycomb like this a structural system and how the its form can be used in like a multiple ways. So we will see the next slide.

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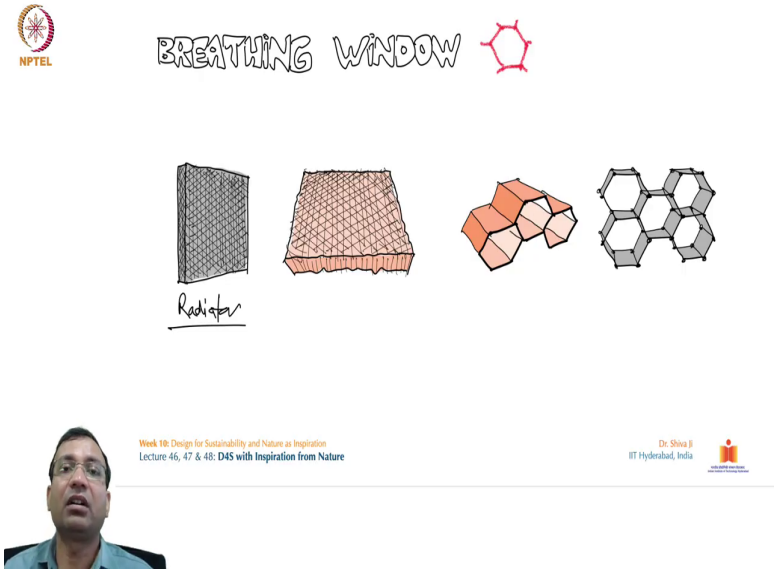

So, here if you see like how this can, the same structure can be used for actually creating breathing windows. So, here if you see like this radiator is actually designed under a using this honeycomb structure to create this breathing window, which in turn actually cools the liquid the of any like engine and similarly here this is structure is also used, this can be used as a mat also, though these films are very thin, but as the overall is a composite structure, this could be like a very strong supporting even a person's like a weight.

And similarly here these is casted in like a ceramic or clay and now this has taken like a, this kind of a form of like a vessels, these hollow vessels, creating actually a structure out of it and similarly here like this also structure, it look like it appears like this is made up in like a wireframe structure utilizing joining with some like a membrane. So, all of these like a geometries if you see have a actually, has the potential of all translating into very interesting actually usable forms for our like users.

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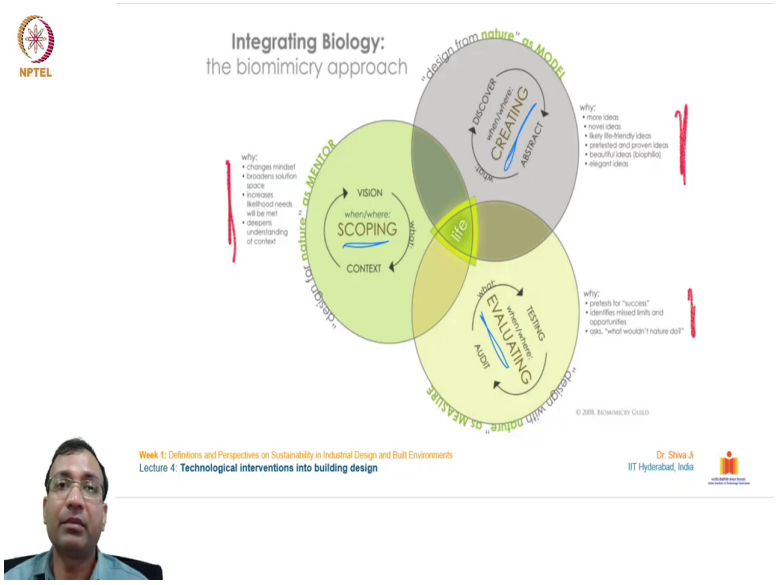

So, how this, like biomimicry, this approach actually works. So, there are actually three levels to it given by the biomimicry guild, we can go seeing like all of these one by one. So, the first actually bubble talks about like a scoping. So, this actually works around actually, the context, in which the study on the actually the study is actually established and then it talks about vision like how do we visualize it to take like a shape like, so the questions of like when where and what actually arise in this domain and under this category, actually the queries of like, changes mind set, broadens like a solutions space and increases like likelihood needs will be met, deepens understanding with the context.

So, actually these sort of like a queries are answered in this actually bubble over here. So, it works as a design for like nature as mentor. So, this is the actually place from where we take like our inspiration, from here we actually take up our like a context actually study and then we take it well ahead.

And the next level we go to the like a creating actually stage, so this creating stage works for like a discovering and abstraction, like the moment we start actually deriving something out of the giving context and in the given actually the example the case example. So, the query like a more ideas, novel ideas likely for life friendly ideas, protested and proven ideas, beautiful ideas, like for example, like biophilia, elegant idea.

So, these actually start coming into like a shape, they start taking actually abstraction like a form and then lastly, we have this evaluating phase where we go for like a testing and auditing and evaluations etc. So, it pre-test for the success, identifies missed limits and

opportunities, ask what would not nature do and yeah, so these kind of like a queries are actually have, take place over here and at the confluence of these three, we get our actually the, the solution.

So, this is where actually how this biomimicry actually approach actually takes lead and leads us for like any like a solution from the nature. Well, biomimicry and nature based designs are always like a very interesting and they give actually insights into like how the nature functions and we try with our like aesthetical and engineering methods to mimic those into like a real life example. So, we will see like a some examples from the like a real life.

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You see this picture over here. So, this is like the East Gate, central building design inspired by African termite mounds. So, this was published in this paper. So, you see over here, you may have seen these like a termite mounds in the like a country sides and forest areas, they grow as tall as maybe a house is like structure, maybe one storey actually high structure and these are all created out of only like a mud and the earth material.

These ants actually they weave this structure like a bit by bit on their own, they take like a sometime, with the group effort actually they build this and it is not just a piece of like Earth or a mound, it is actually a breathing completely like there is a, you can call it as a like a city structure and there are like a, there may be the lakhs of the termites, which may be inhabiting inside actually this chamber in the, inside this actually structure.

And it is a completely like works with the like aerodynamics, there will be like an air movement inside there will be like a chamber to control the heat, control the heat from the

like a sun, there will be actually chambers for like protection of the like a queen termite and their new born babies or their larvae and there may be some chambers to store like a food. So, it works as like a whole, self-sufficient actually living unit, where are these termites and huge number actually reside.

So, taking cue from this actually example, the architect and then designer has actually designed this building, which takes this inspiration of like this, a cooling on its own, so they actually allowing the movement of air from the like a surface and then going in the core and then the stale air or the warm air will rise to the like a ceiling and the roofing area and from there it will escape.

By creating a kind of like a air movement inside the building for like a proper ventilation. So, this building works as a like a properly like a self-ventilated actually system where this warms, warm air actually goes up through this, the provision in the ceiling to rise and it gets released from here allowing the actually fresh air to move again from the like the sides of the building and by the thus like, it creates this like inducing this like air movement inside this premises and this is how, this is actually cross section where it is shown like how the temperature rises from the surface till the like a core areas of the space and how these green region other stuff are also used inside to actually keep the air like a saturated, keep the air like a healthy fresh and comfortable for the like inhabitants inside.

So, this is one of the like a typical examples, where the form is used in a like a much direct way we can see like this is used while adopting the like of form only, though this is a very like a high and bigger in like a scale. So, compared to like this structure this may be like 10 times or even more. So, this is but overall actually principle remains the same.

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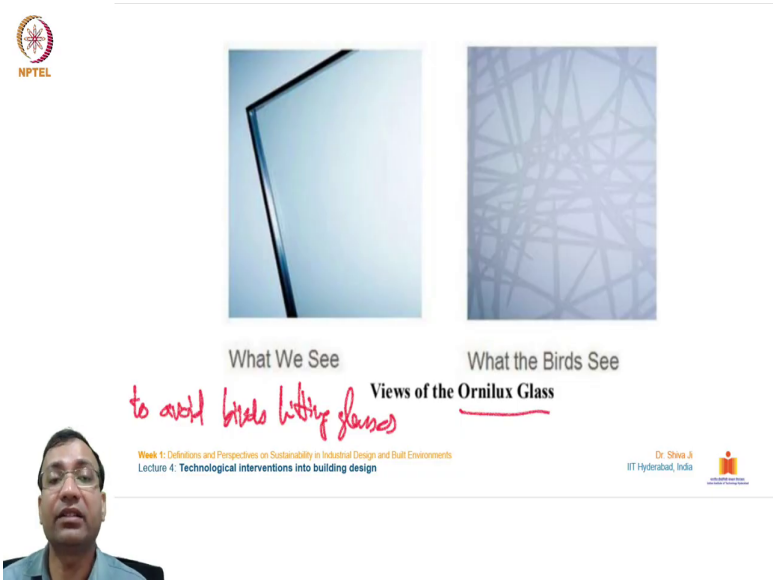

In the next if you see like in a more subtle way like how like we through the glasses and how actually birds and other like these insects, they cannot actually perceive some of the materials well, glass is one of the materials which these animals and other life forms actually cannot completely like understand.

You may have actually witnessed some instances where the birds might end up actually hitting the glass panes and the glass like a windows and the glass openings, in our like buildings, because they do not actually, they are unable to differentiate between like an open space and a space which is like a covered with glass piece, clear glass place and they end up actually hitting and in turn like millions of actually birds die every year out of just like this actually phenomena.

So, it is one of the actually bad impacts and the hazards of having like a clear actually a glass surfaces on the like a building surfaces, because even like a, even with the like the no intention of, we end up actually killing like they have so much of like, so many number of like birds every year unintentionally.

So, how this can be actually taken care of. So, there is this solution you can see over here on the slide, this is the product actually the commercial brand name is Ornilux glass. So, this has actually these invisible to like a human eyes, these structures and these reinforcements these lines inside the body of this glass.

So, we may not be, we able to see these lines through these like a glass, but the birds, they may be able to see it. So, they will understand, okay there is something actually, some

obstruction in their path and they may not actually come this way. Resulting into like, saving up their lives. So, this is one of the approaches from where we can, re-engineer our like a products and our solutions from everyday life and we can help actually nature sustaining in like multiple ways.

So, this is one of the examples I thought of putting up over here, like how the social concerns also can play a role into design and how we can take actually inspiration from nature itself and go back and redesign the solutions.

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Further like coming back again to the like a biomimicry part, here like a lotus flower we are all aware of, lotus flower sits in the like a middle of the water and mud yet it does not actually catch is the mud part or the water part. So, it is so like a non-sticky like a surface not sticky like the coating it has that allows the even a single drop of water to just simply like a rollover and move away.

So, how like, we can actually take inspiration from like a, such a, like a system and evolve and design products which can be suitable in like such scenarios, where maybe human may be working in like a, for example the wet areas or maybe even in the like for the like road construction work or even like a, the people who are like working in the agricultural fields. So, how they can save themselves, how their clothing can be designed to minimize actually the effects of the like natural elements. So, this is one if we start decoding it.

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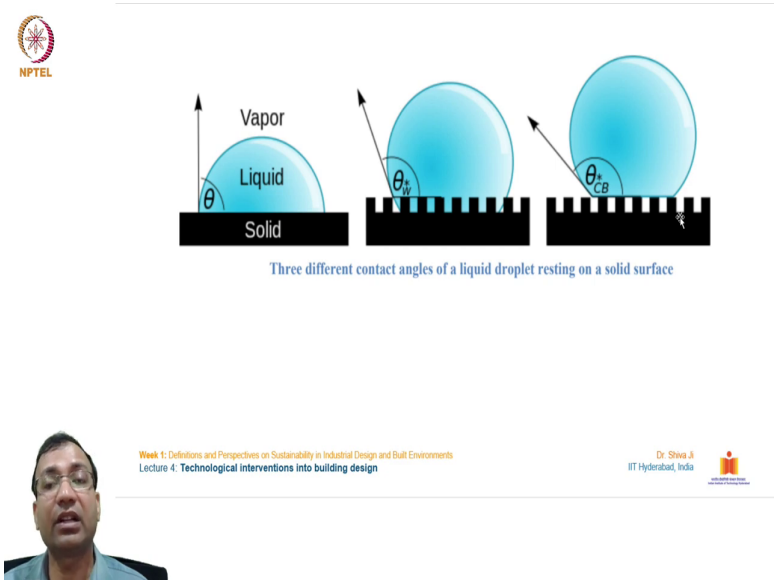

So, this is the diagram I would like to put up like how a surface any like a surface any solid surface, attracts the water molecule, attract the water actually droplets. So, this is the cross section over here on like a solid surface you can see a drop of liquid, is sitting like properly and how this actually, the changes in the structure of the surface, the with these undulations, the surface area of contact is like removed significantly by this, by this actually third illustration over here and this drop of water is just simply sitting without getting attached with the, wider actually surface area.

But with a very minimum actually surface area and the moment this surface will be inclined or maybe some kind of like motion will come, this water is going to just simply roll over. So, this is actually kind of inspiration taken from these a lotus pond, this lotus actually plant, these lotus flower and it's like leaves, and the surfaces are actually designed these days to which can actually, attract little dust or almost like, they do not actually, the dust may not be actually able to attach with the surface in turn if you just wipe it off, if you just like a throw some water, the dust is going to go away simply without causing any stain or any like, damages to the surface. So, such actually inspirations are coming from nature and there could be like, many more we will see.

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So, how this design spiral works, so there is another actually illustration from like this biomimicry guild we will see, so, it starts from like a translation. So, that is the level one when we start actually conceptualizing and visualizing the translation to biology by identifying certain functions. For example, in the previous slide, we saw like how we can take cues from like a lotus flower, lotus's leaves and how we can create like a bio like a hydrophobic surfaces.

So, identifying the function. So, creating the hydrophobic actually surface could be our like for example, like one case function in this case. Then we can go for asking how does nature do that function. So, we can go for the inquiry like how this is being done by that like a plant that lotus plant, reframing the question.

Then again, we can reframe our questions based on our like requirements and suitability and then we can go for like a defining habitat conditions that reflect design parameters, then we can go for again, like further adaptations and other like ways of a, bringing or mimicking it our, in our own application and then further we can go for translating life's principles into design parameters.

So, again we can set like the design guidelines and the requirements and parameters etc. Further we can go to the next stage that is the discovery. So, in the discovery, this suggest to discover natural models, then on the final point it suggest to go outside consider both literal and metaphorical models, (())(22:57) the literature brainstormed with the biologists, create a taxonomy of life strategies.

So, discovery means actually studying, discovery means actually investigation like how things are actually taking place in the nature and for that actually we can go to several like stakeholders like a biologist, are the ones export actually scientists who have or who have actually knowledge and idea of how the animals and how these actually insects and plants work in the nature.

So, with the consultation with the, like a books, literature and other like these biologists we can go for like finding like a state of the art like knowledge, like how this phenomenon is happening on its own in the nature. For the next level, this is like emulating, so emulate nature strategies. So, brainstorm multiple solutions, refer back to the discovery phase and consider (())(23:54) designs, consult with biological experts, go back to your model and explore more strategy.

So, from here actually this is the human ingenuity and this visualization and conceptualization begins, like how we can best transform this actually naturally occurring phenomena or the form or the ecosystem into like a manmade, like application based work and then finally, like evaluating it, evaluate your elevate your design against life's principles, can your design adapt and evolve? Does your design create conditions conducive to life, how can you improve your design?

So, these are actually evaluations and assessments, which we do like a post design and there may be some feedback on which we can work again, we can go again go for this completing this cycle for the second time and we can improvise and improve our product and we can find a most actually suitable solution for any like a given requirement. So, this is how actually are this design spiral works for like taking inspiration from the nature. Further to this.

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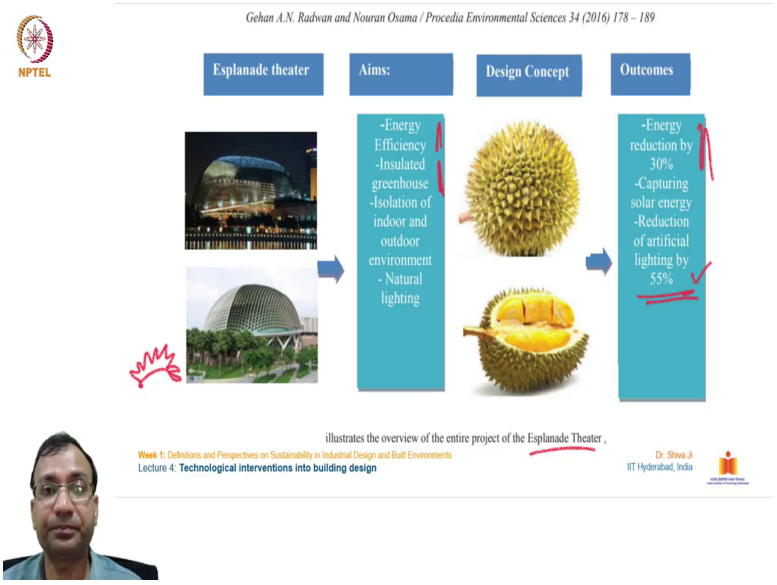

One example, you may have seen visuals of this actually building. So, how they have actually taken example of like such structure from the like the nature. So, this is actually concept or this is the inspiration from the nature and what they have drawn as their aim is to optimize on the like energy efficiency insulating this entire like a structure \and then isolation of indoor and outdoor environmental allowing like natural light.

So, with the combination of like this kind of like a surface, as the outcome they were able to minimize actually energy reduction by up to 30 percent capturing solar energy reduction of artificial lighting by 55 percent as a resultant we can see like how much of like a significant difference, adopting a natural actually form can do compared to any like a traditional like manmade form. So, it Is clearly like evident that there is a potential in following actually nature in our designs.

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In this table, in this actually slide you can see the sum actually matrix is given from where we can see the, how the inspiration was taken and how it was translated into a final product, into a final actually design. So, there are four examples given over here. So, we can see these examples are mentioned over here on the, on the left side, the first example is termite nest second, like a butterfly, third like a cuttlefish and the fourth are like a hippopotamus skin.

So, these are the pictures and the features what are like the features which are actually taken from the inspiration are like optimum, are like air temperature. So, maintaining like the optimum like air temperature even if it is like hotter or cooler outside, the inside these actually structure the ambient temperature remains more or less like under like a normal conditions required for the termites for the living of the termite. So, this natural ventilation system, how efficiently it works is the actually the main feature which we are talking about, over here.

In the second actually case example, we are talking about reflecting the sunlight. So, like a butterflies are one of the beautiful, most beautiful like a creatures in the like ecosystem and there they are existing in like an innumerable actually varieties of colour and scattering and the appearance of it and they are one of the most sexually appealing creatures.

So, how do they work. So, we have actually seen like, how the reflection of the sunlight takes place through the like a microfiber structure on their like wings. So, how that can be actually transformed into like a, certain like a product or certain like a utility. So, we will see over here in the third one like the property of a camouflage.

So, this cuttlefish actually has this excellent property of getting into camouflage, communication with the colour like changes. So, it keeps on changing its colour, with the variation of the change in the colour and appearance of the, it is like a background where it is like placed in order to avoid like the predators.

So, this is one of the amazing like, properties of this like a cuttlefish and there are several other like a chameleon is there and there are several other creatures who actually do this actually camouflage the property. So, how this can be used for building surfaces also. So, we will see over here and the fourth and the last one like how the hippopotamus skin actually absorbs the UV light, and so, we will see like, how this is transformed over here.

So, example like architect example of the bionic, so the building constructed using ventilation with the chimney system. So, the one example we saw in the previous slides, where this is stack effect is used for like, creating a better an optimized actually self-ventilating system. So, how the uses of this actually functionality is taken into like architecture. So, the blight street structure has a natural ventilation system, which represents a kinetic architecture example.

So, this particular actually building from like this street, this place, adopts this mechanism of Termite nests and the sustainability impact if you see of this mechanism adopting this mechanism results into like providing like energy conservation, providing like a fresh air in the like a core of this building and it helps predicting, maintaining the heat level also inside the building premises. So, we can see like, how direct philosophy is implementation into like this design has resulted into like a significant actually improvement compared to our normal like a regular building design.

On the second example, this butterflies, this sunlight reflection capabilities, so the wings of white butterflies have shaped the design of photovoltaics like the panels. So, how these panels can be redesigned for the orientation to face towards the sun or maybe away from the sun at what angles they should reflect the light and all. So, this project, so the Peter Koch is the project manager, he is talking about this project, they see that the shutters open and closed like a butterfly wings in response to heat and light levels inside the building.

So, they are these actually structures are providing the amount of like a controlled sunlight within this premise, by these retracting actually panels, which are designed on top of this building. So, it takes advantage of the daylight and it provides energy conservation, resulting into like efficiency of energy used in this particular building.

Third example of this cuttlefish this, it can be led on like a facades without like without energy, the Galleria centricity has a single actually reflective surface during the day and the nice radiator different light wave. So, you can see in this picture over here. So, this this actually this functionality does not he uses external energy as it is being said over here, but the structure, the intrinsic structure of this membrane only, this is a surface membrane only, it behalves like in such a way that it ends up actually saving a lot of energy during the like a daytime.

So, the passive energy is obtained from like a sunlight absorption with the colour changes. So, this is how actually they harness the sun's like a heat and they actually minimize the heating load of the building also. Lastly, let the skin of the hippopotamus, so UV absorbing material has been developed for like a building in Italy.

The Brisbane domestic terminal carpark absorb energy like water bath skin, it provides energy conservation natural protection from like a UV lights, well this is one of the amazing actually, in the more complex actually phenomena. So, a very minute actually material analysis made exploration is needed to develop like this product and I am sure like these engineers they have like a succeeded in creating a building surface which can actually save from like a harmful like a UV radiations. So, well this material can find utility and different other like places also.

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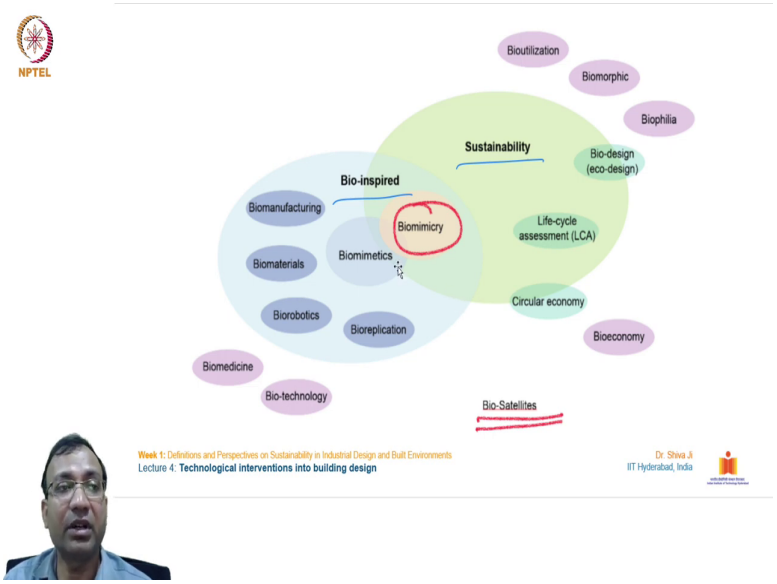

So, further to this like when we see, like how these, intricacies of this design in sync with the nature are actually placed in these two bubbles of sustainability and bio inspired designs. So,

you can see over here, like we have a bio manufacturing, biomaterials, bio robotics, bio replication, biomimetics and biomimicry over here, which is common between these two actually bubbles of sustainability and Bio-inspired design.

In the sustainability, on a like a pure sustainability we have like this bio design or eco design we have like LCA, we have like a circular economy when we talk about closing the loop and we have this bio economy away from here and then we have some more examples on the sides, biotechnology being an extremely like engineering based approach, which cannot be called as like a nature inspired design though it actually reworks the technology into like from like a biology perspective and provides like solution.

So, we see like in this actually two overlaps, this biomimicry is a subset which is falling in the like a common area. So, this is why this biomimicry is like a favourite of like, architects and designers also, engineers also and why it is a favourite of like other like a material sciences also who are developing the hardcore, material exploration they are doing research much deeper into detail we saw at the third level like designing for the like ecosystem through the help of like biomimicry.

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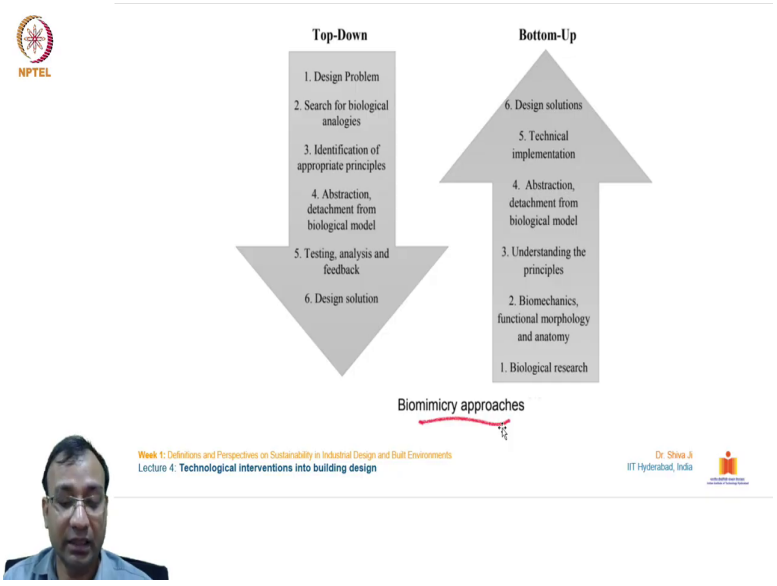

So, how this biomimicry actually approach should work. So, we have this example, two examples top down and bottom up. So, in the top down it goes starts from like a design problem, it goes on till the like a design solution by passing through like a search for biological analogies identification appropriate principles, abstraction detachment from

biological model testing, analysis and feedback the one cycle, one typical cycle we saw in the previous slide and these second actually this approach works like a bottom up.

So, the first one goes for the lack of biological research, understanding the any like a natural phenomenon and natural like a occurring and then going for like deriving like other, biomimetics and biomechanics, the functional morphology and anatomy and then going on understanding the principle, then going for abstraction, detailing all the technical enablement and finding then application.

So, here this actually research, this actually starts from the like research, this approach starts from the research and then finding the solution and hear in this one, we first look for the problem and then we come up with the solution. So, these are the three different like equally good approaches depends on the like the subject area and depends on our like, the interest of the research etc.

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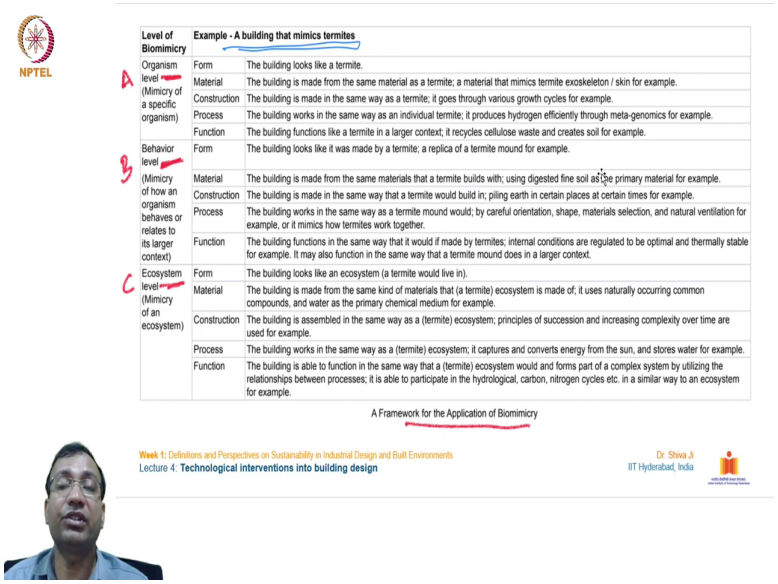

Finally, I would like to talk about here of this is a framework of the, for the application of biomimicry at these three like levels, which we saw, we saw in the previous slides and what could be the examples in each one of them, on them form material construction process and functionality parts.

So, these are very, very important actually slide over here. So, the level of biomimicry, you see at the organism level, mimicry of a specific organism and then the second one talks about like a behavioural level, mimicry of like, how an organism behalves or leads to its larger context and then third one, like at the ecosystem level, mimicry of an entire ecosystem.

So, for the organism level on the form. So, for example, if a building looks like a termite, like a nest, completely. So, that would be like a biomimicry actually approach of like the deriving form through this like organism. Second on the material part, the building is made from the same material as a termite like using the normal Earth material, the mud.

Our material that mimics termite exoskeletons skin for example. So, for example, if you are taking the termite only. So, the material which limits, which actually mimics the termites like an exoskeleton for example, skin and the bone parts etc. In the construction, the building is made in the same way as a termite it goes through various growth cycles.

For example, process the building works in the same way as an individual termite it produces like a hydrogen efficiency through meta genomics, for example and then the fifth and the last one function the building functions like a termite in a larger context, it recycles cellulose based and creates soil for example. So, these are actually different levels of this exploration we see, on these actually five examples of form material construction process and function.

So, how this applications can actually take place, can actually occur, but the variation in these like of five examples. Similarly at the behaviour level, when we go. So, if a building looks like it was made by a termite replica of a termite mound for example, in the material part of the building is made from the same material that a termite builds with using our digested fine soil as the primary material for example.

Construction, the building is made in the same way that the termite would build in piling Earth in certain places at certain time for example. So, we see it is very clear from these examples like, it is possible to actually mimic, add to similar levels, that the several actually approaches, of like the functionality and then the mechanism or the form whatever we want. So, it is possible to dissect our like requirement dissect our like application strategy, our in the design strategy and even inspiration strategy, how we should, how we can actually proceed with this.

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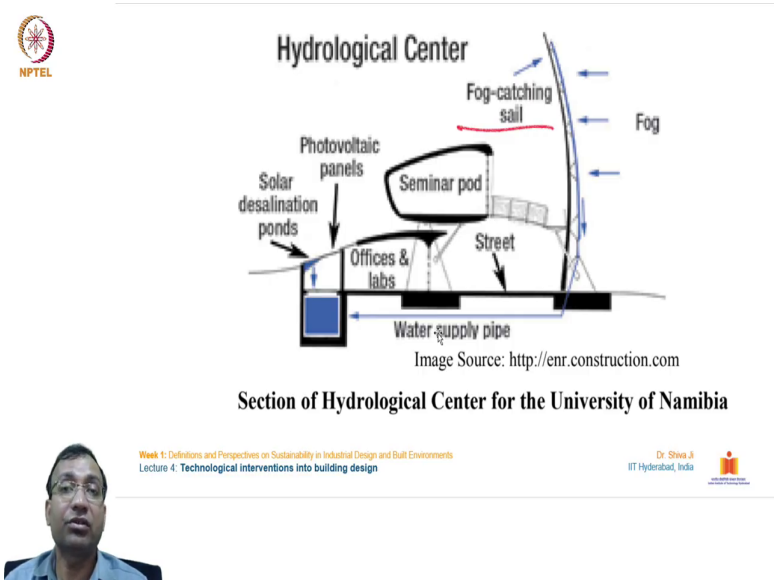

So, one example, taken over here from this section of like a hydrological centre for University of Namibia. So, in this section, you can see there is this actually surface, fog catching sail and from this side actually, there is a moment of fog and this actually structure helps in the condensation of this form, in turn actually collecting water out of it, this phenomena. So, this is actually cross section shown like a how this kind of actually utilitarian strategies also can be actually devised and design on site to deal with the certain conditions which are happening from the like a nature.

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Another very interesting example over here, if you do not read this text, simply I would like to put up this plastic material what you are seeing in this chair is made up of a carbon

material, carbon element, drawn from the air the bare air, this naked air. So, it is not actually fabricated out of like these plastic pellets or these carbon actually pellets, but this carbon is actually drawn from the nature.

So, as done by the these three, this is not something unusual or first time this phenomena like we are talking about here, but the, but actually if you read this text, it says the plastic in this chair is made out of thin air without a drop of oil like the material of the trees, the carbon comprising this chair's plastic polymers are sourced 100 percent from the atmosphere.

Acquiring this ability long practice by plants is a manufacturing game changer. Well, obviously, this is going to change the entire actually mechanism of like producing plastic related stuff, like how we actually source this plastics and how in turn plastics are turning into a hazardous actually waste for our ecosystem. So, this is one of the actually ways from where material scientists are actually playing this biomimicry game and they are actually creating interesting solutions.

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In the next one you may have seen this interesting actually form of this car, this vehicle, so this is inspired by the box fish. So, you see box fish which is on the right side, the bionic car developed by Mercedes Benz gets 84 miles per gallon. Without a hybrid engine, the room interior of this tropical reef fish and it is surprisingly streamlined body attracted the retention of automotive engineers, additional weight saving in the car frame were achieved using computer design software inspired by bone growth, the lightweight frame results in the car

one third of the weight of a like a comparable conventional design vehicle while being just as a like same crash safe as the previous car as any like a normal car.

So, you see the kind of like efficiency this form derivation has given which is taken from this fish, this box fish for like a vehicle. The material actually reduced by like in a larger instinct, we I think it is really hard to imagine like this much of material can be saved from the piece of like automobile because automobile like a pieces automated like cars and all that they are one of the most optimized actually engineering solutions and machines created by like engineers. So, this is one of the actually interesting actually feats with this design actually designers have actually achieved.

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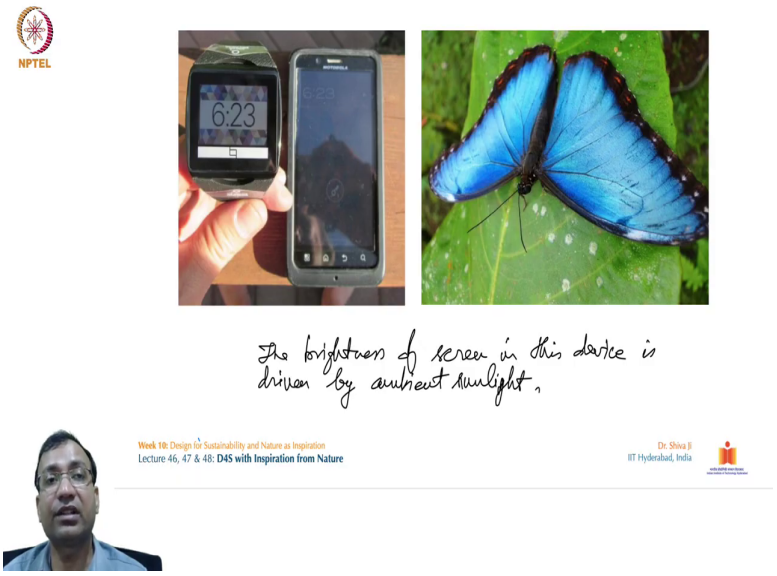

In this example, you see this watch is electronic screen requires no battery power to view clearly unlike the cell phone, the watches brightness is generated solely by ambient sunlight, like the morpho butterfly that inspired the screen technology, the green, the screen relies on the spacing of microscopic optical elements to split sunshine into specifical wavelengths and reflect these back to our other our eyes.

So, we have seen like earlier the feathers of these, the wings of these butterflies, they reflect sunlight. So, how this actually function can be utilized in like our watches, to create actually the impression of the time whatever is going on, without using electricity, without using any like a battery. So, this is one of the most beautiful actually examples of like, how this kind of actually natural like a phenomena can be utilised for creating like a such a like a deeper ecosystems.

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Finally, we have one more example over here, we may have you all have seen like a wet dog or a wet actually cat how do they actually flip their heads, in order to get rid of the water actually from their like a body. So, they shake their heads in like a certain actually, certain rate in certain direction.

So, this was actually found through this study like from mice to bears like all that shake dry at optimised actually speed and that speed was actually utilised for creating actually these spinning of the actually dryers of cloth, these machines, to optimise on the efficiency of these machines optimise on the energy actually. So, this is actually director interpretation and a translation of like how these animals actually shake and shake and get rid of the water molecules. So, yeah.

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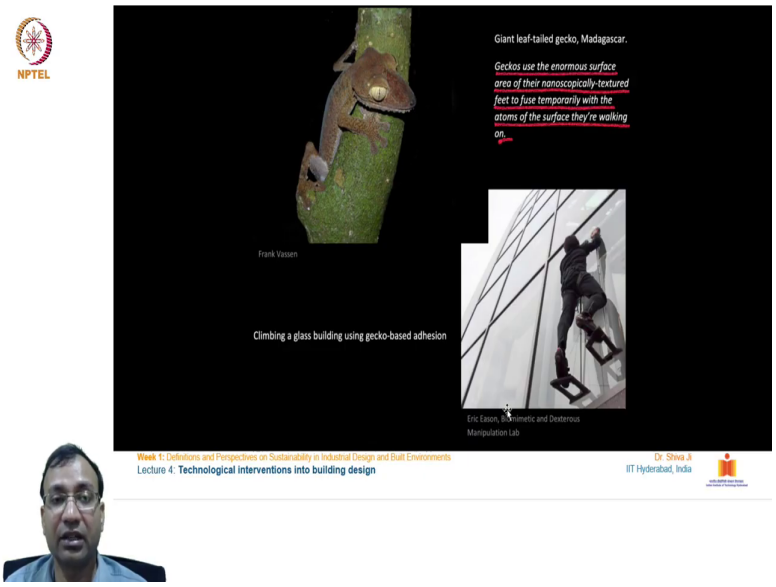

So, how these are actually mechanisms work. So, in this slide, if you see this gecko you are, we are all aware of, you may have seen a gecko, I have seen several geckos while I was staying in like northeast India, northeast India is one of the most biodiverse hotspots of the world and I saw some of these actually lurking around on the glasses of the windows, because the most of the area is still like a forest.

So, whenever we switch on the lights in our houses, so these lights attract a lot of like moths and other flies, towards this light, so they end up like roaming around our like windowpanes in the nigh time, because swathe is all actually swathe is all just a forest dark, actually pitch black, dark forest in front. So, behind those actually moths and wasps, these geckos come to eat them.

So, I have seen actually a number of these geckos. So they have actually, these geckos use the enormous actually surface area of, their nanoscopic textured feet to fuse temporarily with the items of the surface, they are actually walking on. So what do they do? We will see in the next slide, how they create actually a vacuum pad on the surface and with the help of that mechanism, they end up sticking there with a much actually strength. So, this is one of the actually best actually solutions, best actually addition, without using the (())(45:10) which was found in the nature occurring on its own.

So, this actually technique was actually taken for adoption and transformation in the like a human, like a need based like application. So, you see this picture over here this person is comfortably climbing on this glass surface.

So, these are glass surfaces, well, most of our buildings in the modern times are being constructed out of these like a glass surface material and it is very difficult for anyone to clean these glass surfaces from the outside because most of the cases either they are completely like a sealed or in some of the cases even if they are openable it is very difficult to go outside and stand on them, because there is no other like a structural like a member to support the weight. So, this kind of mechanism has come to the rescue in this solution you can see over here.

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So, this is how these microfibers on the feet pads of these geckos look like. So, they see the scale over here is very like a teeny tiny we cannot even see from our like naked eyes and how such arrangement if it is like a replicated or used through this biomimicry, so how much of weight it can sustain. So, see there is a significant actually increase from like this capacity from this arrangement to this arrangement. So, how these micro fibres in engage, the adhesion from like a one component to the other. So, this is actually learning from this nature based actually design exercise.

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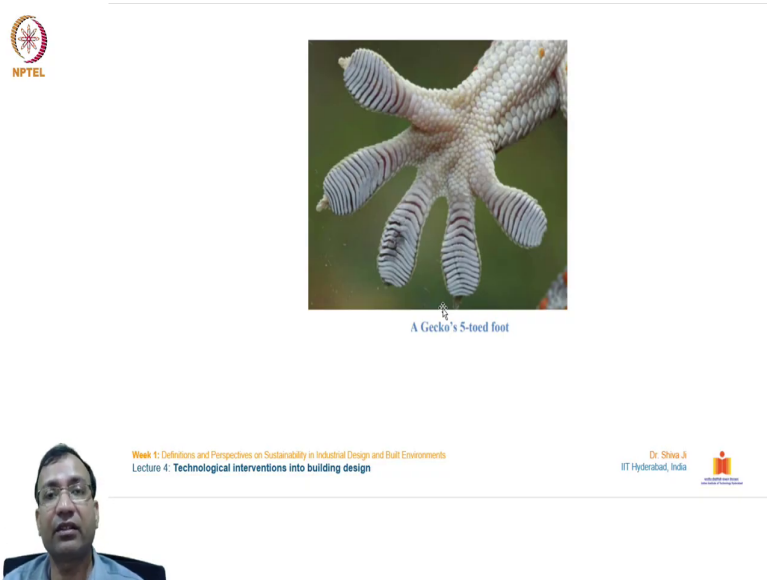

You see this the close up of the feet of a gecko over here. So, they have usually like a five toes, okay and toes you see these ribs kind of like structures. So, while sticking they create a vacuum over here and within actually these ribs and in turn they actually end up actually comfortably sitting on any like a glass surface any like a finished shiny surface also, they do not find it difficult to stand on any like a shiny surfaces also, they always like succeed in standing on them.

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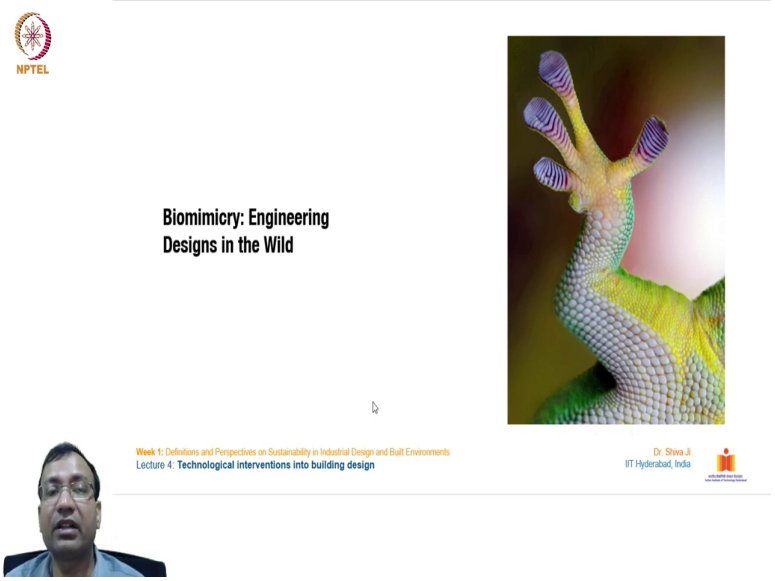

So, from. So, what is this actually biomimicry, we are talking about here, is the engineering designs taken from the examples from the like a wild So, there are several examples like gecko being the one.

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From the ants also like how ants actually work in like a team how ants actually we have, there like a, there like ant hills also how do they actually work? How do they actually produce labour? So, there are several examples, how do they actually carry weight and so, compared to their own body weight, they actually carry multiple actually times of their own body weight, which is very actually powerful if we see considering these tiny actually structure of, structure of these like ants.

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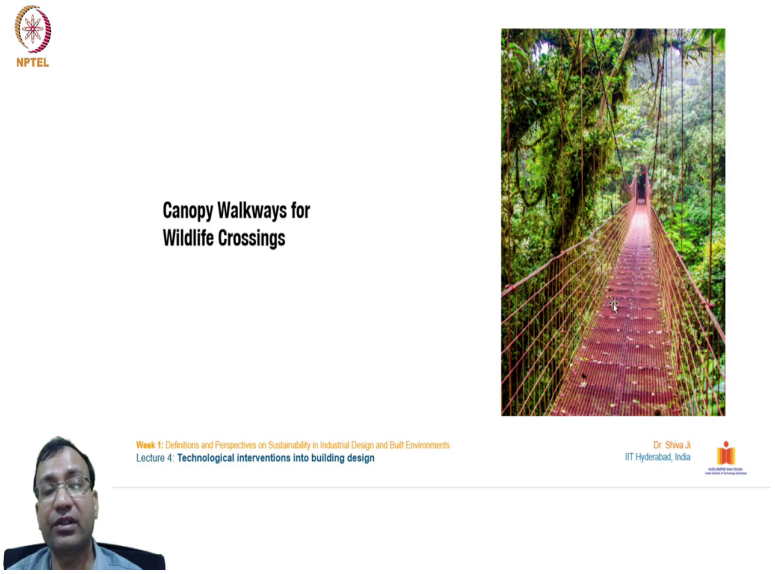

Several more examples like this is a canopy walkway for like a wildlife crossing. So, how like in the nature without disturbing we can go. So, there are several examples actually taken.
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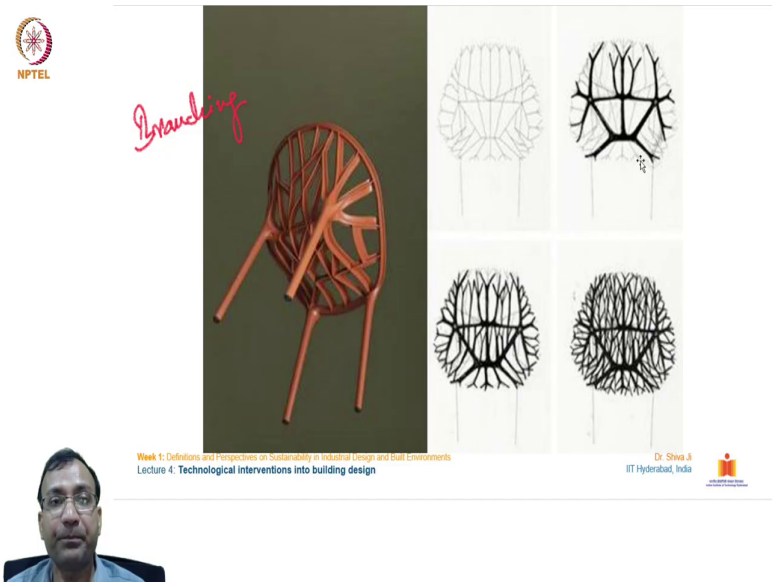

If you see over here, this represents the fashion of like a branching. So, the how branching can give us like a optimise structural system. So, here you see this, this chair here is a very simple example of like any product, so this branching actually can be utilised in creating like a bigger structural systems also, such as like hangers and museums and maybe creating like auditoriums and bigger like a spaces, where a huge span of actually space is needed. So, this branching can be actually useful in several like applications.

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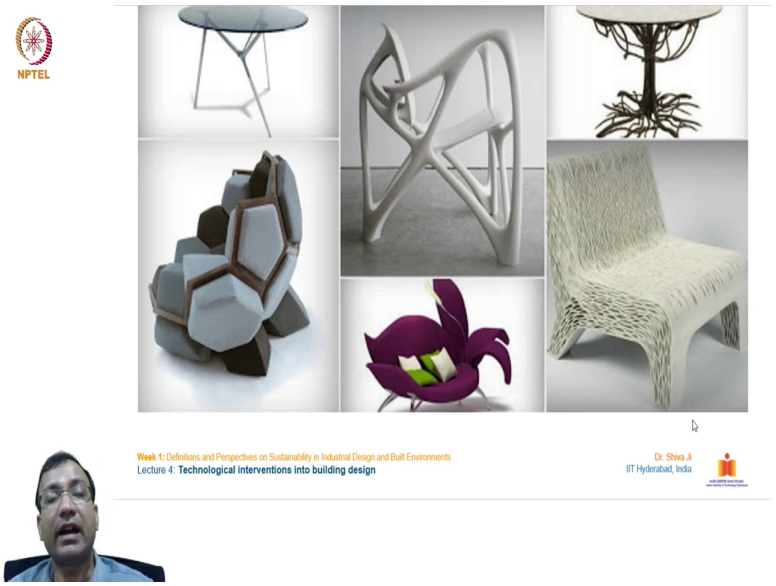

Here you see some more actually more examples like how the reduction of the material is made possible this chair actually was derived through like an AI, actually algorithm model on

minimising actually the material, just going for the material where ever it is needed the most and reducing all others.

So, this is actually this computer developed model using like the AI and several other examples you can see from here, this to this to this to this. So, they all actually offer a certain kind of actually innovation certain kind of like a, this idea which is existing in the nature and these are the examples which the designers have actually adopted from the nature.

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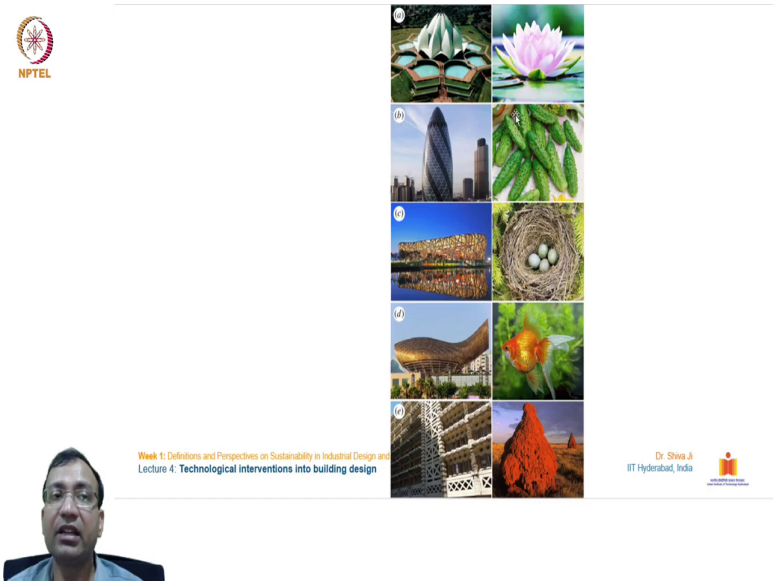

Finally, we have some more examples, you may be aware of most of these actually structures. This is the famous Lotus Temple from New Delhi, this is Gherkin tower from like London. This is the Bird's nest stadium from like Beijing. These are all actually if you see the, they are taken directly from like a certain actually naturally existing like entities from the like nature. So, how they are using utilising the form, how they are utilising the mechanism, how they are utilising the like a functionality. So, all of them have actually certain approach, certain like leading approach and the adoption has resulted into like these beautiful actually executions.

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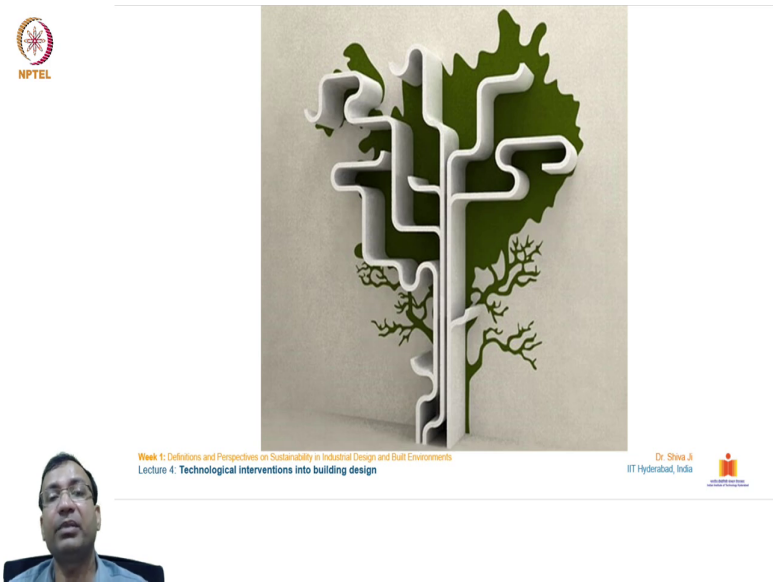

Further well, there are no limits to the creativity and innovation. So, this bookshelf, I thought of actually putting up over here, it looks really appealing as well as it solves the problem also of like, minimising the material and optimising on the efficiency.

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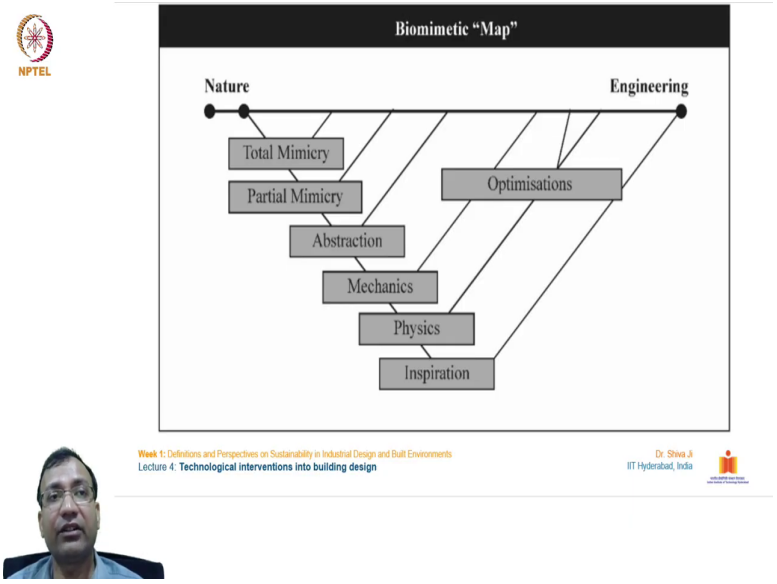

Finally, with this last slide, I will to bring this biomimetic map on the like a nature's front, on the like engineering front, how with the help of like a total biomimicry, with the partial biomimicry. So, with the abstraction mechanics physics and inspiration, we can actually deal with this, we can actually adopt these nature based actually designs in our own like engineer designs.

So, inspiration, which is the, this is the minimal one there we are just taking the form or maybe some inspiration and we are utilising it or this total biomimicry is like a total replication of whatever like we are referring to for it is like a form mechanism function your ecosystem, so the complete replication complete like a mimicking will be called as like a total biomimicry and in between there are like several other steps also, where like for example, if you are referring only the physics part of it, even if you are looking only in the mechanic mechanics part of it or if you are going only for the abstraction or partial mimicry etc.

So, there is a full range which we saw in the previous slide also from like just the aesthetical part to the most actually functional part also. So, nature actually offers immense potential for our designs to get improved in order to actually be sustainable on environmental, social and economic actually factors and nature is still one of the best actually sources of inspiration. So, one must actually look for, such actually inspiration from the nature, in order to minimise the impact with this I would like to actually come to the end of this lecture. Thank you, everyone.