**Bonni:** [00:00:00] On today's episode Dr. Meg Urry shares approaches we could use to help our students correct inaccurate mental models and grasp complex information.

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**Bonni:** [00:00:20] Welcome to this episode of Teaching in h=Higher Ed. This is the space where we explore the art and science of being more effective at facilitating learning. We also share ways to increase our personal productivity approaches so we can have more peace in our lives and be even more present for our students.

**Bonni:** [00:00:48] If you've been listening for a while you may remember episode 60 with Edward O'Neill where we talked about practical instructional design. Well with him as I do with every guest at the after we stopped the recording I asked him if he had any suggestions for guests and his suggestion was today's guest.

**Bonni:** [00:01:05] I am happy to be welcoming Dr. Meg Urry. She is an American Astrophysicist. She's currently the president of the American Astronomical Society. Prior to that she was on the Hubble Space Telescope faculty and was chair of the physics department at Yale and Meg is still at Yale as the Israel Monsen Professor of Physics and Astronomy and the Director of the Yale Center for Astronomy and Astrophysics. Meg, welcome to Teaching in Higher Ed.

**Meg:** [00:01:37] Thanks it's a pleasure to be here.

**Bonni:** [00:01:39] I would love to hear a little bit about your research.

**Meg:** [00:01:43] It turns out every galaxy like the Milky Way galaxy that we live in has a supermassive black hole at its center and probably that black hole grew

to be its current size something like a million to a billion times the mass of our sun over the last 12 or 13 billion years of cosmic evolution.

**Meg:** [00:02:03] And so what my research group does is try to figure out when and where these black holes grew and how they affected the galaxies that they live in. Probably your audience is familiar with astronomy and the idea of looking through a telescope to see stars in our galaxy or collections of stars that are other galaxies but what you might not realize is that many of these cosmic objects including stars emit at many different wavelengths than the visible light we can see with our eyes.

**Meg:** [00:02:33] And in fact the growth of supermassive black holes is best traced in X-ray and infrared lights for X-ray light we actually fly satellites above the atmosphere because the atmosphere doesn't let x rays in which is good for our health and we detect x rays from the black holes that are growing at the centers of distant galaxies.

**Bonni:** [00:02:52] You're already predicting questions I was going to ask you I love it because I thought how do we study black holes when we can't get can't get that close to them and that's fascinating. Tell me a little bit about how you first started getting interested maybe in science in general and then specifically in astronomy and physics.

**Meg:** [00:03:09] My story is not the classic one I mean many of my colleagues were interested in science from an early age and knew they wanted to be astronomers when they were schoolchildren. For me I was interested in everything English History Maths Science was kind of almost the last place finisher because.

**Meg:** [00:03:28] Maybe because of how it was taught all those years ago it was more about memorization than discovery. So you know I was late to come to science I had a horrible Internet service too loudly had it not great physics class in high school that didn't inspire me in any way. So the fact that I ended up a physicist is kind of amazing when I got to college.

**Meg:** [00:03:52] I kind of realized a couple of things. First of all I think like a scientist which is to say pretty logically and always comparing things rather than just saying when you stop at a red light. Somebody is going to rearrange you well know you have to say what fraction of the time it's going to happen and how do you come about that you compare an event with their control sample.

**Meg:** [00:04:15] I realized I thought like that and also I had in my second semester physics and this is the kind of thing we're going to get around to discussing you know first semester is all about stuff you have experience in life like velocity and acceleration and movement and you have you have quite a bit of intuition for it if you throw a ball you have a sense of where it's going to go.

**Meg:** [00:04:37] First semester physics is often not that not so troubling also students have had high school physics that covers that territory and in many cases and they're somewhat familiar with it when you get to second semester physics. Electricity and magnetism. I mean I'm I have to say I'm a smart person but I was sitting in class thinking What the hell are we doing and why are we doing this. And I was just so so lost. I had no clue what was going on or why mostly why. Like why are we doing this.

**Meg:** [00:05:11] You know there's no infinite plane of metal in life. Why are you why are you suggesting a problem is often INFINITE PLANE OF METAL I mean it just made no sense to me. And then I decided this cannot be that hard and I'm just going to do it and I'm just going to master it.

**Meg:** [00:05:25] Something happened where at some moment it clicked and I understood what we were doing and I understood what it meant. You can also say that look not only was that the moment I started to like physics but it was also the moment I realized everybody can learn physics if they get this you know key unlocking the door.

**Meg:** [00:05:46] You don't want to leave them in a state that I was in. Wonder why the heck were doing this and how ridiculous it all seems. You want people to get over that hump and and suddenly see that wow this is real simple and straightforward and beautiful and useful.

**Bonni:** [00:06:00] Was that around the same time when you also started to discover that some fellow students had set up a lab incorrectly.

**Meg:** [00:06:07] Yeah it was. It was a few years before that but that also happened in undergraduate lab. And I don't it's all mixed up together in my head now I realize that it was very typical for me to be one of the very few women in the class and the guys were always so sure of themselves.

**Meg:** [00:06:26] And and sort of they took over you know these kind of pull you out of the way and say oh here I'll do it blah blah blah blah blah. And I would be

saying wait a minute you know I'm not sure that's right whatever. But I hadn't played with circuits as a kid the way they seemed to have done anyway.

**Meg:** [00:06:40] The thing that you referred to happened in a graduate class when these guys were you know putting the circuit together and then the circuit didn't work and they're all going to go run with. And instead of trying to troubleshoot their circuit.

**Meg:** [00:06:53] I'm back looking at those circuit diagrams and then tracing what they've done and realizing they didn't put the circuit together correctly and that was kind of an eye opener to me because I always assumed if someone claimed authority about something that they must indeed know about it that you wouldn't claim that authority if indeed you didn't know about it.

**Meg:** [00:07:13] But it turns out they do and lots of people do that all the time and so kind of you know what I realized at that point that I shouldn't interpret other people other people's behavior as if it were me doing that I would only claim authority if indeed I really really knew about something and then I had to kind of reset my expectations.

**Bonni:** [00:07:38] What can you share about what it was like to be a woman and emerging into the field of science.

**Meg:** [00:07:44] When I was younger I probably thought of it as you know a big adventure because it was a time when women have been polluted from many institutions in our lives and work you know. Now getting a look in for example when I entered graduate school in 1977 at Johns Hopkins University it had allowed women in as undergraduates only since 1970.

**Meg:** [00:08:11] And so we thought you know I thought Oh my goodness you know they're just you know women didn't have the opportunity in the past but now we do and there's not going to be any problems. And I'm going to be the pioneer and it was kind of like almost a little bit of a motivator to be the first woman this or that or the only woman this or that.

**Meg:** [00:08:31] It took me a few more years to realize that there had always been women like me interested in doing these things. And talented at physics say in math and who who were who were systematically excluded number one and number two that that really hadn't stopped.

**Meg:** [00:08:47] It didn't just turn on a dime you know the reason women weren't admitted to Yale University or Johns Hopkins University or any of the really top ranked programs was not you know you can't turn on a dime. It was because women were not seen as leaders in these universities think they're educating the next generation of leaders. Let me just say it it hasn't been easy.

**Meg:** [00:09:11] And I think. When you know is there any younger women listening or if there are teachers of younger women you have to realize that women and anybody else is a minority in your class.

**Meg:** [00:09:23] Let's say people of color or transgender students whatever they're you know differ difference is people who feel different than the norm who feel outside that tribe have a heavier burden of learning that stuff it's just harder.

**Bonni:** [00:09:42] One of the articles I read about you and forgive me for not digging deeper than that. I couldn't tell if this was research that you had conducted or that they were just collecting your experience as a woman researcher and pairing it up with this.

**Meg:** [00:09:55] I think the paper you're referring to was published just a few years ago in 2012 by some colleagues here at Yale in fact Karen Moss-Racusin was the first author. And let me just set the context. You know there's tons of social science research showing that expectations of women in science are lower than expectations of men simply because if you look at you know who's a scientist out there it's mostly men.

**Meg:** [00:10:19] And that's different from one field to the next but it's in it's particularly bad in physics I have to say if your class is mostly men you subconsciously develop a sense that only men can do this and that women are somehow behind. The problem is when you describe social science to professors of physics or chemistry or biology they object that the experiments haven't been done properly because scientists have been trained to be objective.

**Meg:** [00:10:45] And so we're not like those students in a psych class who were the subjects of the experiment. So my colleagues here at Yale did an experiment on physics professors and chemistry professors and biology professors. They sent a resume around. It wasn't for a faculty job.

**Meg:** [00:10:59] It was for a sort of a lab kind of a lab tech job for someone who's just graduating from college and they asked people if they'd be willing to review

the resume of this person in order to give them some feedback. And they were asked a bunch of questions including would you would you hire this person would you mentor them and what would you offer them for salary.

**Meg:** [00:11:23] Half resumes that went out had a man's name on it and half had a woman's name on it. Those are the only differences and they were sent to both men and women.

**Meg:** [00:11:33] And both men and women in this absolutely mirrors the other the large body of Social Sciences search on resume studies like this that both the women and the men made this gender biased judgment. And these were professors of science who made this judgment.

**Meg:** [00:11:48] And they basically said you know sure we'd hire him and sure we'd mentor him and we'd offer him 30000 thousand dollars a year. But for the one that was the average offer to the man on the average offer to the woman was about twenty six thousand dollars a year and they were less likely to want to hire her and less likely to mentor hers it didn't surprise any of us because we've read that kind of study for many many years.

**Meg:** [00:12:12] And what what was new about it was showing that actual physics and chemistry and biology professors at. By the way six different universities three public the private that professors do exactly the same thing.

**Meg:** [00:12:26] So it's important to know that it's really important to know that we all meet who have these inner expectations which are maybe even generally correct in the sense that most people who do science in universities today are men.

**Meg:** [00:12:41] So it's a fact. Right. But we but we were at the wrong step is to then use that information to infer something about the individual in front of you your student that you're talking to or the prospective employee or of you know a graduate applicant whatever. It's wrong to assume that they fit that mold because they're different right they're new. The research is there it's it's crystal clear that we all have these biases. But I have to say my colleagues are not lining up to take the pledge.

**Bonni:** [00:13:15] One of the things I think is really helpful to consider as people like yourself who have such a passion for teaching. Could you share some of your earlier failures in teaching where you started to figure out. I don't quite have this down yet.

**Bonni:** [00:13:28] Or was it something that always came naturally to you in fact one of the articles I read about you said she was born to teach or something like that. So I wondered Were there any things that kind of shifted your teaching approaches early on or did it all kind of just fit. From the beginning.

**Meg:** [00:13:42] I have enjoyed teaching my entire life and I'm you know I can remember in elementary school helping kids with their math. That was just the common thing. I would finish mine and then go help the other students. It's something I always enjoyed and I think part of it is I can figure out what it is they're not getting which is the key to learning right.

**Meg:** [00:14:02] You have to understand what they're thinking incorrectly in order to change their thinking. When I was teaching I did a lot of wrong stuff when I was a graduate student teaching assistants. I think I did a good job in presenting material sort of but I wasn't receiving the questions. I had kind of a difficult manner at that time.

**Meg:** [00:14:25] I didn't realize how hard these students were working and I did them anyway. I was great at that. And then I didn't teach for many years when I was working at the my previous employer was the Space Telescope Science Institute in Baltimore which runs the Hubble space telescope for NASA NASA. So so I worked there and I didn't teach.

**Meg:** [00:14:42] So when I came to Yale I was you know much tenured full professor but I hadn't taught in 15 years so it was. What did I do. The first year I just did a straight lecture intro physics and you know I worked really hard at it and tried hard to help the students but I realized something was missing.

**Meg:** [00:15:03] And I had earlier years earlier seen talked by Eric Mazur who who who was describing his method of peer teach peer to peer teaching and interactive learning instead of lecture. And when I saw this lecture it must have been in the late 1990s before I came to Yale.

**Meg:** [00:15:20] And it made perfect sense to me. He basically said you're trying to load information into their head and you're doing it in a totally inefficient manner where they have a hard time listening to you and learning anyway.

**Meg:** [00:15:32] Fast forward toward the end of my first semester at Yale I thought you know let me try some of these techniques and I started asking the

students questions instead of telling them answers in. And suddenly we had much more learning happening you could sort of see it in front of you.

**Meg:** [00:15:51] So the following year I started teaching almost exclusively that way I didn't have clickers because we the order was late or I don't remember why they didn't come in time. So I used colored sheets of paper and dependent you know I would have each color correspond to an answer and then people would hold up the sheet that.

**Meg:** [00:16:13] That course find what they thought the right answer was and the idea was that it was sort of you know just to pull the students to see how well they were learning and to get them thinking about the issue. But what happened was.

**Meg:** [00:16:25] Well let me give you the symptom and you should invite with through this semester. The students got slower and slower at holding up their piece of paper but they got more and more accurate. And it took me a few weeks to figure out what was happening.

**Meg:** [00:16:40] It was this classroom full of high achievers was afraid of being wrong. So they would come into class not knowing anything not having prepared for class and not knowing the answers and not having thought about them.

**Meg:** [00:16:53] So they didn't know which was the right answer so they would sort of wait for the person who understood the stuff to put up their piece of paper and then they'd put up the same color.

**Meg:** [00:17:03] So that was that's where I learned that you know they really need and on Nemati the effect to pull them effectively. So those are some of the many many takes I made. But yeah you just try to do better next time when you talk about anonymity are you because you're using clickers today or have you moved onto a different tool at this point to use it.

**Meg:** [00:17:27] The last time I last spring we used an online software that the kids were logging in with their own devices either their laptops or their smartphones that they basically could answer on there. So that was more flexible than the quicker you could have people do things besides just pick multiple choice.

**Meg:** [00:17:47] They could draw vector or indicated direction or something like that. So but it's the same idea right. It's you're asking them to think before you tell them information.

**Bonni:** [00:18:01] The reason I ask is I've been using a tool that I talked about on the show before called Pole everywhere which may be the same one that you're using and.

**Meg:** [00:18:08] You're using learning catalytic. It's like a commercial.

**Bonni:** [00:18:11] Yeah. We've talked about it before on the show. I'll link to that that shows people want to learn more. Right now I've decided to just use the free version from this pool everywhere software and that that both has the advantage or disadvantage depending on your perspective that I don't know who's answering.

**Bonni:** [00:18:27] How they're answering I'm not able to therefore reach out and tell a student Hey I've noticed that you're never able to answer any of these questions they is back on them to reach out for help if they need it.

**Bonni:** [00:18:38] But it does I think reduce a little bit of that fear of failure because I tell him if you don't know just guess I'm never going to know that it's you and no one else is going to know that it's you. And that that helps with the learning process. I wondered if you had any opinions about if you know who they are and if that affects their fear of failure at all.

**Meg:** [00:18:56] Yeah that's a really good question I guess I guess with learning analytics I could figure out who they are although I never did. And part of that's a holdover from when I first did the stuff of the clicker is each clicker has a unique number so you could go figure out who is what. But I promised them I would never check.

**Meg:** [00:19:14] And in fact what I did was my method is to ask to start the class with a question generally get them thinking and then often again following Mazur's approach. If if if it looks like they don't instantly know something I have them talk among themselves and I walk around the room and listen you know I've done this in classes with up to 140 students is my biggest one. So you listen to what the groups are saying and you can you can tell from that what their misconceptions are.

**Meg:** [00:19:48] And I have here's the different part. I have them do a group vote that is they have to come to consensus in the group and then they vote and that vote I actually give some points for. You know I give them I found that if I didn't provide certain incentives people didn't participate.

**Meg:** [00:20:08] So there is a set of students who can get the right answer every time which is useful for their fellow students but they don't actually know how to explain it. And so the best thing for them they thought was just to answer and not engage. Right. They couldn't really explain why they knew the the right answer but they just knew it. But in fact that part of the class that set of students.

**Meg:** [00:20:30] That what they need to do is to explain it to someone else because that is how they will come to understand it better. So I had to create some incentive for them to try to explain it to them or to their fellow group members.

**Meg:** [00:20:45] And that's what this group vote was and that was the only one I promise to look at. That way the individuals not feel under the gun when they give their answer.

**Bonni:** [00:20:54] And is the group vote is part of that. That the group gives an answer but then provides a rationale for their answer collectively as well.

**Meg:** [00:21:02] I haven't done that partly because when they give the answer you know there's not the space for the rest and I occasionally will call on them to ask for an explanation or if someone wants to volunteer.

**Meg:** [00:21:13] And I'm I'm still I'd actually be interested in your opinion. I'm still waffly about that because I you know I see the value in having students saying things and saying right and wrong things even you know that you can sort of parse why it's right or it's wrong. But but the. Emotion they feel when they get it wrong is pretty severe. It's a very negative thing for them and so I just don't know if it's worth exposing them.

**Bonni:** [00:21:42] I always have a hard time with that too. I sometimes joke with my students I was never in sports growing up I took ballet for 11 years in this whole competitive nature where someone has to win and someone else has to lose I'm never very good at and especially that gets amplified when they're in public.

**Bonni:** [00:21:57] And they can be so sensitive to things like that that I never want to be that story of that professor that they say destroyed their confidence in some area or something like that but at the same time I've had students tell me that I excel at being able to say oh that wasn't right but without making a judgment on someone's intellect if I only I could unwind how it is to do that.

**Bonni:** [00:22:17] I think that it's still I do like to hear how they came to their answer. And oftentimes I can find something right in that even though their answer may technically not have been correct their thought process might have gone down paths that had some accuracy in them.

**Meg:** [00:22:36] Yeah. Yeah. I'm right with you. I'd love to be able to do that. Certainly better than I can you know sort of say this just this piece of thinking is right. I mean I save those things but I I think you know maybe it's just especially true of the students who are so smart and so capable but they've excelled their whole life and they don't have big experience with getting things wrong and they know they haven't had many of these get pick yourself up dust yourself off moments.

**Meg:** [00:23:08] So yeah. So it's just is just difficult. And so I try to put things out there that are you know I just try to avoid the personal shame and talk about things collectively. Usually if I'm walking around the room and I can hear them saying wrong things I don't need to get them to say it. I can say I heard a lot of people saying blah blah blah.

**Meg:** [00:23:30] And you know I can try to nudge them say that like for example if they're trying to conserve energy and I say you know I've heard a lot of people talking about conservation of energy and I just want to remind you there's friction in this problem so there's going to be some dissipation of energy so that approach is not appropriate in this problem or something like that to let them see what the wrong approach is and why.

**Meg:** [00:23:54] But without personally attaching it to someone.

**Bonni:** [00:23:57] You've shared some approaches that you used to identify where students mental models may be off they might not have quite grasped whatever it is and you talked about starting a class with a question and having people respond using clickers or a device based polling system.

**Bonni:** [00:24:15] How do we then correct for those inaccurate mental models. How do we then. Because I don't want to put words in your mouth but it's almost

like an and learning process has to happen before the learning can happen. So if I was wrong about it in the first place I have to unlearn the wrongness. That's my technical [chuckles]...

**Meg:** [00:24:33] Yeah yeah. And I think I think the one thing we all can kind of acknowledges that they're not going to get there by you talking at them. It doesn't it just doesn't work. I can give a good example. I used to hate fluids.

**Meg:** [00:24:48] By the way I don't know if they're boring but once you start teaching these questions fluids have the best questions and we will start with some simple ones that they can sort of reasoned out. But I always go to this one problem that usually takes them half an hour to figure out at least maybe sometimes longer than a class.

**Meg:** [00:25:06] So here's the deal I tell them that it is. Well first of all everybody in the class having done the homework the night before if I said to them write down what Archimedes Principle is they would all be able to do it. That it that a body is floating in a fluid is displacing its own weight in that fluid they could all write that down. But they don't understand it. We do have the problem with an ice cube floating in a glass of water.

**Meg:** [00:25:29] And what happens when we do a couple other problems like that and then I say you have a ship in a lock. I have to explain what a lock is. Make sure everybody knows it's an old fashioned technology. But anyway ship is in a lock and the amount of water in that lock weighs less than the ship. This is the ship floating. And 90 percent of them answer no the ship cannot float because there is not enough water in the water.

**Meg:** [00:25:53] And then I say and usually the only time we have a discussion is when things are more 50/50 but it is 90 percent usually they're all right but this one they're always wrong. So I say OK. You have to discuss it. Like what. What. You know. And so they start talking and they're like all over the place and I say to them.

**Meg:** [00:26:11] Well look if a ship were floating in a lake with not a single breeze and no waves let's just idealize a situation and a bunch of frogmen swim up to the boat and construct a wooden box around it that nearly touches the ship but never touches it.

**Meg:** [00:26:27] So there's very little water in the box. Would the ship suddenly sink to the bottom of the box because it can't float because there's not enough

water in there and they'll go. No that's not going to happen. We think you know we can see that but what with him how could this be how could this possibly be true.

**Meg:** [00:26:43] You know whatever. And then I say well why don't you draw a picture and point out to me where is it. What is the volume of the fluid displaced. You know this thing from Archimedes principle you tell me the weight of the displaced what show me where the volume is of that displaced water.

**Meg:** [00:26:59] And when they finally do that by the way this whole take 45 minutes when they draw where the water is not that's the volume that counts right.

**Meg:** [00:27:08] The piece of the ship that's pushed the water out is what counts not the amount of water that's left at the end of that class. Every kid in that class will know what Archimedes principle really means.

**Meg:** [00:27:23] And I think you can only get them to understand stuff when they've had to think about it and sort of reject some possible alternatives. You're constantly trying to refine their thinking so that they start thinking well frankly like physicists do and they can they can you know some of my colleagues I think think that you're born with the talent to be a physicist you know like kind of like a religious calling you're born with a talent.

**Meg:** [00:27:50] And that's what makes a good physics. I just totally disagree. I think everybody can think this way but they haven't always had the opportunity to be taught to think that way.

**Bonni:** [00:28:01] I had a similar thing like this come up although it very much more elementary level. But my students had taken a test on they had to talk about four different types of competition in a capitalistic economy.

**Bonni:** [00:28:13] So there's pure competition. There's a monopoly and so on and so forth. And with a monopoly there were a couple of students not anything massive but a couple of students when they were asked to give an example of a monopoly said a company that sells bottled water.

**Bonni:** [00:28:28] Of course that's not that's monopolistic competition and but one of the things I discovered is that I had used the example of water as a utility coming into their dorm rooms and so their brains had just memorized something that meant nothing to them.

**Bonni:** [00:28:44] Oh water but they don't know why water not any water's going to work in this example of water utility. But what you're describing I blogged about this recently or I'll put a link in the show notes for people who want to explore a little bit more that maybe don't read the blog that much but it is a instructional design principle to not only show students what what is right in a scenario what is correct but also to show what is not right or not correct or in the case of teaching a skill.

**Bonni:** [00:29:14] Yes this is what the skill looks like when it's performed correctly but then we also need to end our learning process. See what that skill looks like when it's not performed correctly and that's where I was a weakness in my teaching I wasn't doing enough of the show examples that won't work as a monopoly or won't work as pure competition and so on to really solidify that.

**Bonni:** [00:29:33] And I as you described I either need to decide that I've tried to cram too much into this class or I really need to dive in and have them have an experience in class where they get to have that where the water is not the same epiphany that you have for your students.

**Meg:** [00:29:48] Real learning takes time and we often don't allow students the time they need to get there.

**Bonni:** [00:29:56] Yeah for sure.

**Bonni:** [00:29:58] Let's talk a little bit more about the problems that you set up at the beginning of class and I wonder is there anything that's happening outside the class that we should know about before we try to put that into practice to wrap our class or at least start our class out with the question. Is it dependent on something haven't happened before they come into the classroom.

**Meg:** [00:30:18] Yeah yeah. Again these are things I did wrong the first time through. You know I realize students coming in to class just had not prepared for class. You know why would you. I'm a last minute person myself. You perform when someone asks you to perform something. So I realized I had to give them a homework assignment.

**Meg:** [00:30:38] Do the same the night before every class so that they would read the chapter and try to think about it a little bit before they came to class so that we were you know instead of reading Shakespeare in class they read it the

night before and we just talk about it. That was my model. The idea of having it be more like discretion.

**Meg:** [00:30:58] But they wouldn't do that without something that would carry the grades so I had to assign a homework was very important that they did online homework because they got an immediate feedback of whether they were on the right track or not.

**Meg:** [00:31:10] So I incorporated that into my teaching and another piece that I didn't get right at the very beginning when I gave them an exam. I went back to the same kinds of exams that all was given with mainly just problem solving.

**Meg:** [00:31:23] And now I realize I'm asking them to understand the concept. That's what we're spending so much of this class time on. I need to ask them those kinds of questions on the exam. So from then on more than always about 50 percent and a bit more actually was concept questions of the type that they were getting in class which is really making them think about the physics and understand it.

**Meg:** [00:31:48] You know one of things Mazur said in his lecture all those many years ago that made such an impression on me. He said you know when he first heard about some other person and talking about concepts that even really good physics students didn't really understand the concept.

**Meg:** [00:32:02] He thought,"Oh I've got Harvard students and they're all doing really well in my class and you know I'll just throw in a couple of these concepts questions in my next exam and see how they do." And they did miserably. Now things like there's there's a good one where you have a truck a big heavy truck collide with a small you know like a Fiat 500 or something.

**Meg:** [00:32:23] And you ask what happens to the momentum of the car and you can you know when you have a collision momentum is conserved so whatever momentum one of the vehicles loses the other one has to gain whatever. So you you but you ask them and everybody's intuition is that the little car gets smushed and so the big car killed it. And so.

**Meg:** [00:32:47] You know they they have the wrong ideas in their head. So it's really important to to test for that because that then that's what students are trained to learn and they don't learn unless they've really thought about it.

**Bonni:** [00:33:01] I wonder if the example you just used and get I have the world's most elementary understanding of this is one of those because I have experienced that in real life I've seen it happen then I have to unlearn what my own mental model was of why that occurred and then what the results were. Before I could actually then apply this new learning that you are teaching me. Does that sound right in that scenario.

**Meg:** [00:33:27] Yes that sounds exactly right. And it's tricky right because because in principle everything you experienced up to now is governed by the same laws of physics that I'm trying to teach you. But the fact is that when you experience that when you learn it you feel it differently.

**Meg:** [00:33:44] And if you don't help people see why their intuition is not correct then they'll never get it. You know they'll never understand what's really happening here.

**Bonni:** [00:33:53] Is there anything I haven't asked you about that you want to share about reshaping students mental models helping them grasp complex information before we go on to the recommendation segment.

**Meg:** [00:34:03] I don't want to make you run long but I was talking to a colleague of mine recently who was teaching intro class.

**Meg:** [00:34:09] And you know he's a great teacher or a really charismatic and I'm sure he's wonderful lecturer but he was trying to tell his students things before they were in a state prepared to listen. And they're good students so they look like they're listening they're taking notes and you know paying attention.

**Meg:** [00:34:26] But but you have to make them care about what you're saying before you say it or they're not going to hear you. And that's such a key thing you have to open up their brain before you try to force feed the information in there.

**Bonni:** [00:34:41] What would be ways that you do that beyond I know you said you start every class with a question but what are some other techniques to used to help students care about what you're saying.

**Meg:** [00:34:50] Well one thing I've had added in recent years is I have them do problems in class so you know the classic physics homework or exam or whatever is you're given a word problem and you need to figure out what

principle applies and what equation corresponds to that principal and then you know what variables you need. So you need to solve a world problem.

**Meg:** [00:35:11] And so I'll give them one to do what I find is the students who are under confident and unsure of what they understand. Just kind of look at the blank page and don't know what to do. That moment where they don't know what to do is a perfect teaching moment. Really it's a moment when they might listen to what you say.

**Meg:** [00:35:32] So I in fact have a very prescriptive checklist for how to solve problems with about 10 steps starting with don't panic and step two is draw a picture always draw a picture of the situation you're being asked to address and then what I hope with. It's not that I think prescriptions are necessary.

**Meg:** [00:35:50] That is I don't think you have to do this to solve a problem but just that when you have that blank page feeling where you're staring at the page and nothing is happening and no inspiration is coming this checklist gives you stuff to do that will walk you toward the right approach.

**Meg:** [00:36:07] So draw a picture figure out what the principle is that you're supposed to be applying. Is this a conservation of energy problem. What are hints for white. That's a case where there's no friction and where it's too complicated to calculate the way.

**Meg:** [00:36:21] Or maybe it's you know Newton's second law if he gives them a situation where you need to draw some forces so you know I try to get them. It's like it's like running a race.

**Meg:** [00:36:33] You just try to get them used to running right used to doing things and gearing up to do things properly and eventually I think it's going to click and they're going to find it's easy to do.

**Bonni:** [00:36:45] This is the point in the show at which we do recommendations and I'm going to do mine quickly and that is that it's a musical one but it's not a musical. Since I know I've been doing a few musical ones lately it is less about the song and more about the title. This is a song from David Wilcox and it's called Leave it like it is and they need to share about coming home.

**Bonni:** [00:37:06] Well actually it started with a text message from my husband that said I just want to let you know that our son he'll remain nameless but he's our only son to figure it out. He had scaled the baby gate wall that goes up to

my office on the third floor of our home and had decided he was going to get out my craft paint yesterday and just painted like nobody's business.

**Bonni:** [00:37:28] The banister and the wall had handprints. Apparently he had painted himself to his face for my project table my desk my keyboard. In fact I'll actually take a picture of the keyboard and put it in the show notes because people just need to have a visual for what those was like.

**Bonni:** [00:37:44] And the first thing I thought of because not only did my husband mostly obviously is concerned about my office but was also concerned about the poor young woman who takes care of our kids a few days a week and her just reaction to devastation of feeling like she had broke our house and we don't own anything that can't be broken and you know we just don't like clinging to things that tightly.

**Bonni:** [00:38:06] So I sent her the link to this song called leave it like it is and the lyrics talk about a paint jar tipped off the table you watched it as it started to fall. Glass popped shattered and splattered and paint spray hit the wall bright blue glassy enamel across the kitchen floor. You said Good God look at that pattern. I've never seen that before. Leave it like it is. Never mind the turpentine. Leave it like it is. It's fine.

**Bonni:** [00:38:35] And it reminded me a bit of our teaching that sometimes things aren't going to go like we planned. And students are going to struggle when we've talked about that in past episodes. And I think a good phrase for me to remember especially at this point in the semester leave it like it is that is my recommendation.

**Bonni:** [00:38:51] Great one. That's a great one. And just as a mom can I say make sure those handprints on the wall they had already cleaned the .

**Bonni:** [00:39:00] I have a picture is all I have. But they were precious. They were just two on a blue wall a little bit lighter blue just kind of going down almost like he was sliding down. Thank you and I know you have a recommendation for people listening to.

**Meg:** [00:39:16] Yeah yeah I'd like to recommend a book. Well The Only Woman in the Room just published by Eileen Pollack a woman who I met in 2010 when she visited Yale I was the department chair of physics at the time. And Eileen who had graduated in 1978.

**Meg:** [00:39:34] She's in one of the first classes where women actually had been admitted to Yale. And she and her classmate were the first two women ever to major in physics at Yale University. She came to visit to finish a memoir that was about her lifelong desire to be a theoretical physicist and how basically it was beaten her in college she was just so discouraged that the end of four years here that she gave up that dream and became a writer.

**Meg:** [00:39:58] Now I have to tell you she's just a fabulous fabulous writer so I'm kind of glad she didn't do theoretical physics she's actually made you know so many. This book is a gift. This book is a gift to anyone who who is or who knows someone who is a minority in science. It explains how it feels to be the only one and how isolated you are and how much harder it is to do your problem sets because you're doing it by yourself while the boys are down the hall doing it in a group. When I read this book she sent me a draft. After early on I was just blown away and I thought I have to I have to tell people they have to read this book.

**Meg:** [00:40:38] Especially young women who might think you know it's 2015. Gender discrimination is a thing in the past it doesn't happen but there and after a few years of studying physics they're sitting around thinking they they aren't good enough for it in fact not two days ago I got an email from a colleague at another university who has three physics majors two women one man and they're doing equally well you know they're getting the same grades are the women I do be doing a little bit better. But the guy thinks he's facing the class and the two women think they're too terrible at it and they should quit.

**Meg:** [00:41:14] So you know this is happening today and people need to know about it and understand that you know that it's going to affect your experience and you need to inoculate yourself against that stuff.

**Bonni:** [00:41:31] Thank you so much for the recommendation and I am absolutely so thankful to Edward O'Neill who introduced us via e-mail and said you would be a great guest for the show and you have lived up to his promise and more I just really appreciate your time.

**Meg:** [00:41:44] I was delighted to talk to you I'm definitely listening. I listen to your podcast now when I go when I'm walking and it's really I'm learning a lot. Thank you.

**Bonni:** [00:41:51] All right. It's been so great having Dr. Meg Urry on the show and I'm just so excited about some of the guests we have coming down the line. I hope you'll keep on listening.

**Bonni:** [00:42:02] And as always if you have suggestions for the show you can do that at teachinginhighered.com/feedback I've been getting some wonderful messages from people with great ideas and encouragement to keep me going. Speaking of keeping me going.

**Bonni:** [00:42:16] I love when you can pass on word about the show to your colleagues and people that have a passion for teaching. And another great way to do that is by considering writing a radion or a review on whatever service it is that you use to listen to the show such as going to teachinginhighered.com/iTunes and you can write a review there.

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