Using Spatial Reasoning Skills to Boost Female Retention by 42% in One Semester

Host: Donna Milgram, Executive Director, Institute for Women in Trades, Technology & Science

Presenter: Dr. Sheryl Sorby, Professor of Teaching and Learning, Ohio State University

Interview Transcript:

Donna: Hello and welcome. My name is Donna Milgram, Executive Director of the Institute for Women in Trades, Technology and Science. I'm so excited to welcome you to this session of the *STEM Success for Women Telesummit* funded by the National Science Foundation. We have an interview with a very special guest.

Dr. Sheryl Sorby is a professor of teaching and learning in the Engineering, Education and Innovation Center at the Ohio State University and she's Professor Emerita of Mechanical Engineering and Engineering Mechanics at Michigan Technological University. She recently served as program director within the Division of Undergraduate Education at the National Science Foundation. She began her academic career on the faculty of Michigan Tech in 1986. Dr. Sorby is a former associate dean for Academic Programs in the College of Engineering and the former department chair of Engineering Fundamentals at Michigan Tech. She's been the principal investigator and co-principal investigator on more than $7 million in external funding for educational projects most for the National Science Foundation. She's the author of numerous publications and also several textbooks.

She currently serves as an associate editor for the American Society for Engineering Education's new online journal *Advances in Engineering Education*. Dr. Sorby is the international expert on boosting spatial reasoning skills in female STEM students to improve retention. I jokingly tell everyone that I'm the head of the Dr. Sheryl Sorby fan club but I think I really am. So welcome, Dr. Sheryl Sorby.

Sheryl: Hi Donna. It's nice to be here.

Donna: So Sheryl, I was so excited when I first learned of your work I think over 15 years ago now. I saw that female students who had gone through your short spatial skills course were retained at a rate of 77% in engineering design compared to 48% of the women who didn't take the course, a 29% difference. This was a short course. I realized that many of us who were working to support women in engineering could do more by teaching spatial reasoning than providing traditional support services to improve retention.

I'm so glad your work has now become mainstream and there's even a video interview of you on the U.S. Department of Education's website. I so appreciate the work you've done to improve retention of female students in engineering through spatial reasoning. I think what we should do is have you start off describing what spatial reasoning is and why it's so important to engineering and perhaps other STEM career pathways as well.

Sheryl: Okay. Well, I think if you look in the literature that spatial skills have been important to pretty much everyone who's in STEM and there's lots of stuff out there that shows there's a correlation between being active in STEM or majoring in STEM or being even a professional in STEM and having really well-developed spatial skills. Some of the research also has shown though there's a strong, strong link between spatial skills and your ability to solve mathematics problems. I think since mathematics is kind of the foundation of all STEM, it stands to reason that if you want to be successful in STEM or in mathematics, you have to have good spatial skills. For example, people have found that spatial skills are important for success in doing story problems for children. It's important for number sense and measurement concepts.

I recently was on a PhD committee where they used EEG to look at brain activity in people who were solving mathematics problems. They gave three types of problems. One type was kind of an analytical type of problem, one was a visual type of problem and the third time was a problem that could be solved either analytically or through visualization. What they found is that for that last class of problems where you have a choice, the people who thought about the problem visually actually got the problem correct more often than the people who thought about it analytically.

So there's a very strong link between spatial skills and mathematics. I think if you think about engineering or some of the other technical trades, engineers are designing things. They have to fit things in. They have to fit all the components of the engine inside the car hood. All of that takes some kind of spatial ability to think about how things fit together, how things work together. So like I said, there's tons of stuff in the literature that shows that spatial skills are important to success in STEM.

Donna: What I'm hearing is not just engineering but other types of STEM areas and you gave actually auto technology as an example. Would this be true in other career pathways as well?

Sheryl: Oh yeah, I think anything that has to do with STEM. So even an HVAC technician who's thinking about how duct work goes through a building or somebody who's thinking about wiring something and how do you fish that wire into that right spot and how do you go around obstacles — those are all kinds of spatial tasks. Some of the recent research also is showing a strong link between spatial skills and your ability to learn how to program like computer science type programming and also a link between creativity and technical innovation and spatial skills. So there are all kinds of stuff out there if you look in the literature that shows how important spatial skills are for success in pretty much all STEM fields.

Donna: Interesting. Computer programming is one of them, interesting. So given that these spatial reasoning skills correlate with more success in all of these STEM areas and also in innovation as you described, could you talk about the research that shows – and I know you've done some of it yourself – that female students overall have less spatial reasoning skills and why that might be?

Sheryl: Well, I think we need to make a distinction between spatial skills in general and mental rotation specifically. Mental rotation is a specific type of spatial skill and there are many. Again, if you look in the literature, there are lots of different types. A lot of times on the other types of spatial skills, there are no gender differences but the gender differences are really pronounced on the mental rotation ability. So that's really where you find women at a disadvantage.

For a program like engineering, they've shown that mental rotation is the most important one to be successful in engineering. I don't know exactly why there are gender differences. I think personally, what I believe is that it's an interaction between some kind of biological factors and the environment that –

it's the nature versus nurture. I think it's both. There's research out there that shows that spatial skills are linked to male hormones.

There's also research out there that shows that – or that some people believe — it has to do with evolution and how we evolved as hunters and gatherers that the gatherers really were confined and they knew their own space around them very well. This is why the standard joke is like if you want to know where something is, ask your mom because she knows where everything is in the house. The hunters, they might be pursuing prey and then they had to be able to find their way back home. So they had this bigger kind of spatial awareness built in through evolution.

Some of the things what we've found and what other people have found is that there is a lot of the nurture in this, too. The types of toys that children will play with to improve their spatial skills are things like LEGOs, taking a shop class in middle school, doing those kinds of things, taking apart a car and putting it back together. Those are the types of things that help children develop their 3D spatial skills and these are the kinds of things that typically girls don't do. So I think it's actually a combination between the nature and the nurture in terms of why women tend to have lower mental rotation ability. But I don't think there's any definitive study that says, "Oh this is exactly the reason why."

Donna: Sure. So, what I'm hearing you say is that you believe it's a combination of those who believe female versus male brain and, of course, there's research on this and then also the nurture part. We have in our proven practices collection on our website, iwitts.org, two of your studies. One is actually a presentation. I know in your research that you did jointly with Brazil that it was between a university here in the U.S. and Brazil. You said there was statistically significant differences that showed playing with building block toys and doing drafting correlated with having higher scores on spatial reasoning. So I know that you've done some of the research on the nurture side yourself.

Of course, I know also that from your work which I've been teaching about in our WomenTech Educators Training for quite a few years now, I think for like 15 years, that in a very short time you're able to teach these spatial reasoning skills and make a huge difference in female retention. I wonder if you could maybe just talk about what kinds of numbers and differences. I mentioned one study of yours. I think it was the initial study that you did. I don't know if you've got other numbers since this time but could you maybe talk about the difference your work has made in terms of teaching spatial reasoning?

Sheryl: Yeah, so we've been looking at data for more than 20 years now in terms of the impact of the spatial skills training on student success and also in particular, the success of women. We just gathered some data recently. The study you're talking about where the difference was 77% to 48%, some people would criticize that study because those students were largely self-selected. They chose to go into the spatial skills course. So a lot of people would say that that's not as scientifically valid as a different kind of study.

But we recently looked at some data. At Michigan Tech now, they're requiring the spatial skills course for anybody who comes in with weak spatial skills. So now, there's no self-selection. So if you come in and you test poorly on the diagnostic test, you automatically are enrolled in the spatial skills class and you can't get out of it. We compared the performance of those girls – actually all of those students — the ones who came in with weak spatial skills and were required to go into the course and then we compared them now to the people who came in with kind of marginal skills. So they passed the test but they barely passed the test. They got like maybe a 65% or 66% on the test.

We're still finding a 20% difference in retention for those students. So it's like 80% versus 60% retention at the University and it's 60-some% versus 38% within engineering. So we're still finding these huge and significant differences even when we remove the self-selection factor. I think there is something to it other than just that helping these people, especially the young women, develop their spatial skills. We're really helping them to be successful in engineering.

Donna: So can you describe how many hours go into that mandatory course at Michigan Technological University so that our listeners can have a sense about how long this is? How much time does it take of the student's schedule?

Sheryl: So at Michigan Tech – I should give a plug for Ohio State because we offer the course here as well but most of the places around the country that are now offering this course offer it pretty much as a one-credit course. It's not an hour a week. It's an hour-and-a-half just because there are a lot of hands-on activities. It's more like a lab than it is a lecture. So we spend about an hour-and-a-half a week. There are ten modules.

We have done this over an entire semester. At Michigan Tech, they do it over an entire semester where they have some days built into the schedule for quizzes and things like that. Here at Ohio State, they just do it one day a week for ten weeks and then they're done. Other places are doing it two days a week for five weeks and getting it done at the beginning of the semester. Basically, it's about 15 to 20 hours of instruction total. It seems to have a huge impact even though to me it seems like a very small investment to have a big impact.

Donna: 15 to 20 teaching contact hours is what you're telling me. I realize that I have some older data from you in which we were talking about 12 hours. So we may have over-represented that but I still think only 15 to 20 teaching contact hours is a pretty small investment for a 20% improvement on retention when there's no self-selection involved. How many hours of homework do the students do beyond those 15 to 20 hours in the classroom?

Sheryl: Well, usually there's no homework. The way that we have done this in the past is we assign workbook pages during the class. The class session is about an hour-and-a-half long. If the student stays for the whole hour-and-a-half, they hardly ever have any homework but if they decide they want to leave early for whatever reason, then they might have a little bit of homework. I should say that most of the students that take the class enjoy it. I've had students tell me this is their favorite class because they're not thinking about integrating or taking derivatives. They just come in and they're doing these exercises. There's a lot of sketching in the class so they're drawing pictures and stuff. So most of them really enjoy the time spent doing this. Once they're in it, they enjoy it.

Donna: So how many of the students that are taking this after they take the assessment test — which we'll talk about in a minute — are male? What kind of improved retention is there for male students?

Sheryl: Well, engineering is a male-dominated field as I'm sure you and your listeners know but women are about three times more likely to have problems with spatial skills than men. So what happens is that in the spatial skills class, it ends up being about 50/50. Women are failing the test at three times the rate of men. So there is probably about 30% or a third of the women are failing the test and about 10% of the men. But because of the gender imbalance in the field, the class ends up being much more gender balanced than any other engineering class out there.

So we end up, like I said, with 50/50. There are some male students who also have weak spatial skills. We find differences for them too but they're not as dramatic. Instead of a 20% difference in retention, now we're looking at a 7% or 8% difference in retention. So we are helping the male students as well. It's just that the difference for the females is very dramatic. I think that has to do with what's called self-efficacy.

If a woman is in a typical first-year engineering class or a typical STEM class and she looks around there's like three women and 50 men, then she already feels like, "Well, maybe I don't belong here. Maybe this really isn't for me." Then when she starts struggling because of bad spatial skills in that class, then she's more likely to say, "Oh yeah, I'm right; I don't belong here," and leave. Whereas men, when they come in with poor spatial skills, they're not already feeling like they don't belong. So it doesn't impact them as much.

Donna: Sure. Sure. Now have you looked at the impact on underrepresented minority groups? Because I understand, again, looking at the nurture part of it that some of them have also not had the same kind of informal learning experiences or the same opportunities as females so that they may also have a difference in terms of spatial reasoning skills on the nurture side. Has that been something that's been looked at or have you seen any literature on that?

Sheryl: Yeah. Most of the research in this area is not really about race and ethnicity. It's about socioeconomic status. So what they've found is that students from low SES groups, the ones that didn't have the advantages growing up they generally have much weaker spatial skills than the people who came from high SES groups. It could be that they don't have access to the kinds of toys; they don't have the same kinds of educational opportunities. I'm not sure they know exactly why but it seems to hold true that people from low SES groups have very weak spatial skills. In some studies, the SES differences are stronger than the gender differences. So they're much more robust.

At Michigan Tech, we did some data analysis and for some of the minority groups, we did see huge differences between, say, the majority students and the minority students in terms of their spatial skills but we didn't look at whether or not that was an SES thing or anything like that. I'd hate to say that it's related to race. I think it's actually more related to your upbringing and your socioeconomic status. Now, we have not looked at the data and that's probably one of the next steps. We've got more than 20 years worth of data and so we keep going back and mining it and trying to figure out what's going on. So yeah, I believe it would help the students from those low SES groups but I haven't looked at that specifically.

Donna: Not yet.

Sheryl: Yeah, not yet. We also have found though that some of the students coming from some foreign countries seem to be at a big disadvantage in terms of spatial skills. We think that that's mostly because of differences in education systems. So in places where they really stress rote learning above problem-solving and projects, those places tend to produce students who come to our universities with very low spatial skills.

Donna: I know that you haven't yet done a study where you have given the treatment of your 15- to 20-hour spatial reasoning course to the lower socioeconomic students, but it does seem quite possible in view of the fact that it also helps these male students as well as female students – so not as high percentage – that really this 15- to 20-hour spatial reasoning course could make all the difference,

considering that there's such a high dropout and transfer out rate in STEM. Disproportionately for women but also for the many other STEM students that are not retained. I mean that is amazing. Why is this such a well-kept secret?

We've been teaching this for over 15 years in our WomenTech Educators Training and I always ask people, "Raise your hand if you've heard about this research and that there's a course, off-the-shelf course that's going to make sure that you talk about that you could utilize to teach this?" Very few hands go up all these years, still today. So why do you think that is?

Sheryl: Well I think there are a few things at play. One is that I've been looking at some of the earlier literature lately and apparently in the '50s or '60s – I can't remember this person's name but he was a well-known psychologist. He basically published this article saying that spatial skills are a fixed quantity and they can't be learned. So you either have them or you don't and if you don't have them, there's nothing you can do about it. Now, there's been lots of research including my own work that shows that that's absolutely false, that spatial skills can be learned.

I think though that this early article by this person, this renowned psychologist kind of made people think about spatial skills differently. But I think another part of the problem in my mind is just the fact that this is not something that's formally taught. We all just assume that you're either going to get it or – somehow you're going to get this. Somehow you're going to figure this out as you age. A lot of people do.

So at Michigan Tech, we have about 10% of the males and about 25 to 30% of the females failing the test. So that means that 90% of the males and 75% of the females got it somehow before they went to university. So I think we just kind of rely on the fact that people are going to develop these and we've never actually done this kind of formal training for people in the K-12 system to make sure that they have good spatial skills when they graduate and go onto the university.

Donna: Wow. When you consider how these skills correlate with success in STEM it seems to me – of course I'm biased here; I'm head of your fan club – that this should be aggressively promoted by all of those of us who care so much about increasing the success of a diverse STEM workforce because it seems to be a really critical factor. So I want to shout from all the rooftops about this. Wow, okay. Let's go back because you keep talking about a test and assessment. I'm sure that our listeners are wondering what test and what assessment they should be giving their students to determine if they would need a spatial reasoning course like the one you've described. So could you talk a little bit about that?

Sheryl: Yeah. So the test we use is called the Produce Spatial Visualization Test Rotations. It's a 30-item test. It takes about 20 minutes for the students to complete it. The test is designed to assess a person's ability to mentally rotate an object in space. Earlier, I was talking about the fact that mental rotation skills are really important to success in engineering. Then this is one of those tests that will measure that. There are other spatial tests in the world. So there's another one called the Mental Rotation Test. I'm most familiar with the Purdue test because that's the one I've used but there are other ones that are out there.

Donna: Okay. Now the Purdue test which takes about 20 minutes for students to take how would educators get access to use of this test and can they also get access to an online version that their students could take?

Sheryl: Yes. One of the original authors of the test – his name is George Bodner, B-O-D-N-E-R – he's an emeritus professor at Purdue but I think he still has a Purdue email address. So you could email him and ask him for a copy. Then ETS, the Educational Technology Services for $25.00 I think they will send you a PDF of the test. Then there's another organization called EngageEngineering.org – all one word, EngageEngineering.org – and they have access to the test there that can be used in an LMS system. So there are a number of ways to get a hold of the test. It's pretty much free or $25.00 if you go through ETS. But yeah, that's how I would recommend getting a hold of it.

Donna: Okay. Because from what I understand that the way you've convinced students to take the spatial reasoning course is by taking the test and seeing they're not doing well. I wonder if you could just talk about the whole idea of convincing students that they need to do this. I know having attended a conference presentation of yours at ASEE in Vancouver with some of the colleges that were using this test that some colleges make it mandatory, some colleges strongly recommend it and train their counselors, other colleges – it's a variety of things. So I'm sure our listeners are thinking, "Well how do we get our students to take the test in the first place?" Can you just describe how that has sort of played itself out with the schools you've worked with?

Sheryl: Yeah, well at the university level, what we've done is we've worked with colleges of engineering and during the summer before the first fall semester that the students are enrolled, they send them an email and some of them actually require them to take it but most of them have like this very strongly worded email, "Click this link and take this test because this is going to help us diagnose whether you need this extra help." Now I've got a current project with some community colleges and they included taking the test as a homework assignment in one of their classes. So the students go to campus and they were told, "Okay, here's your first assignment; you have to go and take this test for 20 minutes." So there have been various ways of getting the students to take the test.

At Michigan Tech, they do it at orientation. When they come to the university one of the first days of the orientation week, all the engineering students go and take this test. So I think there's various ways that you can get students to take the test in order to diagnose whether or not they have poor spatial skills.

Donna: It would seem to me it would be important in bridge courses that – like a summer bridge course, etc. – to incorporate the assessment of spatial skills and to incorporate your mini-course into like a summer bridge program. Like the one I was talking about yesterday with Lily Gossage who is at Cal Poly Pomona and has a program that's both for underrepresented minorities and also females. That seems to me like that would be a good place to also have that. Of course, from my viewpoint, I wish all schools would make this a part of the fabric of what they do to potentially help ensure support in success of all students in STEM. I don't know if you know of any examples in bridge courses, if it's being used that way.

Sheryl: Yeah. You know I think there were a few. So the Engage Engineering project was a multi-year project that WEPAN headed up and it was aimed at getting universities to adopt research-proven strategies to improve retention of engineering students. One of the research-proven strategies was the spatial skills intervention. Through that project, there were probably 30 or more universities involved who did some kind of spatial skills instruction and there were some who did some spatial skills training in their bridge programs.

I can't remember the names of those off the top of my head but yes, there were some who tried it as part of a bridge program. I know I have colleagues at Penn State Erie for a number of years they had spatial skills training as part of their summer bridge program. The person who did that is now retired so

I'm not positive they're still doing it there but I know that they did it there for a while. I know that they were doing this in the College of Technology at Purdue for a while but I'm not sure that they're still doing it. But yeah, I think it's a viable topic to include in a bridge course.

Donna: Now you mentioned that you're doing work with two-year colleges. Is there any differences? Many of our listeners are from two-year colleges. Is there anything different for two-year colleges that you're seeing from four-year colleges? So far, I think this is a relatively new project you're working on.

Sheryl: Yeah. Some of the differences are that the two-year colleges tend to have much higher failure rates on the Purdue test then you would find at a place like Michigan Tech or Ohio State. I think that's just a function of the students who are going to community colleges, right? Typically there are more women and also more people from lower SES groups who start out their educations at a community college. You would expect them to have higher failure rates. So I think that in some cases what could be done is that if a community college wanted to test their students and find out whether or not they have a problem with spatial skills among their students, then they could incorporate spatial skills as part of a regular class.

Typically, a lot of these two-year programs will have some kind of a class on engineering graphics. Well what we've found is that the typical engineering graphics course is too advanced for many of these students who have poor spatial skills. So instead of just going right into the engineering graphics what some people have done – I had a colleague at Virginia State University and she had students who had very weak spatial skills. So she just took the spatial skills intervention and put that as the first few weeks of her course and then she moved into the graphics. So she ended up doing a little bit less in the graphics but they actually understood it better because they had their spatial skills kind of figured out by the time they got to the harder engineering graphics problems.

Donna: Well actually that is my preferred way of incorporating building block skills that I've identified female students overall have less of — and spatial reasoning being one of them — is putting it up front in the beginning of the course to ensure that everybody gets it. So that is interesting. I think your work, teaching spatial reasoning becomes even more important at the two-year college level. I know that there's less research on the two-year college level. I'm so glad that you're doing that research now because it seems like it would be even more important at the two-year college level.

Sheryl: Yeah. Oh I was going to say one of the problems at a two-year college that we're running into with this study is this. Students come into engineering and the first semester, they take XYZ classes and the second semester they take ABC classes. Community college students are much more fluid in terms of which classes they take and when they take them. They might be full time, they might be part time, and they might have a job. So it's harder to kind of fit this in. In engineering, it's a little easier because it's a very strict and regimented curriculum. Most of the students are residential; in a community college, you don't have that. So the project that we have with the community college students is actually to take the course and turn it into an online course so that students at a community college in particular could more readily take the class.

Donna: I remember that you actually worked with one of the colleges we were working with in our CalWomenTech Project, Cañada College. You were so generous to donate some of your time to help with that. It totally makes sense in a commuter college as two-year colleges are to have an online version of it. So that's pretty exciting and important to keep in mind as we look at how to ensure that students are getting these skills. Now I'm wondering for listeners who we've convinced that they should

incorporate this into their courses or programs or colleges, they're probably wondering, "What exactly do you teach and who should be teaching it, what type of instructor? Would it be an engineering instructor only, engineering professor or – and is there anything off-the-shelf so to speak to guide them in teaching the course or anything for the students?"

Sheryl: In one of my previous grants, we developed some software and a workbook and that's primarily what we use to teach the class. There are ten modules and basically, we go through them. The one thing that we've found is particularly beneficial for the students in terms of developing their spatial skills is doing sketching exercises. There are a number of sketching exercises in the workbook. We also have found that using handheld manipulatives are very important for people to develop their spatial skills.

We recommend using blocks to build things and then the students can turn them and look at them from different angles and see what they look like and try to then put what they're seeing down on paper. So those are the kinds of things that we've found have been really helpful in developing spatial skills. So we have worked with this Engage Engineering project and they do have a website that has a lot of resources. Typically, in our classes what we do is we have like maybe a five- or ten-minute lecture at the beginning of the class to introduce the topic and then we have the students work through the software module. The software module is kind of a repeat of the mini-lecture is but it's in more detailed and it's got better graphics.

It's got animation so you can see a cutting plane coming in, slicing through an object or something like that. Then we just have them work on the workbook pages. It's actually pretty simple. I always tell people it's really not rocket science. It's pretty simple.

We've had lots of different people teach it. We've had graduate students teach it. We've had engineering faculty teach it. We've had high school teachers and middle school teachers who have no engineering background teach it. Once they get the training with the software and workbook, they're able to go and teach it to their students. You don't have to be a Ph.D. in engineering to teach this stuff. Like I said, it's not really rocket science. It's actually pretty simple. I think what we're doing is we're giving people a chance to exercise this part of their brain that they've never exercised before. I think that's what the difference is.

Donna: So where would they actually go for the ten modules, the teacher guidebook? I know we have actually a link to it on our website, www.iwitts.org if you go to projects in the meta-menu and you browse down to our Learning Library. We have several sections including spatial reasoning and there is a link to your teacher's guidebook which I think you have to be an education institution to purchase. Then I think the student version you can also get on Amazon. But you may have your own favorite places that folks can purchase because you have to purchase these things. Is Engage the best way for both of these things or do you have a separate kind of way? You have both the student resources and the teacher guide.

Sheryl: Starting in 2002, the software and workbook were published by Cengage Learning. They're still available through Cengage Learning. However, last fall due to reasons too long to go into right now, the rights for the software and workbook were reverted to me. So I'm in the process of building a website and I will be selling this as soon as I can get everything going, probably sometime in the summer. So for now I think the best place is either to look at what you have on your website or to go to the Engage Engineering site. I think that the Engage Engineering site eventually will have a link to my company website so that people if they went to Engage Engineering they could get to the materials that way.

Donna: Well we'd like to do that as well.

Sheryl: Okay.

Donna: The other thing I want to mention for our listeners, I mentioned it earlier but I just want to repeat that if you go to our Proven Practices Collection of primarily academic articles that we've gotten permission to use and also some case studies you will find two holdings from Dr. Sheryl Sorby. That would be another good place to take a look at the research.

So I'm seeing that we do have a few questions. I am wondering so that we have time to go to the questions if sort of in closing, if you had any advice for educators that want to incorporate these spatial reasoning skills into their schools or programs or classes.

Sheryl: Well, I think the first piece of advice is to get a hold of the Purdue test and just test your students. Maybe you don't have a problem. Maybe your students are all brilliant and you don't have a need for it. I'm guessing that that's not going to happen but you should try. You should see.

I think one of the things that happened through the Engage project is I think a lot of people were really surprised when they looked at their test results. There was one kind of elite private university and they thought, "Our students aren't going to have spatial skills problems." They tested them and, oh yeah, they did find out that they have – it's not everybody. It's just at that particular institution, it's this small group of students, primarily women, who have the problem. Like I said, I think at community colleges though it's going to be a larger problem for you, for community colleges just from terms of the students that you're attracting to your programs.

So I think also what I tell people is that why I think this was never done before within engineering is that if you think about most engineering faculty, they've got advanced degrees in engineering. They probably have really well-developed spatial skills. Most of them if you talk to them, they can't conceive of the fact that somebody can't see something. They can't conceive of the fact that somebody doesn't have this skill because it's so obvious to them.

The other thing is they don't ever remember learning it. So they might remember learning math or they might remember learning grammar but they don't remember how they learned to think spatially. So I think a lot of the people we've worked with so far who have been mostly engineering graphics teachers or intro engineering teachers they were actually pretty shocked to see that, "Oh yeah, there is this group of students who really is struggling in my class and it's probably because they have poor spatial skills." So I would think the first thing you'd want to do is test your students, see how they're doing and then if you do have a large percentage of your students who are struggling with your spatial skills, then I would just look at your curriculum and say, "Well maybe this engineering graphics course that we're teaching we're starting out too advanced for most of our students because they're coming in with poor spatial skills." Maybe revise your curriculum to include this or think about trying to do it as a special extra class.

I would caution people though that a number of people in Engage and other places have said, "Well, we don't want to put in place a one-credit class. We're just going to do this as voluntary help sessions." Typically, what happens is nobody shows up to the voluntary help sessions. If your thought is that you want to do this as voluntary help sessions, you'll be wasting your time. You have to somehow make it a meaningful experience for the students. What I mean by meaningful is that it has to be somehow for

credit, either part of an existing for credit class or a separate for credit class. But the voluntary help sessions that never works.

Donna: Good to know. Okay, so let's go to our questions. I see one from Susan Christenson in Spokane Valley. She says, "This question relates to high school level courses. Do you think there would be a benefit to incorporating a spatial reasoning pre-assessment and related skill developed activities directly into high school level engineering, computer science, auto classes, etc.?" Good question.

Sheryl: Yeah. I'm actually in the process of trying to get that project funded. We have worked with high schools and middle schools. We've used the same materials I use in my one-credit course with seventh-grade students and they have absolutely no trouble learning from them. So like I keep saying, it's not rocket science. It's really kind of basic stuff.

I think that if I was doing this at the high school level though, I probably wouldn't do the testing to identify students because I would just do it for all the students. My data shows in previous studies I've done that the students will kind of develop these skills as they age. So typically, if you're starting out with ninth or tenth graders, they probably are all about the same place. You'll probably see some gender differences but the guys aren't that great at that point in time. If I was going to do this in a high school engineering course, I would just do it for everybody and not worry about testing them to identify those who need the help.

Donna: Okay. So next question is from Christina in California. "Should we as educators be telling women and girls that spatial relation skills are important and if we do, can they improve spatial relation skills on their own if we point them towards resources?"

Sheryl: Yeah. In my personal teaching of this stuff, I don't usually tell the girls, "Oh you're at a disadvantage when it comes to spatial skills," just because of this thing called stereotype threat. Say you had a group of young women that you were with, you could say, "This is something that's important to success in STEM and you could help develop your spatial skills." The kinds of things that will help are things like actually playing some of the 3D computer games although many of those aren't very appealing to young women. Those will help.

Things like putting together. I would say go buy some furniture at IKEA and you get this box full of parts and you get this little diagram and you have to figure out how to put it together. That will help you build your spatial skills, putting things together like that. What we found is that sketching objects helps. When I say sketching, I'm not talking about the kind of creative sketching that an artist might do. I'm talking about what is called representational sketching.

You actually have an object that you're trying to put on a piece of paper. You're not just making some kind of fancy doodle or shape. You've got this real-life object, you're holding it in your hand and now you try to put it down on a piece of paper. Those are the kinds of things that you can do to help you develop your spatial skills if you're not in a class like the one that we've been talking about.

Donna: Isn't Tetris one of the computer games that research shows improve spatial reasoning skills and that one is not objectionable to many females as some of the other games can be, to play with Tetris?

Sheryl: I think it's the 3D Tetris, not just Tetris.

Donna: Okay.

Sheryl: My kids used to play Tetris but that was many years ago and that was mostly a 2D thing but it's the 3D that you really need to get at. So I think yes, 3D Tetris is one of those that will help. Angry Birds is like a 2D thing. Angry Birds isn't going to probably help with your 3D spatial skills. It might help with your 2D spatial skills but not your 3D ones.

Donna: What about LEGOs?

Sheryl: Yeah. The evidence is that if you played LEGOs as a child, you typically will have good spatial skills as an adult. I don't know if playing with LEGOs as an adult gives you good spatial skills but I know that if you played LEGOs as a child, it will typically mean that you have good spatial skills. I think anytime you have a piece of paper, a drawing of something and then you're trying to create what that thing looks like in 3D, that's probably the kind of thing that will help you develop your spatial skills. I think it's a lot of going between the 2D piece of paper and the 3D model in your hand or like that.

Donna: You know something else just came to me. You can let me know if this would be along these lines but I know that there are now computer programs that are not super-expensive where the average person could do modeling for like interior design of what's going to go in their home. Maybe you do some sketching and then use the computer program? Do you think something like that could possibly be helpful?

Sheryl: I'm not sure. A lot of people think, "Well we'll just do CAD and CAD will help my students develop their spatial skills." What we've found is that's not the case. Working with CAD, you get a very small gain in your spatial skills over a semester, say, whereas doing sketching of any kind you get a huge gain in your spatial skills. So working with CAD is not necessarily beneficial.

The other thing that we have found and that others have found is that if you have poor spatial skills, you have a really hard time learning how to use CAD. So you might get frustrated. A lot of times people will say, "Oh you don't need visualization skills. Just let the computer do the visualizing for you." But that's actually not how it works. If you don't have the good kind of fundamental spatial skills, then you really can't take advantage of the CAD and you can't take advantage of some of the computer-based visualizations.

Donna: Okay. That's important for us to know. Well, we're out of time. Thank you so much, Sheryl, for joining us for the STEM Success for Women Telesummit and sharing your expert knowledge of spatial reasoning and all of the work that you've done and what a difference it can make of retention of female and also male students in engineering. It's been such a pleasure talking with you today.

Sheryl: Thank you, Donna, for inviting me and thanks to everybody who was listening, too.