Sue Nelson
Hello, I'm Sue Nelson. And thanks for joining me on the Create the Future podcast brought to you by the Queen Elizabeth Prize for Engineering.

There's plenty of laughter ahead in this podcast, as my guest is a firm believer that being an engineer shouldn't be incompatible with levity. Kristala Jones Prather is a professor of chemical engineering at MIT, the Massachusetts Institute of Technology in Boston, United States. Although she studied there as an undergraduate and gained her PhD in chemical engineering at the University of California, Berkeley, her route to becoming an academic was via industry. She's won all sorts of awards as an investigator and a teacher and runs her own research lab at MIT as well. Kristala's research interests involve biochemical engineering, bioprocesses, and synthetic biology, a lot of biology in other words. And since many people might think a chemical engineer is primarily a mix of chemistry, and engineering, I began by asking how she would describe her work.

Kristala Jones Prather
Well, it is chemical engineering. And we're very proud of the fact that as a discipline, chemical engineering is extremely diverse. Our focus is on using biology, but we use biology to make chemical compounds. So, what that means is that we engineer microbial systems, mostly bacteria, sometimes some yeast, to be able to produce chemical compounds from very simple renewable substrates, things like sugars, glucose, glycerol, other carbohydrates that you may have heard of. And so, for us, even though the tools that we use on a regular basis are the tools of biology, we're using biology to do chemistry. So, I often will tell my students or especially undergraduates that I'm teaching, we just envision that these microbial cells that we're using are just really teeny, tiny chemical reactors. And they just happen to be processing hundreds and thousands of chemical reactions at a time with hundreds of different chemical molecules. So that still makes it chemistry to us. But the scale at which that happens is very small, which is what makes it biology. And the tools that we use are the tools to engineer biological systems. I will say that I've been doing this at MIT as a professor for 16 years now, when I first started graduate school in the mid 90s, this kind of engineering and chemical engineering was still relatively new, but it really has become very much mainstream. And it's a recognition of the fact that even systems as complex as biological systems are really just composed of chemical molecules. And we can apply some of the same principles of engineering to these biological systems the same way that we would to a large-scale chemical manufacturing plant.

Sue Nelson
So how would you do that? You mentioned using the tools of engineering? What tools? Are they?

Kristala Jones Prather
Yes, so we do a lot of cloning or genetic engineering, or genomic engineering even, so our goals, our objective is to be able to engineer a cell and microbial cell to produce a chemical compound, then we have to start with first thinking of what is it that we want to make, and then recognising that when biology does chemistry, it uses catalysts. And by the way, when chemical engineers do chemistry or organic chemists do chemistry, they often use catalysts as well. But those are catalysts that typically they have built from other materials. Biology makes its own catalysts. So it uses the building blocks of life. These are amino acids to make specialised proteins, and those proteins will then allow you to catalyse chemical reactions. And we're very fortunate that the central dogma of biology tells us that DNA goes to RNA goes to protein. And as long as we're able to pick the right DNA encoding for those right proteins to make the enzymes that we want, then we can mix and match around many different kinds of both DNA molecules and the enzymes that they encode, to be able to produce the chemical compounds that we want. So if you come back to then what are the tools of biology that we're using to do this, we're using tools that allow us to introduce pieces of DNA from completely disparate or heterologous

organisms, to piece them together with pieces of DNA, and that will allow for those genes to be expressed in the cells that we want. And then that allows them now to make the proteins that are those enzymes that create the chemical compounds that we're interested in. I should say, one of the big advances and the work that we've been doing over the past couple of decades, are the tools and technologies that have come out of synthetic biology. So if I go back 20 years ago, when I was first learning how to do these kinds of things, or first doing them professionally, I would say as soon as I was out of graduate school, then I The way in which you would be able to introduce new DNA into a cell required you to have some DNA template to work from. And then you could use something like PCR to make copies of that. Fast forward to today, most of the genes that we use to now encode these proteins, we order them. So we go through commercial DNA synthesis suppliers, and we're able to then specify a sequence that we want. And we receive that in the mail as physical DNA that we can then introduce into the cells to have the functions that we're interested in.

Sue Nelson
Now, it's quite interesting that I asked you what were the tools of engineering? And in your answer, you said the tools of biology. And I think that's interesting, because it's difficult to discern a difference between the two disciplines from listening to your answers, actually.

Kristala Jones Prather
It is and so to me, this is one of the most fascinating parts of being a part of modern science and engineering. And, and I often, at times, I'm very proud of being an engineer, I'm very happy with my engineering discipline. But there's a lot of science in what we do. And the same thing is true that for a lot of people who are trained as scientists, there's a lot of engineering in what they do, you know, I think it's oftentimes more useful than thinking of things in terms of disciplines is to think of them in terms of the problems that we're trying to solve. So if you think about the kinds of work that we do, the tools that we use, whether I call them engineering tools, or tools of technology, or tools of biology, they all have the same objective, which is to allow us and our case to be able to produce these personally designed or custom design cells that allow us to make renewable chemicals. And for us, even though we're in a chemical engineering department, you could find some of the same work that we're doing the same tools that we use in a biology lab, or biological engineering department, or in some cases in environmental engineering labs or environmental science departments as well.

Sue Nelson
Now, you said renewable chemicals there, what do you mean by that?

Kristala Jones Prather
So when we talk about renewable chemicals, the context or the juxtaposition is with something that's fossil derived. So I teach as part of my chemical engineering curriculum, the first class I teach is one on mass and energy balances. And we teach the students that you can think about systems on a number of different scales. And so if I think about the earth as a system, if I'm using fossil derived inputs, those are materials that were stored deep below the Earth's surface, millions of years ago, and I am extracting those and using them to make all sorts of things that we use in everyday life from the plastics that may cover your laptop, or a pointer if you're using one, or the fabrics, actually, that are covering the chair that you may be sitting in. And so that's not really renewable, it's not really sustainable, because the timescale that it took to actually deposit that feedstock that we're using, is much, much longer than the timescales over which we are pulling those materials out of the ground, and then converting them into compounds that are going to be of use. When we think about renewable chemicals, what we're saying is that we're using feedstocks, that can actually be replenished on a timescale that matches the timescales that we're using them. So for us, that means anything that's going to be derived from biomass. If I have a biomass or a biobased feedstock, that's something that we know can be replenished

just through the normal growth cycles. And that will allow us to then produce materials that can be considered to be renewable.

Sue Nelson
So this is something that's very current at the moment with people worried about resources. I mean, you mentioned yourself, you know, it is a relatively recent, I hate to use the word discipline, but I will use the word discipline in terms of chemical engineering. What got you into it? Because it was something that was not so commonplace when you studied chemical engineering at university?

Kristala Jones Prather
Yeah, so chemical engineering itself is an older discipline, it comes out of applied chemistry, synthetic biology is much newer. I went into chemical engineering from what I would describe as a more traditional perspective, but one that was very limited. And in particular, when I was coming out of high school, I knew I needed to decide what I wanted to choose as at least initial career path. So what I would study at university. I was interested in math and science. And so I was told that the fusion of math and science was engineering. So that immediately resonated with me as something that I was interested in doing. I was always more interested in science and technology than I was in an arts and literature, for example. And I happen to be taking a chemistry class at the moment that I had this first conversation with a with a beloved teacher in high school, about what my future might be. And so I sort of latched on immediately to this idea that chemical engineering would be a great discipline for me to be able to study going forward. And that was my junior year of high school. So one year before I was scheduled to graduate. When I was a senior I met a mentor who has been a wonderful family friend and mentor over the 30 years since, who gave me a couple of books published by the American Chemical Society. And they were intended for really high school age to first- or second-year university students talking about different application fields for the chemical sciences. One was on polymer science. So, materials, the kinds of things that I'm talking to you about now in terms of what we make from fossil materials, and the other was on biotechnology. And that was actually the first introduction I had to biology in connection to the chemical sciences. And of course, I knew that biology had some chemical molecules in it. But I'd been taught biology more from the taxonomic perspective in terms of whole organisms and water plants versus animals, and not really the molecular biology perspective that allows you to make that more immediate connection between biology and chemistry. But I found both of these articles to be wonderfully interesting and thought, okay, chemical engineering seems to be a field, a discipline where there are a few different options. I grew up in a part of the US in Texas that was very well known for having large chemical plants and oil refineries. And so that was initially my view of what chemical engineering was. But getting introduced to these other areas where the chemical sciences could play a role, was the first time that I really understood that chemical engineering and chemistry in general will be much, much broader than that. So, I went to university with this idea that I knew I was interested in chemical engineering, I wasn't quite sure if I want it more of a biological focus, or one that was more focused on materials. By the way, since those are the only two books that I had. Those were the two things that I was interested in. I imagine that had my mentor had given me a book on nanoscience, maybe I would have decided that.

Sue Nelson
Or botany.

Kristala Jones Prather
I would have decided to look into that as well. Now, what's true about me being in University at that time, and I was in university from 1990, to 1994. And there was the biotech revolution, which was very closely associated with chemical engineering. So when you had the first biologic drugs, things like monoclonal antibodies, the most famous ones are ones that have been used historically to treat stroke. There are lots of cancer

therapeutics now, for example, that are these biologic drugs, chemical engineers played a really major role in launching those industries, both in the US and in Europe and around the world. But not from the perspective of engineering the biology, but rather from the perspective of engineering the manufacturing processes. So, if I'm going to have a new therapeutic, I have to have a way to produce large amounts of it, enough to be able to satisfy whatever the demand is for that patient population. And that entire discipline around how do you think about processes and developing large scale manufacturing processes. That absolutely was chemical engineering, it had been chemical engineering, since the first chemical plants were put into existence. And there was comfort in taking those same principles and philosophies and practices, and just applying them to a new kind of reactor, or a new kind of product. But what started to happen around the time that I was going to graduate school was a recognition that you could start to apply engineering principles with this chemical engineering framework to the biology itself. So you started to have the emergence of protein engineering, an enzyme engineering. So now these were engineers, people trained as engineers, but who were starting to work on the molecules themselves, to be able to get the proteins to do new kinds of functions. And then the research in the lab that I was a part of in graduate school, this was a Jay Keasling lab at the University of California, Berkeley, Jay was looking at how do you actually engineer now these cells to be able to produce chemical compounds more efficiently. So it was new and different in the sense of trying to figure out how do you actually apply the principles of chemical engineering on now a much smaller scale, but the field of chemical engineering over this time, so about 25 or 30 years now has become much more molecular, in the sense that there still is very much a focus on processes. We do that professionally. We do that even in a university or educational sense. But a lot of the research that's happening in chemical engineering is recognising that the discipline and the way our discipline is structured, lends itself very readily towards engineering things at the molecular level as well.

Sue Nelson
And you've described synthetic biology as repurposing nature. And it does sound the way you're describing it that the engineers role is very much that of an instigator of thinking, new ways to apply things which is very much what people talk about engineers, they come in and they see solutions to problems that you didn't even know were there or, or they see new avenues opening up in innovative ways.

Kristala Jones Prather
Yeah, so engineering, to me is a very interesting discipline. One of the things that I find most fascinating in the relationship between engineering and biology, is just how much of a challenge nature is to apply the traditional rules of engineering. Okay, so what I mean by that? Well, as engineers, what we're taught is that our goal is to first observe the physical world around us, then we develop mathematical equations to help us to describe that world. And if our equations match our observations, then we can use those equations predictably, to now design the world that we want to see. So how does this work for building a bridge, for example? Well, you learn about civil engineering, and you learn about the physics of mechanics in terms of stresses, and how different construction architectures will allow you to distribute stress and weight evenly to be able to hold a certain number of kilos or kilotons of vehicles that are crossing a particular span, right. And so when an engineer builds a bridge, you have this whole framework that says: "you know how to build a bridge, you know, the construction materials you can use, you know, how long it's going to last, you know, what it will support", and you build the bridge one time. And then the bridges, there's usually a big ribbon cutting ceremony or whatever, right, the fanfare, and then you can cross the bridge, if you try to apply those same principles and practices to biology, biology laughs at you. In the biological realm, engineers have come in under this domain of synthetic biology, in part, and said, well, let's apply the same framework to how we think about biological systems. Let's actually look at how the systems are behaving and let's develop a mathematical equations to help us to describe that. And then let's use those equations to design something. And the problem with biology is it evolves, it ages. It has a mind of its own in some ways. And so in biology, what engineers find over and over again, is that you can have

what you believe as a very robust design, but you build whatever that biological instantiation is, and you observe it, and it doesn't work. Or, to me the most fascinating cases are, it does what you expected it would do, but not for the reasons that you expected it would do it. And so in biology, when we're now doing synthetic biology, we find ourselves having to repeat the design process over and over and over again. Whereas you're never going to build a bridge and go “Ah, it's leaning a little bit too far left”, and tear all down and start over again. So we're still very much behind because nature has figured out how to be robust, while also being very, very noisy and unpredictable in some ways. And our engineering practices, in principle still have to catch up with that a little bit. So we can look to nature for inspiration, we can take this very engineering approach, as you described it and look toward solving problems. But a big part of what we have to do when we're using biology is to first try to understand how nature has already solved similar problems, to then determine what's feasible or most likely to be possible for the particular solution approach that we want to take.

Sue Nelson
Is this part of what's called this retro biosynthesis, this sort of reverse engineering with biology?

Kristala Jones Prather
Yeah, it's a little bit of that. And in that particular case, when we talk about retro biosynthesis, we're looking specifically at how nature produces chemical compounds. So what we want to do is to go beyond what nature has given us explicitly, and there's some wonderful case studies, penicillin is a great one, penicillin is something that's naturally produced by a fungal organism. It was discovered and first used right there in the UK, and really revolutionised the treatment of wounded soldiers during World War Two, that's sort of the big, hanging our hat from a biochemical engineering perspective of how learning how to mass produce that was very effective. But biology is both unlimited and limited in the sense that it makes a number of different chemical compounds, but not necessarily all the ones that we think could be useful. So if I use sort of the penicillin example, again, penicillin itself was originally developed, originally discovered as a natural product of this organism, but the kinds of beta lactones. That's the broader class of antibiotics that have been used commercially ended up being what are described as semi synthetics, meaning you take what nature has given you, and then use the tools of chemistry to change it a little bit and have it be more effective or more appropriate, as a pharmaceutical or as a therapeutic. So what we're interested in doing is learning how biology makes certain chemical compounds, and then adapting that to design new chemical compounds that the cell hasn't already made, but that we think it should be able to make if we're following along the same sort of roadmap or path that biology has used in the past to make similar compounds. So this is absolutely about observing what nature has done, and then figuring out how do we take an engineering approach to expand upon what nature has already provided us in order to give us something new.

Sue Nelson
I mean, this will make sense like engineers are taking nature and making it better.

Kristala Jones Prather
Well, um, you're not going to get ***me*** to say that. I think nature is phenomenal at what she does. And I don't actually consider it improving upon nature, I consider it learning lessons from nature, and then adapting what we have learned to be able to help us to meet the needs of mankind. I'm not going to knock nature. Nature's been at it a long time. And nature has figured out a survival and a robustness and a persistence that can be informative for all of us. But I also think nature has given us tools and said please use this, please use them responsibly. But you can use these tools to actually help benefit humankind overall. So I'm not going to call it making nature better. I'm going to say actually learning from nature, in order to continue to advance our society and well-being in a way that benefits as many humans as possible.

Sue Nelson
Okay, I'll let you say that, then. I'll let you say that. Now, after university after MIT and Berkeley, you worked for four years in industry at Merck Research Laboratories. Now you were developing ways to produce drugs there, why did you decide to leave industry to go back to MIT, but obviously in this case, as somebody who is teaching and nurturing other future chemical engineers?

Kristala Jones Prather
So that was always the plan. And it is not the typical plan. So any aspiring academic, the traditional path that one takes is you do your undergraduate studies at university, do your graduate studies at university, you typically would then move into a postdoctoral position. So something that would be a little bit of extra training, independent training for you to be able to develop your skills. And then that is the launch point that you have to go into an academic career. So, this is a much more linear approach to be used to do this. I, again, went through school as an engineer, but as an engineer being taught by academics, right? And so with a lot of the trainings, the best way to describe it.

Sue Nelson
I can hear a lot of action going on behind you there. If it's if it's not a dog barking it sounds like someone's making a cup of tea.

Kristala Jones Prather
My husband was washing his hands.

Sue Nelson
Oh, well with the Coronavirus. It's very good.

Kristala Jones Prather
Yeah, in an earlier email you said there can be editing. So, I'm assuming you're gonna.

Sue Nelson
I may or may not, I'll see how I feel.

Kristala Jones Prather
Hey, this is what happens in life during COVID. Everything happens in the background. The traditional route is your formal education. And then you stay within the academic world, because it's easier to continue in academia from academia. And that wasn't quite what I wanted to do for a couple of reasons. One was because I had this wonderful academic experience. But I chose engineering because I was very much interested in applications. I wanted to focus on problem solving, not discovery. So I wanted to be an engineer. And I had this really interesting and extremely humbling experience. When I was in graduate school, I had a fellowship, I was supported by a company. And one of the conditions of the fellowship was that I go to visit a company and give a talk on my research. And so, I did this and I gave, as I described to people what I thought was a brilliant presentation. I had worked very hard on this. It was the first full length seminar I had ever given. I had done these shorter conference kinds of presentations that were 15 or 20 minutes, but this one I had the whole hour and I was expected to speak for 40 to 45 minutes and have questions. And I delivered this talk that I got a few laughs along the way. So, I said great, they're listening. And I got some questions. And I saw from the nods and the smiles that they thought I had answered the questions well, and I thought I have nailed this. And then I went to have a one on one conversation with one of the scientists there, a guy named Charlie Nakamura. Charlie has retired now, so I can say his name in a podcast. And Charlie said to me, the motivation for your work is all wrong. And he said, don't get me wrong, I think what you're doing is very interesting. I think it's important.

And I think the field is going to learn from what you have done, and it will be important, but you have motivated this by things that are relevant to industry, and you've just got it all wrong. And he was very straightforward and direct. And and I don't even remember the details anymore. But in sort of saying, you know, you've got these three points. And one of them was, yeah, that used to be a problem, but we figured out how to solve it long enough ago, that it's not an issue anymore. And one of them was sure, that's a problem but it's so minor, that it doesn't really affect the economics at all. And the third one was, yep, that's a real problem… but you have to solve these other five problems first, before you even get to that problem. Because if you don't solve these other ones, solving that problem is not going to matter. And this was a extremely informative and really influential exchange that I had.

Sue Nelson
Was it crushing, though, I mean, for some people, depending on who they are, that could either yes, that could be one of those things, you say, this is my learning moment, after you've picked yourself off the floor in a in a heap of tears.

Kristala Jones Prather
So I will confess, it was a little, it was a little startling. And this was someone that I had never met before. Now it turns out, I ended up then doing an internship with the programme and this person was my boss, and I and I came to learn that he was just very matter of fact, and direct. And even if you were best friends, and he loved everything about you, he was just matter of fact and direct. But I actually decided to take it to heart. And it was surprising, right? It was a little bit and I appreciated the fact that he said, at the beginning, don't get me wrong, I think the work you're doing is great, because then I could relax, and actually hear it not as an attack on me or what I was doing, but more as an opportunity to become more informed about the context or the framework in which I was actually doing this work that I thought was going to be important. And he was telling me: “Sure, it's important, but not for any of the reasons that you think it is”. So yes, it was humbling to say the least.

Sue Nelson
That’s something actually that is great advice for young, young engineers, chemical or otherwise, or synthetic biology or whichever area they want to, to go into, is to be able to take criticism, and sometimes not take it personally. And rethink.

Kristala Jones Prather
Oh, this is this is such a difficult thing to do. Because the cornerstone of any sort of frontier research science, engineering, is criticism. The process that we go through, the scientific process that we use, is one in which we produce material, and we send it away to be critically analysed, which usually results in people writing comments back to you telling you the things they think are awful. Now, they'll tell you the things they think are great as well, but we've been trained to really emphasise those things that are not so great. And so it does take some adjusting to accept that kind of feedback and not see it as a reflection on you as an individual. But as an opportunity to take in that information and have it helped to advance your science to help you to be more effective as an educator or as an engineer, or as whatever it is that you're doing. And it certainly is not easy. I think that's one of the most difficult things actually, for young scientists, is to learn how to separate the feedback on the work from the feedback on you as an individual. And I think that's just human nature to conflate the two of those.

Sue Nelson
I think it's something though that's also very specific to STEM. My degree is not engineering. It's physics. But I did do a year of electronic engineering as part of my course. And that particular lecturer was one of the most brutal because he would, using almost superhuman strength would try to rip apart your circuit board in order

to prove whether or not it was soldered correctly, or that you done that the right thing. But it wasn't until I was a journalist, I don't think, that when I was attending different science conferences that I saw – and brutal is the word – that's how I felt as a journalist and let's face it, journalists are not always the most sensitive, was how brutal scientists were at attacking other people's science. And at first, I did think, oh, my goodness, that is so rude. Oh, my goodness, but then, you know, you get used to it, you realise, as you say, that's part of the process. And it's extremely rigorous, I think to observers who've not seen that before. It's quite shocking. Yeah. But it is part of the experience. And also part of the growth, I suppose in terms of how you, in the same way that if you write a piece, if you first get that editor, who tears all your sentences apart, and says, why have you put this with this this way? And why me that? Again, it's that moment, you either go into a crumpled heap and think I'll never write again, or you pick yourself up and think, okay, they've got a point here, I'm going to do this slightly differently. And then you become a better writer, or you become a better engineer, or a better scientist.

Kristala Jones Prather
I will say, I don't think the manner in which the critique is delivered is always helpful. There are certainly some disciplines that are more infamous than others, for actually crossing that line into really trying to destroy, or to poke holes in the individual rather than in the science.

Sue Nelson
News editors are very on that side.

Kristala Jones Prather
Yeah, so you know, I would certainly argue that there is, there's progress that can be made on multiple fronts in terms of how the sort of feedback can be most effectively given. But it is really important to both give it and receive it. And I think that's the case, actually, I know this is the case because all too often, in what we are doing, the stakes are so high. And you can look across history, at examples of major failures of science and technology and in all those cases, it's fair to ask, were there people who didn't ask questions? Or were there people who did not like the answers to the questions that were given? And who made decisions to move ahead in spite of those answers? And so I think the practice, is the word I'm looking for, the practice of questioning science and engineering and questioning those of us who are doing science and engineering has a very, very critical role to play. But I do think that that we have to be very mindful to do it in a collegial way and in a constructive way. Because to be perfectly honest, I'm afraid that some of the historical practices of the way that that kind of feedback has been given, has really driven really promising individuals – and honestly, a lot of women – out of science and out of engineering, who do not like being yelled at, or who do not like and who do not appreciate being treated as less than rather than actually having a respectful, productive conversation, a discussion around the science without taking those other elements out of it.

Sue Nelson
Is this partly why you set up this Prather Research Group, which I saw was described as the inclusive, creative, collaborative, and using words that you don't often associate with research, which is of saying, mindful of the impact and, and also you emphasising the mental health of people who are part of it.

Kristala Jones Prather
So this is actually part of a larger effort within my department that started around a year ago. As a faculty, we actually decided we need to be much more proactive, thinking about culture, and not just science. And so this was that there's been a number of years and a number of efforts that have happened at our university, some specific to the department, but many, many more around the university as a whole, about challenging and changing the culture of science and engineering to make it more welcoming, to make it more inclusive, and to have more of an appreciation for the unique strengths and talents that individuals of very diverse backgrounds

have. And so as a department, our department of chemical engineering department head led an effort and discussion with the faculty where we all agreed that we would develop these culture and value statements to be posted on our websites. And so my group did this. And the process I thought was really interesting, and for me very informative, because it was important for me that it not be a statement that I write, that it'd be a statement that actually reflected the collective thought process of the research group. And so it's It actually took us a little while to do it. We had a we had a conversation at a group meeting where we talked about ideals and ideas and words that we wanted to be reflected. And then that all went into a Google Doc that could be shared and came up with something that we all could agree with and decided to post it where it could be easily found on our website. I will say I did put in a plug for fun.

Sue Nelson
Yes, I saw that we embrace laughter and levity. I saw that sentence. And I love that.

Kristala Jones Prather
That's something that I feel very strongly about, especially if I think about graduate education and the age that most students are at that stage. They are young adults who are at such an important developmental period in their lives, both professionally and personally. And I just think it's important for everyone to remember fun, and to embrace fun, and to recognise that they are whole persons, not just students are not just postdocs who are pursuing this particular bit of their formal training, they're still human beings, they're still individuals, and they need to be able to really take care of their whole selves, and to embrace the things that give them pleasure and the things that give them joy. And to figure out, it's a wonderful time to actually figure out how do you do both? How do you progress professionally, without losing a sense of self. And I mean, I like to laugh. I'm a lighthearted individual. And so, you know, I like to have and foster this atmosphere where coming to the lab is not a drag, right? When you wake up in the morning, you go, okay, off to do this thing, again, that I really just have to tolerate. And I don't, and I don't like it very much. And so I've worked hard over the time that I put my research group together, to try to make sure that that everyone understands that I want them to be whole individuals, I always describe it as we work hard, so we can play hard. You know, if you're working at a time when you haven't had a chance to rest, the work is not very peaceful. But if you're resting and playing at a time, when you haven't been productive in your work life, then that part's not fun, either. So we've really tried to work hard to emphasise the need to have that kind of balance, and to figure out how to be successful at both simultaneously.

Sue Nelson
And is it working? I'm assuming and hoping the answer is yes, I think it is.

Kristala Jones Prather
I mean, speaking for myself, the past six months of life and COVID have really shattered all sorts of illusions about how my life works. And I'm not alone in that, because what many of us especially those of us who are academics have often had to struggle with separation balance between work life and home life and making sure that we're dedicating enough time to the home life, it's so easy to ignore it, because the work just never ends. And when you bring work home, you know when I'm sitting here and my daughter actually just walked through the kitchen, because her school is remote right now as well. It becomes impossible to really have those barriers. And so that makes it even more important to think about, what are you doing for fun and what are you doing for rest? So speaking for myself, I think it's working, I'm rethinking it certainly a lot in this new way of working mostly from home. And for my students. There are good days and bad days for all of them. But I am happy to say that when every single one of them have graduated, and when they've done their thesis defences, and they come to the part where they do their acknowledgments. I hear from them, and I see on their faces, and I feel in their body language that it worked, that they felt like they were able to be themselves and to pursue

their dreams to really chart their own path and figure out what it was that they wanted to do. And they felt like they had the freedom to do that and the support to do that while also getting the appropriate guardrails and boundaries that allowed them to be successful scientifically as well.

Sue Nelson
Concentrating on mental health, for instance, that's totally relevant now, as you say, in terms of how we're all we're all working. Do you ever feel any pressure? Because it's not just that there are often you know, women are generally underrepresented in engineering, also women of colour as well, do you then feel under pressure to be perfect?

Kristala Jones Prather
Oh, never to be perfect. No, never to be perfect. And in fact,

Sue Nelson
Tell me you've got a drink problem or something.

Kristala Jones Prather
No. No, I actually I don't drink at all.

Sue Nelson
So don't worry, you don't have to justify that question.

Kristala Jones Prather
I'm going to tell you a very funny story. And you may choose to splice it out, I'm not going to use any names, I'm going to totally protect the innocent and the guilty here as well. But I was at a conference about 20 years ago. In Italy, actually. And it was the last night. And I was sitting next to the spouse of a very well-known scientist/engineer in my area. And she saw me pass up the wine that was offered for dinner. And I passed up something else, I think maybe I wasn't eating dessert, because I'd gotten aware, I was eating too many desserts. And she says that she wanted to go outside for a cigarette. And she asked me if I smoked – oh, and I passed up the coffee. That's what it was. I didn't have the wine. I didn't have the coffee. She said something about smoking. And I said I did smoke and she said "Oh, you don't drink coffee. You don't smoke. You don't drink wine. You must have a vice. You must have something that you do". And then she leans over very close to me and says: "Do you like men?". With a little twinkle in her eye. And I said, I'm very fond of my husband. And then she starts laughing. But I do not have a drinking problem or a smoking problem or a men problem. But I actually think it is critically important to admit mistakes and to not be perfect. I think there is a tremendous, I think what you're saying is correct, yes, there's tremendous pressure to be perfect. And I find myself constantly fighting back against that. Because I think it is ridiculous and unfair and wholly unsustainable. It's just not. I have two daughters that are now 16 and 12. And when I first started as a faculty member at MIT, my oldest daughter was two months old. And both her and my younger daughter were at day-care on campus. And so I got into the habit of having them in my office, I would often go pick them up, especially the older one, when she was just one. Pick her up, bring her back to my office for about a half hour an hour to work, to let the traffic dry down a little bit before we would drive home. And I did that in part out of necessity. But then if I had evening activities with students, I would bring her with me and I did it purposefully, especially any time where I thought women would be in the room so that they would see this was part of my life. That I couldn't pretend that I didn't have a daughter, because I had a meeting to go to. And that trying to figure out how to balance these two things, was a big challenge. I still remember we have a holiday party. Usually, well, we're probably not going to have it this year. But in our department, and everyone does skits, these little funny performances and, and they're always at the end of the day, and I had picked up my daughter who must have been about three at the time. And I had

to perform in this skit. And I had some M&Ms that were part of the skit, and I'm in the skit and I'm performing and I am slipping my three year old M&Ms on the side, she keeps running up to me in the middle of this skit, for a handful of M&Ms. And then she would go back and sit again. And everybody loved it. They're like, you know what? It's so real. I said yes and now you can see it's insane. But it's so real. And so I think it's really important to allow, especially younger women to see imperfections, right? To see that the bobbles to show up and say, oops, yeah, I got that wrong. And especially even in science, you learn from the failures, oftentimes, so much more than you learn from the successes. And that idea, that we have to be perfect. It's just one that has to be shattered. And so I try to fight against it. You know, no one will call me perfect, that's for sure. But I try to be as honest and authentic and as genuine as I can be, because I think that's going to be most useful and most helpful, especially in this this role of someone that that younger woman may be looking to figure out what options or what paths they may have that they choose to pursue.

Sue Nelson
Well, I must say I think your students are incredibly lucky to have you as their professor Kristala Jones Prather, thank you so much for being on the Create the Future podcast.