Nobel Laureate for Chemistry Prof. Ei-ichi Negishi's dialogue with high school students at Stamford American International School in Singapore on Wednesday, January 28, 2015, as part of the ASEAN event series "Bridges - Dialogues Towards a Culture of Peace" facilitated by the International Peace Foundation

Prof. Ei-ichi Negishi:

I like to begin with how you, all of you, might pursue your career to one day receive the Nobel Prize. I was asked this question many times over the last few years, and so I thought about this, and here is my message: The probability, the sheer statistical probability of winning a Nobel Prize is roughly one in ten million. A couple of hundred Nobel prizes have been awarded since 1901, and so you can estimate that, as I just said, the probability of winning the prize is one in ten million. I don't know how many people are living in Singapore, but I am sure it's not quite ten million yet. Tokyo proper has about ten million people while greater Tokyo has about 30 million. So, if we're looking only at Tokyo proper with ten million people, then there is only one Nobel Laureate there. If you're having this in mind when one wants to win a Nobel Prize, then it's just like buying a lottery ticket to win a million dollars. When thinking about this ten-in-a-million chance, I offer you to look at it as a competition, a seven step competition. Ten million is a ten to the seventh, ten times, ten times, ten times, ten times, ten times, ten times ten – that's all.

At the first elementary level you become one in ten. If you do well in your elementary school, then you're one in ten. By the time you graduate from junior high you can become one in hundred. In my case I went to an elite high school wanting from there to make an entrance to Tokyo University, which I managed to do. I didn't study much at Tokyo University, but I managed to graduate, and at that point, looking back, I was probably a one-in-thousand kind of intellect.

But that's not enough if you want to win a Nobel Prize in natural sciences. So what is needed?

You need to study and train yourself as a researcher. One common way is to seek a PhD or its equivalent, and in my case I was lucky enough to win a Fulbright full expense scholarship. The only problem was that already there the success ratio was one in hundred. But I managed to win this Fulbright scholarship and for three years I went to America, without spending any amount of my own money, where I attended the University of Pennsylvania. This is a very high elite university, and in my second year there I decided to learn as much as I could, and boy, I was excellent! Top student!

I got my PhD degree in three years and returned to Japan. At this point I guess I was roughly one-in-ten-thousand kind of intellect for seeking a Nobel Prize, at least that's what I thought. Some people asked me how I can support a statement like that. Well, in the last 50 years of the US Fulbright scholarship program in Japan about 5000 Japanese students went to the US to study, and of those several thousand 4 or 5 have won a Nobel Prize. So you see my one in ten thousand claim is more or less statistically supported.

When I came back to Japan I had some conflicts with my company which led me to resign from that company to pursue a career in academia. Then I sought a postdoctoral mentorship, and this was the fifth step, in my opinion. In this case what was important was one-on-one mentoring, and this is true in any field, arts, music, sports as well as in science. When an athlete becomes a top-notch candidate for an Olympic medal, they usually have up to three or four coaches. This kind of very intimate mentoring is very, very critical. In science we can do that as postdoctoral students, and I chose Prof. Herbert C. Brown at Purdue University, who later won a Nobel Prize in 1979. I went there in 1966. That was my fifth step, and boy, he was a tough trainer. But I learned a lot there about becoming a top level professional scientist.

Then people ask me what my 6th and 7th steps, and I say: Come on, now it’s your time and turn, so take care of the last two steps by yourself!

Normally, if you have done well during the first 5 steps, then you are statistically one in hundred, by my way of reasoning. So, if you have reached this, to become one in hundred, then you can take care of the rest yourself.

Which I did, I suppose, and these last two steps took me about 30 years. But how can we do all these things for such a long time? Well, first of all you have to be good, you have to have a one in thousand kind of intellect by the time when you graduate from college, and secondly you should like what you do. If you don't like it, then you won't be able to sustain your intense efforts for such a long period. So, if you like what you are doing, then you need to keep pursuing, and that's, looking back, how I got this big award. This big award is really big, in every aspect and from every perspective, and I can highly recommend winning one. That is my story, and I am looking forward to hearing your questions now.

Question:

One of my favorite quotes come from the scientist Sir Isaac Newton, and it goes something along the lines “If I have seen further than others, it was by standing on the shoulders of giants”. I’m wondering who the giants in your world were, and how did their knowledge allow you to accomplish what you have?

Prof. Ei-ichi Negishi:

Science is a kind of cumulative activity, and we have to learn from our predecessors. In my case it was my 5^{th} step mentor. For choosing a post doctoral mentor I say you need to find an area of your intense interest, and the best person in that area, no matter where and in which country, this is the person to chose. Then you go where that person is, and that's exactly what I did. I chose Prof. Herbert C. Brown in 1966, 17 years before he won the Nobel Prize.

But already in 1962, when I was a second year graduate student in Philadelphia, I attended his lecture on the discovery which won him the Nobel Prize about a reaction called hydroboration, and I was totally overwhelmed. Hydroboration uses a Boron, and in the periodic table you have Boron right next to the left of Carbon, but at that time hardly anyone was using Boron in organic synthesis. I was wondering why we didn't use this element, and I was looking around, and my curiosity expanded.

But back then in 1962 I chose Prof. Brown as my mentor. I went back to Japan and worked for a company called Teijin, because I was a member there since 1958, but later I resigned there and went to Brown and Purdue University.

Question:

What are the dominant science research areas at the moment, and why do you think they are the dominant ones?

Prof. Ei-ichi Negishi:

There are many. Shortly after I won the Nobel Prize I had the opportunity to meet the Japanese Prime Minister, and I presented my proposal. There are easily 10 or more important areas, and I had a list of 10. But let me tell you the top three now.
I felt at that time that by far the most important issue was the reduction of CO2, because it is needed, and no one has successfully solved this problem. At that point carbon dioxide was considered to be a bad thing. It was said that we shouldn't emit more carbon dioxide, because that leads to global warming.

I said what nonsense that is, because we are all made of organic compounds, including ourselves, but also what we wear is mostly organic, the carpet, much of the building materials, food and fuel. So we need more organics and the origin of most raw materials are historically all organic compounds. Carbon dioxide (CO2) and water, from these two nature produces organic compounds.

Trees and leaves absorb carbon dioxide, and leaves grow, eaten then by cows, and then we get the milk from the cows. So there is no question, water and carbon dioxide are the two dominant raw materials for most of the things that we need. Instead of saying that we should not produce more carbon dioxide because it leads to global warming, we should learn how to make more use of carbon dioxide and water to recycle into useful organics. That's what I told the Prime Minister along with ten other things.

Second on this list were organic molecular electronic devices, super conducting nanotechnology. Imagine Organic compounds can conduct electricity the best, and there will come a time when these organic superconducting materials will be penetrating into our lives.

The third thing I told him is organic compounds, amino acid, protein, peptides, DNAs and RNAs and so on are all handed. Right hand and left hand – they look alike, but they are never the same. Most of the important organic compounds are handed, so we have to learn how to synthesize them. Just if you need a right handed compound, you make a pure right handed organ, if you want a pure left handed one, then you should be able to do so. This pursuit came from someone most people know: Louis Pasteur from France, about 150 or 160 years ago. Last year we have finally learned how to synthesize all kinds of this handed compounds, as pure as you want. It is a very exciting time for us!

I just heard that Japanese automotive companies Toyota and Honda will start selling cars that run on water. Can you imagine?! Water in chemistry is usually a side product of very low value. But now they use water to run a car. It is just a prototype now, but this is something we can look forward to.

Question:

How long did it take for your ideas and the LED (light-emitting diodes) technology to get from your labs to the shelves?

Prof. Ei-ichi Negishi:

As a professional organic chemist, when I was 26, a 2nd year PhD student at the University of Pennsylvania, I wanted to make all kinds of organic compounds, not just this and that. In one sweep, isn't there a general way of synthesizing simple or complex organic compounds? Then a notion came to my mind when I was 26: Lego game!

If you invent a chemical organic Lego game, that should solve an organic synthetic problem. In a Lego game you have some pieces with one or more sticks and others with holes. You can then couple them to build whatever you want. Basically, the Negishi cross-coupling is an organic synthetic Lego game. What was needed was a catalyst, a third component, and the best catalyst turned out to be Palladium at this point.

I got this idea when I was 26, and I discovered my version of coupling in 1976, when I was around 40, so these things take time. You don't want to throw away good ideas. You must keep pursuing them.

Question:

I was wondering if there are any branches of science were the discoveries are kept secret from the general population, because of the possible misuse of this knowledge.

Prof. Ei-ichi Negishi:

There might be but I don’t know of any. In science we have the problem that discoveries and knowledge spreads out and becomes public so rapidly that sometimes the second or third runner claims to have made the discovery. Luckily in science I have never felt that we should keep something as a secret and away from the public. If you find something good and helpful for the public and humanity in your research, then you want this to be out as soon as possible.

Question:

Working in culturally very diverse settings have you ever faced any hardships, and how did you handle these challenges, and what have you learned from the experiences? For example was it difficult for you when you came to Purdue to work with Americans, were there any barriers or difficulties stemming from the different cultural backgrounds?

Prof. Ei-ichi Negishi:

I have never felt that there were obstacles when I came to Purdue University, because my motivation to learn and study chemistry on a higher level and to make use of it in the future was my overwhelming concern. English is the common language, and I felt, when I was 20 years old, as a student at the University of Tokyo that I needed to learn English. Back then my knowledge of English was miniscule, because what I learned in high school was just enough to pass the college examination, but I had no practical English skills. So I began learning with several friends, and that turned out to be a very useful thing to do. A few years later I graduated and joined a company, and the president of this company was very impressive. In his welcoming remarks he recommended us to learn at least three different languages: English, German and French, and if we acquired these skills, then that would make us useful individual in many areas. He also mentioned about the Fulbright Program and that the company would support any successful applicant. I was amazed by that, because we were told this on the first day in the welcoming speech.

Question:

Could you describe in simple terms the field of organic electronics, and how is it being used at Sony?

Prof. Ei-ichi Negishi:

My consultant work has been terminated now. I had a wonderful time there, but they went through a rough time recently, and I am still dealing and working with the people who were colleagues there.

The area of organic electronics brings fantastic new technology and will lead to many more advances in the future. I can't predict what exactly, as I am not involved in these things anymore. As I mentioned before, I chose this area as one of the most important areas for us chemists in my presentation for the Japanese Prime Minister.

Question:

What books do you like to read for pleasure, and what are you reading currently?

Prof. Ei-ichi Negishi:

The majority of my reading time is spent on research. This is a very intensive process of learning new facts and tools, so the majority of my reading time is spend on my area of expertise.

Question:

Since we are 10th year students we start thinking about our post secondary studies and ultimately a career. When did you realize that you wanted to pursue a career in the field of chemistry, and did you have any aspirations as a post secondary student?

Prof. Ei-ichi Negishi:

I was telling you that you should first be a good student in elementary, junior high and high school, because if you are one of the top students in high school you get to enter a good university. This I managed to do, even though it was quite a struggle for a period of time.

As a student in junior high and high school I liked electronics. There is a big area in the centre of Tokyo where you can buy lots of electronic parts, and I specifically liked one small store run by two older gentlemen, because their products were cut above, I thought. It turned out that these two were founders of the Sony Corporation. They opened this shop after the Second World War, which they spent in the Imperial Japanese Navy.

I was pretty much determined to pursue electrical engineering, and my senior colleague and I were together on a train daily, and after he graduated he went to Hitachi, a fantastic company. But then he told me that the company and many other electric companies were stingy and didn't pay their employees well. That apparently was quite true at that time. At that time a polymer, chemical industry factory, they merged and became a huge company, and that caught my attention, and so I switched from electronics to chemistry. It was as simple as that, and I liked chemistry, and to this day I don't regret this decision. But this probably doesn't matter so much, as long as you do well and enjoy what you're doing, that's the key.

Question:

We have seen scientists portrayed on TV and movies, but I am fairly certain that what we see there does not accurately fit what a real life scientist does. So how would you describe a day in the life of a research scientist?

Prof. Ei-ichi Negishi:

I have dedicated a few decades of my life and time to science, and I did that because I wanted to. I was telling you already that the first thing to do is to chose the area or field of what you really like. Liking what you do, no matter how hard it might be, is a critically important thing.

If you have you been working in an area that you once chose and things are not going well, you might try another area. Because if you don't like the area and daily work in that area, your life is not going to be very happy, and I think one of the most important things for us is to lead a happy life. At 35 or 40 you can still choose another profession.

I like the concept where the losers of a race are given a second chance and get the opportunity to race again and advance to the next stage of the competition. So once or perhaps even twice in our life you judge that what you have chosen is not what you want to pursue, and if you're sufficiently young, then you can switch. I feel that if you work hard and hit the jackpot, then you are okay for the rest of your life.

For instance my Professor Brown, he made his Nobel Prize winning discovery in 1956, and he was born in 1912, so he was 44. When I recognized that I was 35 and thought I had still 9 years to come up with the Prize-worthy discovery. Luckily, I did come up with a “Big” discovery when I was 41.

Question:

What was your most memorable high school moment, was it in science class, and who was your most memorable teacher?

Prof. Ei-ichi Negishi:

The most memorable teacher and mentor was Herbert C. Brown. He was a giant and my lifelong mentor.

But I was a pretty good kid. Not just in high school, but also in elementary school. When I was 5, my senior sister was 7, and my mother hired a school teacher as tutor for her. I was always nosey, so I used to sneak into the room where my sister and her tutor were studying, and when she was in trouble, then I answered the questions posted to her. At the end of that year this school teacher suggested to my mother that I would be ready for school and should go a year early. So that's what happened and in elementary school and junior high, I was a year younger than my comrades. In high school they stopped me because of that, and only after seeing that I attended all 6 years of elementary and junior high school and always was the top student was I able to proceed to high school. So eventually they accepted me, and I was still a year younger than the other students in my class. The only time that was questioned later was when I got into Tokyo University and we needed to get a certificate that I passed all classes. I am not sure if that gave me any advantages or disadvantages.

My high school was very intense. Even though I passed junior high without having to study as after attending the class I never had to study for tests, because I found them easy. In high school this didn't work. Furthermore I developed a very interesting hobby, just after class I would go to the seashore.

After my first year in high school my grades were down, and I was ranked as the 123rd student. Eventually and as a consequence of this I started to study outside of the classrooms. I woke up early to study in the library and in class and after. After the 2nd semester I was ranked as the 9th best student out of 405. Then I kept studying, and in the following semester I was the top student, and then the pressure mounted because the top student should never fail an entrance examination for Tokyo University. My performance on the two days of examination I thought was miserable, because I was suffering from stress, but I managed to squeeze myself in, I suppose.

So, no matter how specialized you become in the future and in your profession, the foundation is what you learn in elementary and junior high. We didn't learn physics and chemistry in junior high, but the basics of science, and today I still use what I learned in these years. Without this knowledge you miss something here or there or struggle. So this high school education will stay with you no matter what area you will continue on later.

Question:

Should governments fund research, and if universities are funded by governments who owns the knowledge and what sort of problems can this ownership of knowledge lead to?

Prof. Ei-ichi Negishi:

First of all I'd like to suggest you forget about the question of ownership until you get the patent. I am facing this question now, but generally this varies. At my university for instance, Purdue University, whatever we do and whatever we find, if we patent through Purdue then 50% of the ownership goes to Purdue University and the other 50% are distributed among the discoverers. In my case I am the primary discoverer, but I also assigned one or more of my post docs and colleagues as discoverer.

At the same time the university will fund the research, so my name card carries Herbert C. Brown Distinguished Professor, and many of my Japanese colleagues ask why in America we brag about these titles on our name cards. Well, I am partially paid from this Distinguished Professorship-fund, and I am even more richly supported through the Brown Research Foundation at Purdue University, so I must put this among my titles.

Now back to your question, the government should fund research. I was lucky enough to make a big suggestion in this regard to the Japanese Government, and they responded in a big-time way, and this has been further promoting Japanese scientific technological activity. I don't know how governments act on results, but basically they promote promising research that leads to many good things, and after that the matter is pretty much handled by the universities and industry which again usually supports universities research. Luckily the Japanese government is relatively generous, and they are happy when some of us win a Nobel Prize.

Question:

Technology plays such an important role in our everyday life, how have recent developments in technology helped expand your research, and how has technology changed the way you do things?

Prof. Ei-ichi Negishi:

In our area of instrumental identification of the compound, which is very detailed, very specific technologies are needed. There are of course some scientific areas that create these instrumental technical developments. Our scientific contributions are going hand in hand with this fantastic technological development and are similarly important, and without them our research wouldn't be where it is now.

Question:

What do you think will be the next big discovery in the field of science?

Prof. Ei-ichi Negishi:

As I was telling you before, I still stick with the catalytic and economical, because it's got to be economically feasible, carbon dioxide reduction. As you know carbon dioxide and carbon are bonded four times to oxygen, and that means carbon is in a plus four oxidation state, fully oxidized. So what we need is any form of carbon that is not fully oxidized, for instance fatty acid, carboxylic acid. Can you tell what the COOH carbon oxidation state is? It is +3, one less oxidized, and you may wonder if that is still useful, and of course it is. Organic fats are carboxylic acids, and in those compounds the carbon oxidation state is +3, that's why they can give us so much energy as fat.

Two less oxidized is carbon monoxide, CO, that's +2. Then you can try to think of carbon compounds with +1 oxidation states and of a carbon compound of 0 oxidation state, and that would be coal, a very important source of energy. With carbon you can go further to -1, -2, -3 and -4. An example of carbon compounds in which the oxidation state of carbon is -4 would be, for example methane, CH4. This is why methane is such a fantastic fuel. My point is that carbon can be in oxidation states from +4 to -4, and every reduced form is useful, but you have to do it economically, which usually means catalytically.

When you look around, you see green plants which are doing this all the time. Grass grows, cows eat grass and produce milk which is full of energy. But we can't rely on nature to produce the energy that humanity needs, so research is trying to find a solution for that, and this will be one of your challenges in the future.