

### **Sue Nelson**

Hello, I'm Sue Nelson and welcome to the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering, celebrating engineering visionaries, and inspiring creative minds.

[Music]

Today's guest is both a scientist and a ballerina who is increasingly turning to engineering as part of her work. Born in the US, Dr Merritt Moore has a degree in physics from Harvard, a PhD in atomic and laser physics from the University of Oxford, and has performed on stage with the English National Ballet and the Zurich Ballet. Not surprisingly, considering her background, Merritt, who is now based in Dubai, wants to break down stereotypes between disciplines, and is currently combining robotics with her love of dance. Merritt. First of all, when did you get the idea to use robots with your dance?

### **Merritt Moore**

It definitely got spurred on by this pandemic because I couldn't dance with humans, and was looking for a companion. The timing worked out because I had just been invited as an artist in residence at Harvard Art Lab. So I literally spent January and February before the pandemic, working with an industrial robotic arm. I have a physics background, so I've always been curious to see if there is a way to merge both the arts and science in a way that I felt enhanced both. And having watched this documentary AlphaGo, where I saw an AI machine beat a human at the game of Go, which is an incredibly intricate game, the commentary around it were experts saying "wow the AI machine showed like a really creative way to move, like it was out of the box, it's something that no human had done in 2000 years", this game has existed for 2000 years. And they're like, it's doing moves that no one's ever seen before. And I just thought "interesting". I think there's a way that technology can be merged to enhance human creativity, and to open our eyes to new possibilities. And so that's how it all began.

### **Sue Nelson**

It still seems an unusual leap to go from a game that has admittedly so much complexity and effectively mathematics involved with it, to dance because dance, yes, there are a myriad of ways in which a dancer can move their body, which would be very different to a non-dancer. But then you'd also think there are actually only a finite way of being able to move your body.

### **Merritt Moore**

Well, the first question I had when I was watching that documentary, and then I read about or I started learning more about AI. And, for instance, there's these GANs, generative adversarial networks, where you input images, and it combines the images to a different output. So for instance, you would say, "Well, I want 30% bird 30% water, 40% sky" or something I know outputs this weird combination of the three via AI and machine learning. And so I always thought, "interesting", like I'm ballet trained. I've danced with a number of ballet companies. So my expertise lies in ballet. But for instance, my sister, she does hip hop, and she's doing crew and their formations are so unique and different. And I've had experience with flamenco and salsa and hip hop, but I don't have that same expertise that I do with ballet, you know, I've trained in ballet and been in ballet companies where it's like eight to 18 hours a day and training the body. I thought how interesting would it be if you could use these generative of adversarial networks and say, "well, I want a piece give me something that's 30% hip hop, 30% ballet, 30% flamenco, 10% pedestrian. And it gives a new way to find like new choreography, new ways of moving. I think sometimes, ballet is so elegant and beautiful and pure. But, I think the formations are freaking boring, to be honest, right? Like, oh, we're gonna do a line now, a diagonal line, or a circle, like, oh, like two parallel lines. But in hip hop, it's like, they're together, and then they're up in the air. And that's like, the formations are amazing. And I've always been interested in creativity. I've always asked, is it nature? Is it nurture? How do you cultivate creativity? How to elicit more creativity in students? I think if you use

technology, if you use AI, it doesn't take away the human element. I think it enhances it and allows us to learn and be more creative, much faster.

**Sue Nelson**

How does the robot then capture the movement of your body? Is it rather like Hollywood with a leotard and a few sensors?

**Merritt Moore**

So there are multiple ways. I can go into motion capture suit, exactly what you're describing where there are sensors on the ceiling, and you're in a suit with little detectors all over the body. And then the way that you move is then stored as data in the computer. This is sort of exploring, can that data be fed to machine learning, where it then tweaks it and rechoreographs in a new way that you can then map on to the robot and dance with. That's one project we're working on. The second project is, can I use the handset of a VR, when I move my arm, the robot imitates it instantaneously. So, it can follow my movement. What's fun is that we're kind of exploring, like, how can we make it instantaneous, and it still be very safe. So, when I do performances, live performances now, and in some of my social media, I've pre-programmed it so I know where it's going to go so that it's choreographed. But I think it is an interesting question, which is one that I really want to explore more this year, can we figure out a way that I can improvise with the robot, where it's not choreographed in a way that for instance, I don't worry that it's going to hit my head, you know, if I'm dancing next to it, which would kind of be the concern right now. Like, if it just started doing whatever it wanted, it can go fast, right? And I'd be like, I don't want to stand right next to it, where in a lot of my videos, and a lot of my performances, I am standing next to it, but because I have trust and faith that I know where it's gonna go.

**Sue Nelson**

And are you using the robots as a tool, or learning about how they work as you go along? Are you involved in the programming as well or building them to do exactly what you want to do?

**Merritt Moore**

Yeah, so I program everything. I've also collaborated, for instance, Jose Luis at Harvard, and I've collaborated with people in India, who then continue to push it further in terms of AI. That's the fun part of this, I've been in a physics lab for years. And I felt that in academia, there's so much pressure to publish papers in order to "make it". And so what would happen is I was in quantum optics, if you do an experiment with four photons, the next person does it with five photons, and the next person does it with six, it's not very creative. So after my PhD, I felt I'm going to take a different path. So, Einstein has this quote, which is plays the highest form of research, and I really took that to heart, I was like, I am going to play. And this is how I'm going to learn about robotics.

**Sue Nelson**

And now you're merging the engineering to sort of play a larger role in your research. Was that deliberate or was it just coming out of this realising that you wanted to play and you needed to incorporate engineering into this?

**Merritt Moore**

They're just married together I would say he's just constantly like following the questions that come from it. So, for instance, like, art is everywhere. Math is everywhere, engineering is everywhere. I just remember my mom would say, like, I didn't talk much as a kid. But she just remembers me looking out the window and just being like, "Math is everywhere". So, I think in the same sense, I'm like, yeah, you know, engineering is such a big, it's necessary, right? It's a fusion at the intersection of both science and art.

**Sue Nelson**

Absolutely. And do you humanise your robots?

**Merritt Moore**

So right now, like when I work, this is like an industrial robotic arm, it has no legs, it has no arms. I love it. Because it's, for me, it feels like a puzzle trying to figure out how to dance with it. Inevitably, people do humanise it, instantly it has a name. Most of the guys see it as a girl. And most of the girls see it as a guy. It's interesting. It doesn't technically have a face, but people see a face on it and they see emotion and they feel it. The research says that majority of our communication is non-verbal. And majority of that is body language. And so I've always kind of been curious, you know, in order to communicate with body language, do you need a human body form or can it be this industrial robotic arm? I play around with different shapes and forms in different robots. So we shall see.

**Sue Nelson**

That's a really interesting connection actually and one that I'd not made before in this non-verbal communication and that connection between robots and the human body and dance as the ultimate form of non-verbal communication. You mentioned that you had not spoken much when you were younger, is that why you were drawn to dance perhaps?

**Merritt Moore**

I think so. And perhaps physics as well. Equations and body movement, we are good. My parents said I was expressive, but not with words. They understood what I needed or wanted or was feeling, but I think I always used my body, I used my hands, I used my expression. So, when I found dance, which was late, at 13. I think it was one of those moments where I was like, it just felt so raw, authentic and true. Whereas with words, I think I always felt like I could say something, but it doesn't really encapsulate the full meaning that I'm trying to express.

**Sue Nelson**

And I mentioned about stereotypes earlier on and on, obviously, you've broken those stereotypes by being both a professionally trained ballerina and a physicist. How do people react to that? Because it's such an unusual combination. I don't think I've ever heard it before.

**Merritt Moore**

It's been a journey. I've had wonderful mentors, but I think for them, they were saying, look, if I wanted to be a professional ballet dancer, what am I doing by doing physics, and if I wanted to be a physicist, what was I doing by doing so much dance? And there were so many times in which I tried to quit, and just focus on one and it just, it didn't work. Like I stopped dancing and I quit dancing, and my grades dropped and my energy level dropped and my productivity dropped. If I just focus on dance, like I get injured and I'm not as happy and I get a bit critical of myself in the studio. So, it was a mix of I didn't think I was going to make it because everyone said it was possible. But there was something deep, deep within me that was like, but maybe, what if, can I do it. So it was hard, hard work for at least seven years and more. But it was seven years of hard, hard work, where I didn't know if it was going to work out. And I didn't know if I would make it to a ballet company. And I didn't know if I would then actually be able to graduate in physics and go to a PhD. So that was the hardest part is the hard work is hard, obviously. But the hardest part is doing the hard work for many, many years, and not knowing if it's going to work out.

**Sue Nelson**

And what do you think the benefits are to breaking down these stereotypes?

**Merritt Moore**

Well one is, I mean, there needs to be a huge emphasis and push and I think a celebration of creativity and imagination. I don't think anyone is happy with the education system. And a large part is because it's focused on everyone answering questions in a very specific way, right? It's these multiple-choice questions, or it's these exams, and it's like, you need to answer questions, and you need to get them right or you're wrong. But every AI is going to be able to answer any question super-fast. For me, it's like we can't compete with that. But what humans have that those machines will never have is that creative, imaginative aspects. So, it's our ability to ask questions. So instead of focusing on answering questions, I think we need to learn how to ask questions, which is what research is about, what engineering is about, what all that is about, but sometimes I think it's missing. I think Einstein, you know, he imagined himself as a photon on a light beam. And he came up with special relativity. He didn't know the math, he then learns the math and has a friend help him in order to write it down in math to persuade his colleagues. But unfortunately, the way it's taught is, you know, here's the math equation, memorise it, regurgitate it, here's the test. Here's the exam.

**Sue Nelson**

Thinking about imagining yourself on a photon is such a brilliant, brilliant notion. You can't imagine why it wouldn't be taught. I'm gonna move to just a short period ago in the past because in 2017, you took part in the BBC television series *Astronauts: Do You Have What It Takes?* and you had a former NASA astronaut Chris Hadfield as one of the presenters, it was fairly stringent in terms of, you know, the tasks that they made you do. What did you learn from taking part in that series, what did you take away from it?

**Merritt Moore**

It was the most exhilarating and challenging experience I've ever gone through. In the first day we show up and they're like, "Okay, one by one go into helicopter, and hover it". I was just like, "Oh, my God". Yeah, they were going all in and we had to be in capsules that were dunked in water and flipped upside down. We had to break free of that. And they flew us to Germany to go on the simulator that astronauts would use to dock the Soyuz to the International Space Station. I mean, it was so intense, I think it raised the bar for myself, and I have such respect for astronauts in a way that I think you really sort of only appreciate if you're going through those trials and challenges that they throw at too. But also, there's such teamwork that's required and focus. Yeah, but it also showed me I was like, "I want to go to space".

**Sue Nelson**

I was gonna ask you that, have you ever thought of applying to be an astronaut?

**Merritt Moore**

Yeah, I applied for NASA and that's why I'm learning the robotics and becoming an expert in it, because I do believe that's the future in space. For me, you know, I have the physics background and have the dance physical aspect and I just want that robotics expertise as well. And Yusaku Maezawa, who is Japanese billionaire who bought a flight to go around the moon, to bring eight artists with him. So, they publicly announced that I was one of the shortlist, that should be announced, I don't know, sometime in the next year.

**Sue Nelson**

You're part of this women in physics mentoring programme, and you started this SASTers which is science art sisters trying to help younger girls have an interest in STEM. Would you advise engineers to be more visible?

**Merritt Moore**

Oh, certainly, I also would say like, there's no rush to do it either. Because, you know, it does sometimes take time, but I think no engineer should ever hide it. It's such a gift for them to share what they're learning and to share the projects they're working on. Like, that's the part that makes it tangible and real, and inspiring. I was kind of a mole underground, just doing my thing, for at least 10 years before there was any publicity or recognition of it. I liked that, because, you know, some things take time. Sometimes you just work at it, then you can pop your head up when it's worked out

**Sue Nelson**

Is this also why you co-founded SciArt Party, which is this sort of interdisciplinary collaboration and education networking, also includes a podcast and I love the fact that I looked at the website, and the people who are involved all do all sorts of different things, but it was the fact that you had a 12-year-old website team leader. I had to read twice to make sure I'd actually read it correctly.

**Merritt Moore**

I mean, she was amazing. She still is, little Hazel, at 12 years old. She was she was on it, she was telling us all what to do. Yeah, it happened during this pandemic with my co-founder Montse, where I think we realised, you know, we're all isolated, it was at the beginning of the pandemic, people were lonely, and kind of low on hope. And we just did these events, what we thought would be mini events, just to be like," Okay, well, we're all stuck home. Let's meet the other SciArtists, like those who are interested in science or art or both". And we have like, 250 people sign up the first day, which I was like, I didn't know there were so many, I think I was expecting only 20 max. And so, I had astronaut Chris Hadfield come on and he played for us, Space Odyssey, which was so great. And then we had Neil deGrasse Tyson as well, come on.

**Sue Nelson**

It sounds as if the pandemic had an enormous effect on you.

**Merritt Moore**

Yes, yeah. But I think that's the good thing about challenges. I mean, not that I would wish the pandemic again, but challenges in general, I think force questions. And that's what leads to breakthroughs.

**Sue Nelson**

And what would your advice be to engineers, young engineers, in particular, who do have this creative side. Funnily enough, I wasn't as surprised as you when you said, you've got 250 people sort of join up, because I, obviously, through my work, interview a lot of engineers and scientists, and if anything, I'd be surprised if I don't meet an engineer or a scientist, who hasn't got a creative side, because they're all musicians or do art, or, you know, they're very creative.

**Merritt Moore**

I really believe like passion is the magic, right? It just brings light and fun and makes work, not feel like work. It also brings appreciation, like, don't get me wrong, like there are times when I was doing physics, I was just, "this is not working". But then it made me really appreciate when I was in the studio, and with music and like dancing around, I'm like, "Oh, I'm not over a lab table". But then also vice versa. There are times when I am training, and I have bloody toes, and I am sore, and I do not want to move. And it really makes me appreciate just sitting in a library with a physics book. It enhances that appreciation. I think appreciation is the key for success and happiness. So, I think one aspect is don't let that go. And then number two, I would say is, particularly for engineers, give it time, in your own time and in your own way. I think there are a lot of ways that science and engineering is taught that perhaps isn't one's way of learning it. I'll just touch on it. But I think it's one of the reasons why there aren't as many women in physics and engineering and science is because I personally have

never had a textbook written by a woman. I have had a mentor but not a professor or teacher who is female in physics. And I think that there are just specific ways it's taught that I don't think is everyone's way of learning it. So I would say learn it in your own way, which for me was I would go into a lecture and pretend like I was teaching other people the way that I wanted it to be taught.

**Sue Nelson**

I think there's lots of very good advice there particularly in relation to time and also going back to what you said earlier about. Playfulness is don't forget to be playful. Dr Merritt Moore, thank you so much for joining us on the Create the Future podcast.

**Merritt Moore**

Thank you.

**Sue Nelson**

You can find out more about the Queen Elizabeth Prize for Engineering by following @qeprize on Twitter and Instagram, or visit [qeprize.org](http://qeprize.org). Thanks for listening and join me again next time.