Introduction to Biomimicry
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Lecture – 20
Applying the Biomimicry Design Spiral

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Hello everyone. I am Malavika Venkatesh from IIT Madras and following here is the project that I worked on, and this would serve as a case study for you guys.

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So, starting off this is the UN sustainable development goals and as you all know, there are 17 goals here. So, the first step would be to choose one goal out of the 17. Now, the goal that

I chose is goal number 14 Life Below Water. But how did I arrive at this goal? Why did I choose this particular goal out of these 17 goals? So, the reason was my emotional connect behind it.

So, when I was young like about 4-5 years back, I went for scuba diving in the Andamans and the Great Barrier Reef and I love adventure sports. But then, the first time when I went for scuba diving under the water, I found it to be so peaceful and the underwater world was so beautiful. So, this made me love the underwater world so much that I began to watch documentaries on it.

And then I realized as to how much pressure the sea and organisms beneath the oceans are. So, this led me to think that why is it that people are not realizing that such a beautiful ecosystem is in danger and how is it that they are not thinking of solving this issue. So this is what led me to choose this particular goal, Life below Water.

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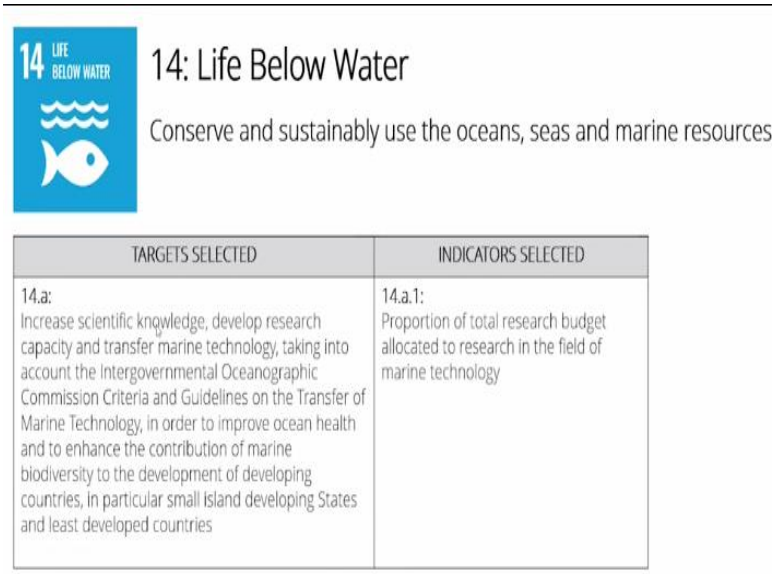

So, the goal as I told that I chose was goal number 14 Life below Water and the basic idea is to conserve and sustainably use the oceans, seas, and marine resources. So, the following are the targets and indicators that I have chosen and this is the direction I want to work towards.

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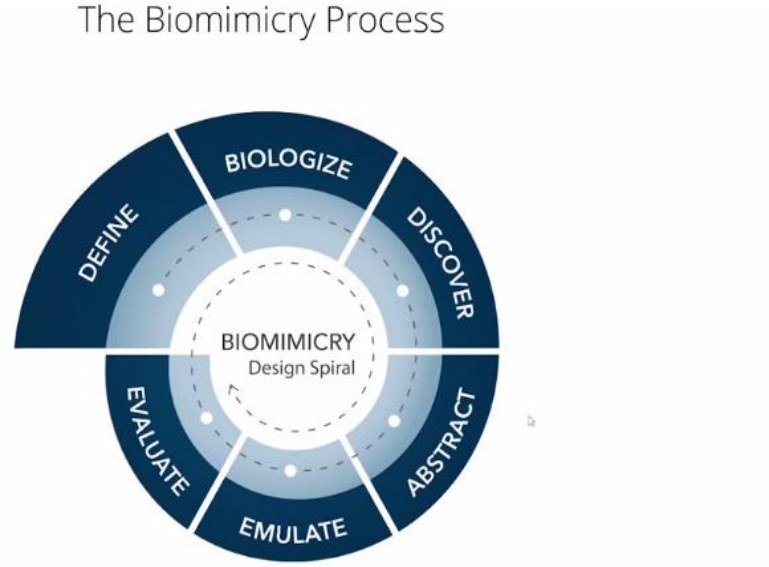

Then going on to the biomimicry process, there are 6 steps in the biomimicry process. The first one being define, biologize, discover, abstract, emulate and evaluate. So, this is called the biomimicry design spiral and this is how you need to systematically work to find the idea or goal you want to work towards and coming to a solution.

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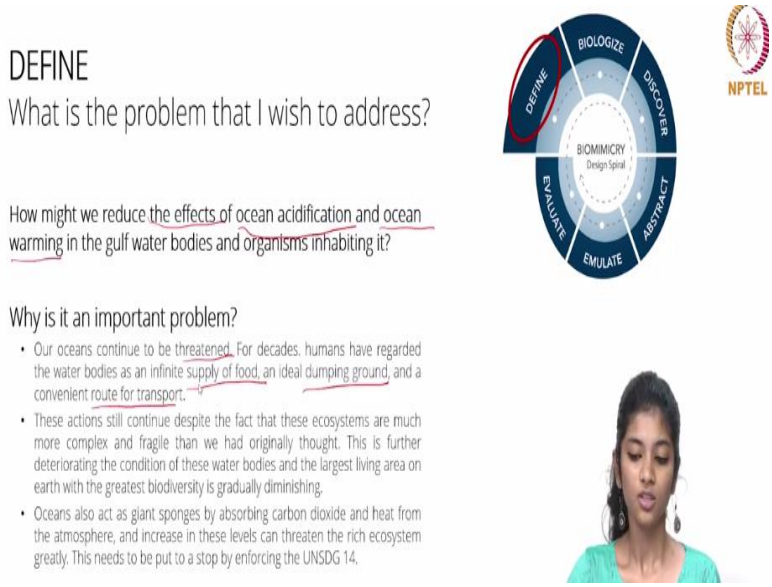

So coming to the first step, define, and define exactly means what is the problem that I wish to address. So, the first step of the whole biomimicry process is framing the right question. So how did I frame my right question? I looked and looked into research a lot about what I want to do and what I arrived at was solving the problem of ocean acidification and ocean warming. So, what leads to ocean acidification is the ocean bodies absorbing a lot of carbon dioxide, which increases the carbon dioxide concentration in water, which makes it more acidic. And the reason for ocean warming is the ocean bodies, the water bodies absorbing a

lot of heat. So how do I reduce these effects? So why it is an important problem is because our oceans are continued to be threatened and we have only regarded water bodies as an infinite supply of food, an ideal dumping ground, and route of transport. So, there are many other reasons as to which you can read in the slide as to why I selected this problem.

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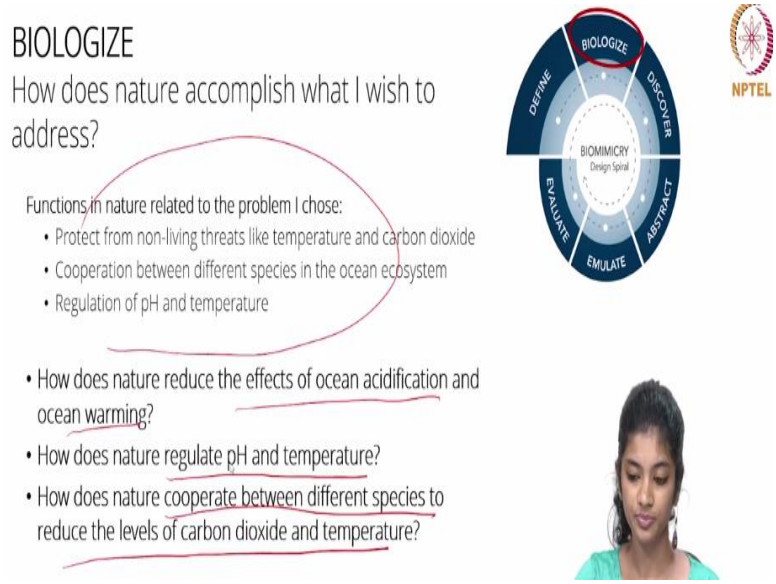

So now going on to the next step is 'biologize'. So how does nature accomplish what I wish to address? So, the first step that I tried to do in 'biologize' is finding functions in nature that are related to my problem as you can see here, and based on this, I questioned how does nature do this. So how does nature reduce the effects of ocean acidification and ocean warming? How does nature regulate the pH and temperature?

And how does nature cooperate between different species to reduce the level of carbon dioxide and temperature? So, these are the questions I asked and I looked at nature for solutions to find out how does nature do these things.

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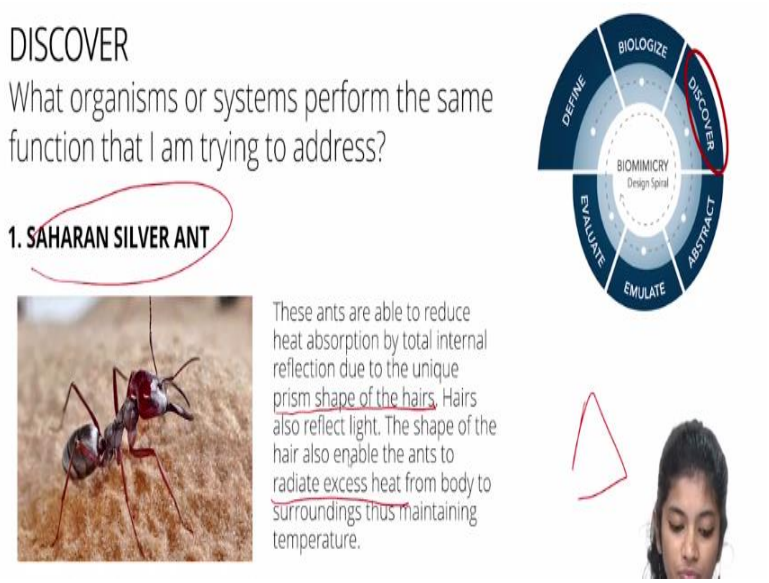

Next, going on to the step ‘discover’. So, what are the organisms or systems that perform the same function that I am trying to address? And after a lot of research in AskNature and similar websites, I found out about the Saharan silver ant. So these ants have prism-like structures, prism shape of the hairs by which they are able to reduce heat absorption. So, as you know the prism can by total internal reflection reduce heat absorption and it reflects light. It also enables the ants to radiate excess heat from the body and thus it maintains the temperature.

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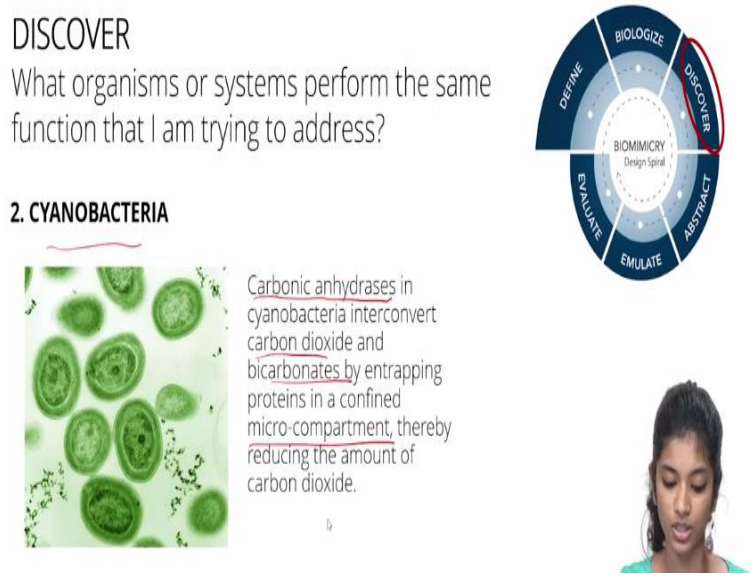

Another organism that I found was cyanobacteria. And in cyanobacteria, I found out that there are carbonic anhydrases that convert carbon dioxide to bicarbonates and this they do by trapping it in a microcompartment and this enables them to reduce the amount of carbon dioxide, which is the goal as working towards it.

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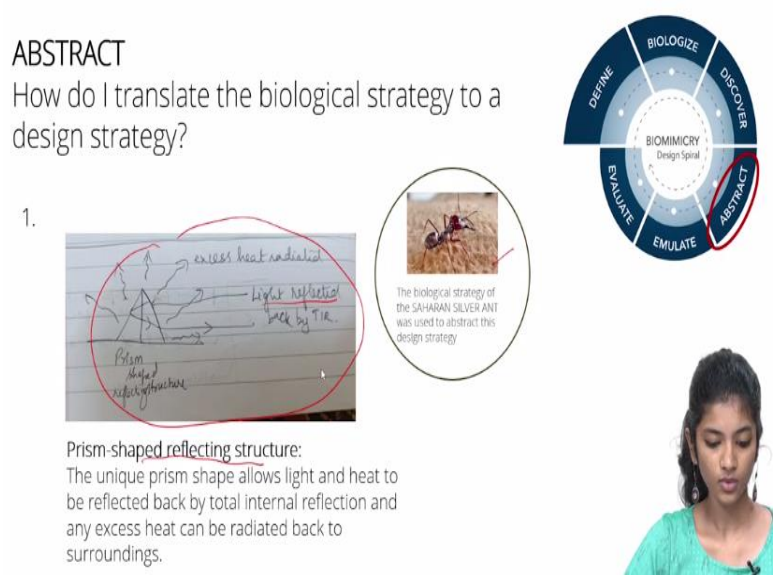

Going on to the next step, 'abstract'. So how do I translate this biological strategy that I got from organisms to a design strategy? So, I need to remove all the biological components to make it into a design strategy. So, the first organism was the Saharan silver ant and I used this to create a design strategy where there are prisms shape reflecting structures by which excess heat is radiated and light is reflected back by total internal reflection. So, this allows us to reduce the amount of light and heat and thus reducing the heat of the body.

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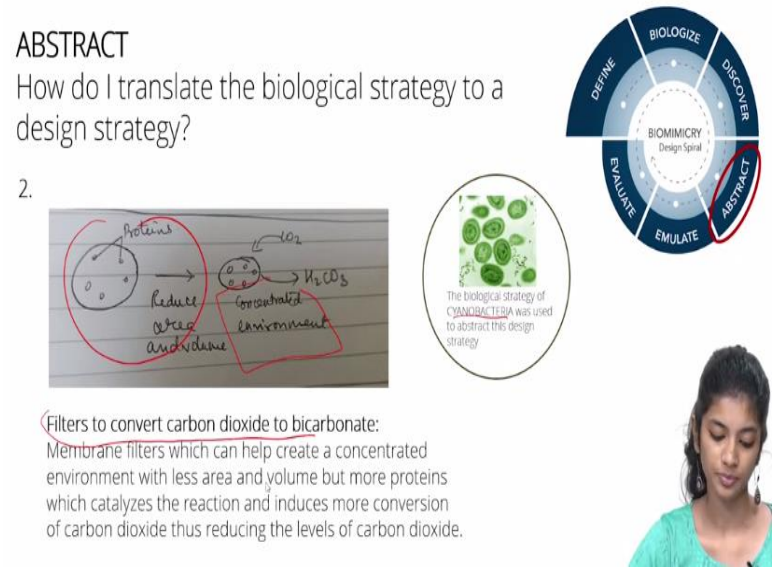

The next organism was cyanobacteria. So here, I came up with the idea of using filters to convert carbon dioxide to bicarbonate. So, in cyanobacteria, there was a similar process. As my main goal was to reduce the amount of carbon dioxide, I chose this by using filters and

the similar idea of using microcompartments to reduce the amount of carbon dioxide and convert it more towards a useful compound that is bicarbonate.

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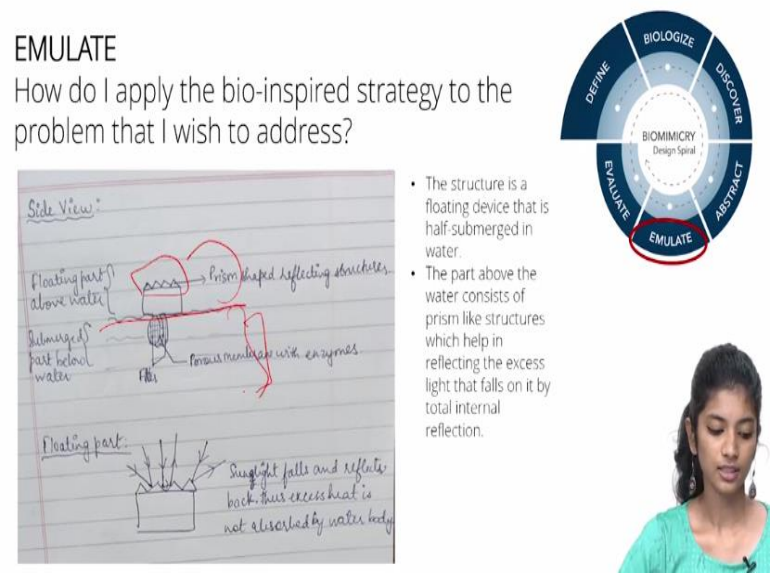

The next step is ‘emulate’. And the question I ask is how do I apply this bio-inspired strategy that is the design strategy to the problem that I wish to address? So, this is one of the main steps where you come up with a design for your product or idea. So, this was the main product or idea that I tried to design. This is the side view where this is the water level. This is the part submerged below the water and this is the part that is floating on top of the water.

So, the part floating on top of the water consists of prism-like shapes or prism-like reflecting structures, which allows me to reflect back excess heat and light and this allows me to solve the problem of ocean warming. So, it reflects back the excess heat and light and ocean warming will be reduced by this.

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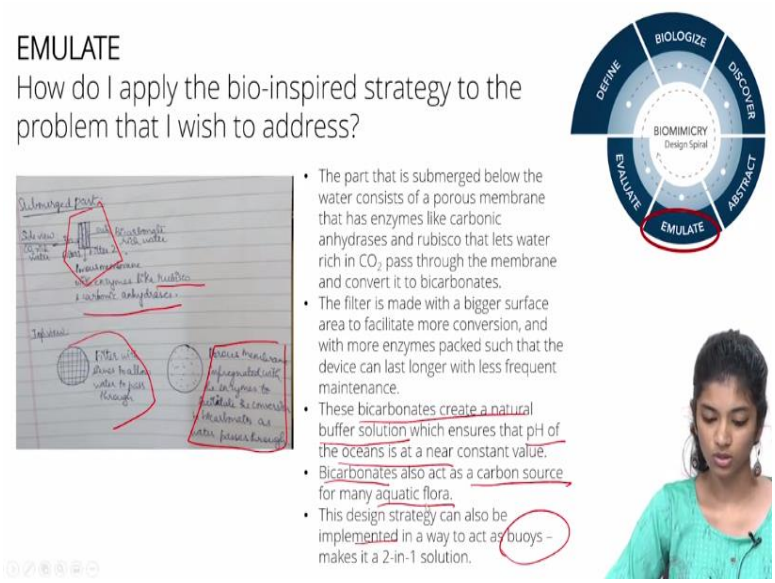

Now the part under the water is the filter. Here, I am trying to use a filter, which has a porous membrane with enzymes like rubisco and carbonic anhydrase. So, these enzymes help in converting carbon dioxide to bicarbonate. So, this is the part that is much below the water. And here there is a filter with sieves that allow water to pass through and surrounding it is a porous membrane, which is impregnated with enzymes and this facilitates the conversion of carbon dioxide to bicarbonates.

So why I choose this step of carbon dioxide to bicarbonate is because bicarbonate also creates a natural buffer solution, which ensures that the pH of the ocean is at a constant value. So, it does not fluctuate the pH of the ocean and this is helpful to the oceans and organisms inhabiting it. Bicarbonate also acts as a carbon source for many aquatic florae. So, I am not only reducing the amount of carbon dioxide, but I am also converting it to bicarbonate which is then used later.

So, this design strategy can also be implemented in a way to act as buoys. So, this makes a 2-in-1 solution and it solves more than one problem.

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Now coming to evaluate. So, 'evaluate' is also another important step in the biomimicry process where we find out how can my solution be applied in the real world. So, the main step of this is finding out how can I relate nature's unifying design principles to my solution. So, here as I told you before the byproducts that are formed in the process that is bicarbonates, it is not wasted.

So, these are utilized by organisms like aquatic flora as a carbon source, so there is no wastage of materials. So, whatever carbon dioxide is converted to bicarbonate can also be used by aquatic flora. So, this tells us about an important design principle that nature always recycles materials and there is no waste of products. The second point being this device is life-friendly. So, it has to be life-friendly and made of non-toxic materials as it is being used in the ocean.

An ocean is a place with a rich biodiversity and anything that is done wrong in this can affect the ecosystem as a whole. So, it is very important to make life-friendly and non-toxic materials to support its functioning in the water bodies. The whole point to make is the chemistry of non-toxic materials, to make them safe for all living organisms. The next point being the solution does not solve only one problem, but two.

One is the problem of ocean acidification. It also solves the problem of ocean warming. Apart from this, we can also use it as a buoy so thus it makes it a multifunction device. And this also connects to the design principle being nature optimizes and not maximizes.

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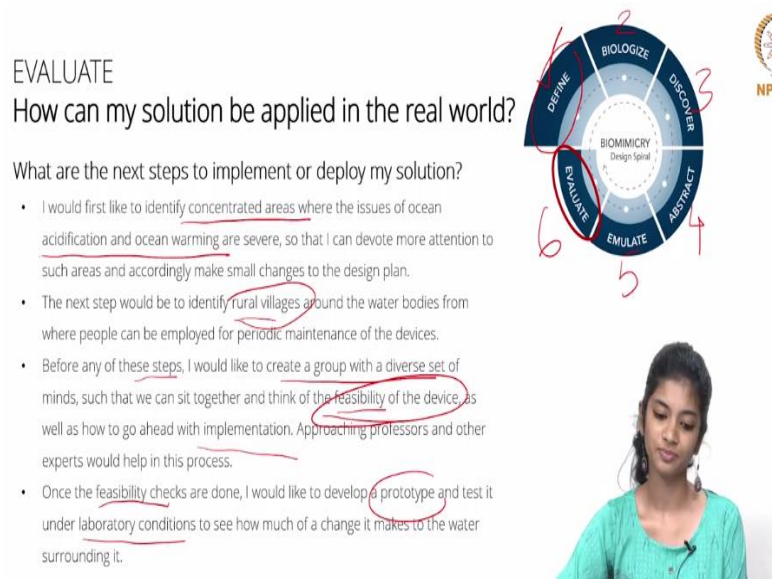

Coming to the next steps to implement or deploy my solution. So first, I would like to identify concentrated areas where this issue of ocean warming and ocean acidification is severe so that I can devote more attention to these areas and accordingly make small changes to the plan. So, the next step would be to identify rural villages around the water bodies for employment. So why do we need this employment is because of periodic maintenance of the device as we are using filters in which enzymes are impregnated.

So there has to be regular maintenance where we remove the filter and fill it in with a new one. So, it would be helpful to use the rural villages around water bodies so it also helps to increase employment in rural villages. Before any of these above steps, I would also like to create a group with a diverse set of minds so that we can sit together and think of the feasibility of the device. So, the main idea behind biomimicry is coming up with the idea. But after you come up with the idea, it is also important to check the feasibility.

So, the feasibility is how we would go ahead with implementation and it is also important to approach professors and other experts who can tell you whether it is feasible or not. And once the feasibility checks are done, I would like to devise a prototype, and first, you need to test it out under laboratory conditions because the ocean is a vast body and it is not that easy to test it in those circumstances.

So, it would be wise to first test it in a lab condition and then see how much of a change it actually makes to the water around it. So, I need to see if it is actually reducing the amount of ocean acidification, if it is actually reducing the amount of ocean warming and then I would

have to implement it in the larger bodies. So, this is how you go through the design spiral first being define, second biologize, third discover, fourth abstract, fifth emulate and six evaluate.

So, there is no step in the biomimicry process that is not important. Each and every step is important. And only if I finish this step properly can I go on to the next step. So, it is important to go in a systematic manner and one problem that you would face in going through the process is you will get stuck a lot. So, you might get stuck in a particular step not knowing what to do.

But if you know that you have done the previous step properly, then it would not take much time for you to overcome the next step. So that is how I went through my process and came up with the idea. So previously, I was like all of you here where I did not know anything about biomimicry. But in a short span of time by going systematically from one step to the next, you can go at your own pace, you do not have to go fast or slow.

So moving from one step to another, I was able to finally come up with the solution. So, I hope all of you would be able to do the same and the main point is going with an emotional connect and knowing what you like and what you love and working towards that. So also, I would like to share how biomimicry changed my thought process and helped me in my life. So as my other colleagues would have mentioned that it did help in changing their thinking process in certain other courses.

But where it helped me mainly is in my artistic thoughts. So, I am a person who loves to paint a lot and I have been painting for many years. So usually what I do is I do not go with a certain mindset, I do not think like I need to paint this today. I just start and it somehow ends up well. But then after a certain number of years, you start losing that thought process, so you are not able to be spontaneous anymore.

So, in that sense biomimicry has helped me. I am able to first think and I need to set the proper process. First, I need to select this one and then go on to this one. So, in an artistic sense, it does help to be spontaneous, but it sometimes also helps to have a proper thought process. So, my thoughts are not in a disarray anymore. It is not all over the place anymore. I am able to properly come up with what I actually want to do and it has produced better results for me.

And I feel like I might have improved my painting aspects or artistic talents in that sense. I would say that biomimicry not only helps in academic places or not only in places related to biology or nature, but it also helps in something as simple as artistic and painting and music and any other thing that you might be interested in. So, this is a subject or this is some concept that can be applied to anything that you wish it to be applied to.

So, I would certainly recommend this biomimicry and I have also taught it to my brother and he is just 9 years old but he has already picked up interest in it. So, this is something that I feel a lot of people would be interested in. So, thank you.