Teaching Spatial Skills to Boost Student Success and Grades in STEM Courses

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Interview Transcript:

Dr. Sheryl Sorby

Donna: Hello, and welcome to the fourth session of the *STEM Success for Women Telesummit.* My name is Donna Milgram, Executive Director of the Institute for Women in Trades, Technology and Science. I'm so glad you could join me and our guest speaker, Dr. Sheryl Sorby, today. She's a Professor of Engineering Education at the University of Cincinnati. She has a well-established research program in spatial visualization and has been actively involved in development of other educational programs. She received her first grant from the National Science Foundation in 1993 to develop a course and course materials for helping engineering students develop their 3D spatial skills. Her spatial skills curriculum has been adopted by nearly 30 engineering programs across the United States. She's published more than 150 papers and journals and conference proceedings, and is the author of seven textbooks.

I want to welcome you back, Sheryl. I interviewed you for our live *STEM Success for Women Telesummit* in 2015, and as you know, I've been following your work for improving spatial skills and retention rates of females in engineering and STEM career pathways for over 15 years. I was so excited when I first learned of your work, and I realized that **there could be such a huge boost in retention rates by simply taking a short spatial skills reasoning course—60% retention versus 38%.**

I realized that so much work was being done to support women in engineering, and that actually teaching them spatial skills and 3D reasoning was extremely important. I'm so glad your work has now become mainstream, and that there are even colleges making the spatial skills course mandatory to help students improve their spatial skills to that they will be retained in engineering.

I'm also really happy that we're going to be discussing how you've adapted your work that was primarily with four-year colleges to the two-year college level, which is our primary audience at this Telesummit. Welcome back, Sheryl, and thank you so much for joining me for the *2018 STEM Success for Women Telesummit.*

Dr. Sheryl Sorby (Sheryl): Hi, Donna. Glad to be here. This is Sheryl.

Donna: Let me start out by having you just describe why spatial skills are so important for STEM retention, especially for women?

Sheryl: Yeah, so there's a lot of research done over the years in looking at the spatial skills of people in various professions or people in various career programs at the university level. What they've found over and over again is that typically the people in the STEM disciplines, engineering, technology, and so on, have highly developed spatial skills.

Typically the kinds of skills that we're talking about are the skills that enable you to rotate something in your head. If you have an object and you rotate it a certain amount, then you would be able to tell what it looks like from this new viewing direction. Those are the kinds of skills that are measured on these spatial skills tests. There have been high correlations between scores on those and success in programs like engineering or engineering technology.

If you think about it, if you've got somebody who's doing heating, ventilation, and air conditioning (HVAC) in a building, they need to be able to think about this 3D structure that is the building, and figure out where to pull the wires, where to have the duct work, where to have the piping, where to have everything. They have to think about the building as a 3D structure and figure out where all this stuff fits so it doesn't interfere with one another, and all of those kinds of things.

All of these things that typically are the kinds of activities that the people in STEM careers are doing require this ability to kind of think about this big, large structure or this big machine where you've got lots of parts fitting together. There just has been a lot of research done over the years showing this strong link between spatial and success in STEM.

We did a study last year with engineering students, and we found that spatial skills seem to be a real factor in a student's ability to solve word problems. What we found is that if we just ask them to solve the math problems, everybody can solve the math problems. But when we ask them a word problem where they have to think about what the words mean and maybe conceptualize what the problem is asking them, that's where the spatial skills appear to play a really important role.

Donna: I understand the link between these skills and being able to do a variety of STEM jobs. You gave the HVAC example. I'm hearing you talk about this from the doing word problem perspective. **What I don't understand and would like our listeners to understand why is this so important for women in particular?**

Sheryl: For STEM, it appears that one of the most important spatial skills that you need for success in STEM is what's called mental rotation, so your ability to mentally rotate objects and say what they would look like in a new position.

From the literature, it's also shown that this is where we continue to see very robust gender differences. For whatever reason, and I don't necessarily want to get into a debate about a reason, the women appear to have much weaker mental rotation skills compared to men. Now that's on average, so just like height, on average, men are taller than women, but there are some women who are taller than some men, because it's an average. It's not an exact number. The same holds true for the mental rotation skills that on average, the men tend to have much stronger spatial skills or 3D rotation skills than the women. Those are the kinds of skills that have been shown to be probably most important to STEM success, in terms of all of the different kinds of spatial skills.

Now some people think, there's a big debate about whether or not these gender differences are based on biology or environment. It's the old question of nature versus nurture. Personally, my personal belief is that there's some biological difference, but I think that the biological difference gets larger as kids grow older because of their environment. I think it's actually a combination of nature and nurture why there are these big gender differences.

In reality, I really don't care why these gender differences exist, because it's something that we can fix. It's not that you can never learn these things. It's just that some people might need more support than others to develop these skills.

Donna: That's what I care about, too. **Can you share with our listeners, before we talk about the adaptation for two-year colleges, some of the research findings that you have about how you've helped females improve their skills significantly, which has resulted in greatly improved retention in engineering courses?**

Sheryl: Yeah, so I'm going to step back for a minute and just talk a little bit about myself. I was a straight-A student in high school. I aced everything. Then I went to the university, and I was majoring in engineering. I took calculus and chemistry and all those things that first year engineering students take, but then I also took my first engineering course.

The engineering course I took was one called Engineering Graphics, which is a highly spatial kind of topic. It was like I hit a brick wall. It was the first time in my life that I was sitting in a classroom and I couldn't do what the teacher was asking me to do. It really discouraged me and almost made me leave engineering, because I thought, "Well, if this is my first engineering class, and if this is what engineering is, I obviously can't do engineering, so I need to leave."

Then I ended up teaching that class later on. There were a number of young women in the class who also struggled. There were some men too, but predominantly it was the women who were struggling. There were a number of them who said to me, "I'm leaving engineering, because I can't do this." I said, "No, no, no. Don't leave. You can get this." That's what motivated me to get going on this path, because of my own personal struggles with this topic.

We developed a course, and we offered it many, many years. The course was voluntary, so we looked at the kids who did poorly on the spatial skills test and took the class, and the kids who did poorly on the test and didn't take the class. What we found is that for the kids who did take the class, both men and women, they went on to earn higher grades in many of their STEM courses.

They were earning higher grades in pre-calculus and calculus and chemistry, physics, and even computer science. They were doing better academically, but we also looked at retention/graduation rates. We found that on average, the students were being retained in engineering at a higher rate, but this was particularly true for the women.

For example, in one of the studies we did where we examined seven years' worth of data, we found the difference in retention or graduation for women who had taken the class, the rate was about **78%**, and the people who hadn't taken the class, the women who hadn't taken the class, the graduation rate was about **47%.** We saw this huge increase in graduation rate among these students who had taken the spatial skills class. Again, if I step back to my own personal experiences, I understand it completely, because like I said, I almost left engineering because I think I had weak spatial skills at the time. I think I've gotten better now, but I think at the time I had weak spatial skills. That's really what motivates me to keep doing this and to keep working at trying to help more students, but in particular, more women be successful in STEM fields.

Donna: Now I just have to say that when I first saw this data 15 years ago, that's a huge difference. **This is, what, how many hours is this course that you're talking about that you've developed?**

Sheryl: Well, it's a one-credit course, and it has 10 modules. It takes about an hour and a half per module. Some modules are a little more challenging, and so they take a little more time. Some modules take a little less time, because they're easier for the students, but around 15 hours of instruction over the course of one semester.

Some people, especially our community college partners on the project, they've found that instead of doing it one session per week, what they do is two sessions per week and get it done in the first seven weeks of the semester or the first six weeks of the semester. That seems to work better for a lot of the community college students, but then it seems to still work. It's not something that is required to go over the entire semester, I don't think.

Donna: If I understand correctly, with homework, maybe max 20 hours?

Sheryl: Yes. Max 20 hours.

Donna: When I think about the amount of time, effort, and money that's put into other kinds of retention strategies, and I'm not saying that they're not important, they are, but when I think about how learning spatial reasoning skills, which might take, in terms of both instructional contact hour and homework, a maximum of 20 hours, could improve retention by 30, 40%, that's astounding to me. I can't understand why every single engineering school is not requiring this or other STEM career pathways where this is really critical, like the HVAC, as you were talking about, HVAC-R. That's why is so stunning to me.

Sheryl: One of the problems, and we all know this, is that the STEM curriculum is very full. When you talk to anybody in engineering or in technology or any program, they're all hesitant to say, "Oh yeah, I'm going to require this one extra credit," because they're already maxed out on credits.

This started at Michigan Tech, and when I was skill there, we gathered data. It was an optional course for many years. Now it's required for people who have weak spatial skills. The argument that I made with the Deans and the Chairs is that... Let me back up a second here. In engineering, the first math class is calculus. We admit a bunch of students every year, and most of them are ready for calculus, but some of them, and it's not an insignificant number, some of them are not ready for calculus. We tell them you are not allowed to take calculus unless you pass pre-calculus. They require these students to take pre-calculus, and they tell them at the same time, "Okay, this is not going to count towards your degree, because your degree starts with calculus."

When I was advocating for making this a required course, I said, "Look, we need to treat this like pre-calculus. It's like you cannot enroll in your first engineering course unless you get a good enough score on the Purdue test or you pass this spatial skills course." They looked at the data, and they said, "Yeah, you're right." I used the argument that we have to treat it similar to how we treat some of our, I hate to use the word remedial, but our foundational math classes that don't really count towards college graduation, but we make them take them before they come in and take the ones that are counted. That was the case I made in why this should be required.

Now other people I've worked on this with at various institutions, trying to get an extra credit kind of into the curriculum is really hard, but then other people have been kind of creative. Like I'm working with a university right now, and they're probably going to implement this into a required course. Instead of adding a credit, they're going to try to fit it into what they're already doing. But it's challenging because college administrators don't want you adding all these courses, don't want you adding credits to programs. I think that if they're serious about trying to retain students, and especially students, women and maybe students from disadvantaged backgrounds, then I think they should be looking at something like this.

Donna: Now I know, because I've heard you present at American Society of Engineering and Education (ASEE) Conferences with school sites that they've done it in different ways. Some have done a credit course. Some have required all their students to take the Purdue Spatial Reasoning Test. That and if they didn't get a certain score, like at least a 60 or a 70, then they required it or they strongly urged them. I've seen it done different kinds of ways to make sure that the students have the opportunity or understood it.

For those unfamiliar, can you first just talk about if they wanted to administer the Purdue tests to their students to help them see if they should do some spatial reasoning, education, how would they get access to the Purdue test?

Sheryl: Yeah, so the Purdue test is a 30-item test, and it takes 20 minutes to do. If people are considering implementing spatial skills instruction, my first advice is always to do some data gathering and figure out where your students are at.

For example, at the university level, we typically find that about 10% of our male students and about a third of our female students score 50% or lower. At community colleges though, what we're finding is that those rates are much higher. At community colleges, the percentage of male students who might be struggling with their spatial skills is typically around maybe 40 to 50%, and for the female students, it's much higher—it's in the 60 to 70% range.

What I try at the university level, you don't want to make people feel bad that they can't visualize. We typically recommend at the university level having a separate course just aimed at developing spatial skills, but at a community college and other universities I've worked with where the struggles with spatial reasoning is more prevalent, then I think it's okay to implement this in a required course. I think the first thing, like you said, is to do the testing and see where your students are at and then figure out where to go from there.

The test, it's available through the Educational Testing Service (ETS). I think it's like a $25 fee. The authors, I've had conversations with the authors. The test was written in the 1970s at Purdue by some chemistry faculty. Their intent in developing this test was that it would be freely available. There is a small fee from ETS. I think it's $25, but basically if you pay the $25, you can make as many copies as you want. You can put it in your Learning Management System (LMS). You can use it over and over again, no problem. It's kind of a one-time fee of $25, and then you're free to use it as much as you want to use it. Yeah. I think it's important to kind of figure out where your students are at before you make plans, but the test is available for, I think, a very small fee.

Donna: I just want to say that that is huge that two-year college students, both male and female, are really scoring so low on the spatial reasoning. I also heard you mention that it's also important to develop those skills for students who may be economically disadvantaged who, of course, also disproportionately are attending two-year college. I see teaching spatial reasoning becoming part of decreasing the equity gap.

What we say in the WomenTech Educators Training that we deliver is that if you have something that is a barrier and over 50% of the students are failing something or failing a particular course, then you need to infuse what we call those building block skills into the course itself, because it doesn't make sense to have a strategy that is individual for more than half your class. **What I'm hearing is more than half of students, both male and female, are not getting passing grades, so to speak, on the Purdue spatial reasoning assessment. I just want to get your thoughts about that.**

Sheryl: Yeah, well besides the gender differences, which I talked about previously, researchers have done work, and I've done work as well, looking at the spatial skills of students by socioeconomic status (SES). What we've found, and others have found as well, is that the students coming from a low SES background, just like they're behind in many things, they are also behind significantly in their spatial skill levels.

In some cases, the differences by SES group are larger than the differences by gender. These students, they come to our programs, and they're at a pretty big disadvantage, in terms of STEM success, because they haven't engaged in the kinds of activities as children that would enable them to develop these skills, or they haven't had the right toys, or they haven't had the right opportunities.

We are finding, in some of our research, we're finding that there are differences by SES, but the SES differences are much, much larger for urban students versus a rural student. The rural students seem to, even though there are these differences by SES, they're not as big, and probably because they're growing up in a very different environment. They're allowed to go outside and play in a safe environment, and they run around the neighborhood and all of those kinds of things. They might be developing a better spatial skills from that, compared to the urban students who are more confined, in terms of the area that they're allowed to explore on their own.

Again, if you think about the average student at a community college, you can see why between the gender and between the low SES, then this puts the community college students at a real, I think, disadvantage for STEM success. In one of our community colleges, I think it was something like 75 or 80% of the students that were tested were failing the Purdue test when they gave it to them. It's not an insignificant problem at a community college, I would say.

Donna: I remember when I brought you in to work with the community colleges in our CalWomenTech NSF-funded Project. One of them did decide to teach spatial reasoning online, and I so appreciated your willingness to help out with that. I was excited, because I know in this NSF grant that you've been working under, you also had an online component. **I wonder if you could just speak more specifically about your work with two-year colleges, and the online component of teaching spatial reasoning, because I know that was something that you were doing as part of this for the first time yourself?**

Sheryl: Yeah, so one of the problems in trying to do this course fully online is that what one of the things that we've found to be the most helpful in helping students develop their spatial skills in the ability to do

kind of paper and pencil sketching. Because of that, the course is not, I would say, 100% conducive to online, but the other part of it too, what we found in our community college program is that we tried to make this like a mook, where it was just somebody could do it on their own. The materials are there, and have at it, kind of thing. What we found is that the community college students, they might do one lesson, and then they'd drop out, or they might to two lessons, and then they'd drop out, and that they really needed that contact with the faculty member.

I think what we've kind of decided on now is that a hybrid model works better than a fully online. We have a number of video clips that we've developed. We've developed some mini-lectures, and we've developed some how-to videos, like making your first isometric sketch like, "How do you do that?" We give them very simple step-by-step on these videos where they can watch it as many times as they want. If they don't understand it the first time, they can watch it a second time, or a third time, or 10 times. It doesn't matter, because it's all online.

Then what the students are doing, really what's happened is that with the spatial skills training, it's become much more of a flipped classroom for most of our community college partners. What they do is they have the students watch the videos. We have software too that supports the program, and the software is all online. They watch the videos, they do the software. They do all that prep work, and then they come into the classroom where the teacher is there. They basically just kind of work through workbook pages, and especially the sketching pages.

Our goal originally was to make this fully online, but then we decided that that was not going to work for this audience. We've got this kind of hybrid where they're doing some of the kind of rote learning on their own on their laptops. Then they come in and they do the sketching with the faculty member.

Donna: Did you end up having in these hybrid courses similar types of results and improved retention or GPA for the two-year college students?

Sheryl: We got similar results, in terms of improvements in spatial skills, and we got similar results in terms of they were earning higher grades in the credit bearing course that they were enrolled in, so that was good. The retention, we're in the process of gathering that data, as I'm sure you and the people listening understand that getting retention data in the community college area is much more challenging than getting the retention data at a university, because people come in and out of programs. They take a semester off much more frequently and those kinds of things. We are just now in the process of getting the retention data for the community college students, but they are earning better grades, and they are improving their spatial skills.

Donna: Okay, so that information will be coming, and it sounds like you're looking not only at completion of a particular course, but persistence through the major, which is great. We'll have to check back with you for that information.

Now I also know that it's the nature of the National Science Foundation grants that you get funded to develop something, but not to continue it. I'm excited, because I understand that you now have a way for schools to access the online curriculum, but also what's different is that there's a way for individual students to also take these courses, even if the school is not providing it.

Can you just talk a little bit about this, because I'm sure that many of our listeners would like to know, well, how will I get this course? Also, who would teach it? Who would be appropriate to teach it? Or is it taught by you in a way that they could access as a school, or can their students access it individually? All of that. Can you let us know what steps they could take?

Sheryl: Yeah. A few years ago, I started a small business, mostly because there was increased interest in all of this, and it seemed like people wanted access to these materials. I have a small business. If people are interested, they can go to higheredservices.org and find out about it, or if you go to spatialskills.net, you'll get redirected to my company website.

We basically will sell the software and the videos and then workbooks. We are looking at different ways of delivering the workbooks, PDF files and things like that. If somebody has an idea, I'd be happy to talk to you about it, because I'm willing to be creative in how we deliver things, but basically we have develop an online course.

Now the online course that we have is more or less the flipped classroom where the students would have access to the videos and things like that. Right now, we only are selling the online course do individuals. That's not because that's what I want. It's just that that seems to be more of the market that's there. What we do is if you sign up for the course as an individual, we ship out a copy of the workbook goes with it, as well as some snap cubes. We can talk about snap cubes later, but they're kind of essential for doing the curriculum.

You sign up for the course as an individual. You can then you get the workbook, and then you can just kind of work through it on your own. Unfortunately, there's no teacher there to help you, but it's probably better than nothing. We have kind of toyed with the idea of trying to offer this through a community college or something like that, but we haven't done that. If anybody's interested, please contact me, and we can talk about how to do that. If you wanted us to take over "the instruction" for the online version, we can do that. We can figure it out.

The cost of the online version of the course for an individual is $100, but again, that includes the workbook and snap cubes. Obviously if we were doing this on a larger scale, like at a community college, it wouldn't be $100 per person. It would be something less than that. Anyway, those things are available.

As far as teaching the course, I always tell people it's not really rocket science. I've trained a number of teachers over the years to do this. I've trained math teachers and art teachers and all kinds of science teachers and all kinds of different teachers to do this. You don't need a PhD in engineering certainly to teach this spatial skills class. We, at the university, have had the class pretty much taught, especially in the flipped classroom kind of setting, we've had it taught by graduate students, even undergraduates who are good at some point in time. No, you don't need a PhD in engineering to teach this. I think pretty much anybody can.

Now obviously if somebody wants to teach it and they have weak spatial skills themselves, they probably want to do a lot of practicing to get up to speed, but I don't think it would be impossible for that person to teach this class.

Donna: You have a trainer's manual, as I recollect. **I believe we have a link to it somewhere. Is that right, you have a teacher's manual?**

Sheryl: Well, the one that you would have access to, we have greatly expanded and improved that one, but yes, we have a teacher guide that basically says, "Okay, here's lesson number one. These are the important points to emphasize. This is about how much time you should think about spending on this. This is the workbook assignment that we think you should give people, and these are the materials you need to gather before you go to class." We have a pretty comprehensive teacher guide, in terms of helping you through teaching this, if you choose to.

Donna: Okay. We're going to go right to the questions. **If they were interested in teaching this, could they talk with you about maybe licensing this? Is that what you meant by if schools are interested, you could have different kind of levels, in terms of cost with multiple students? That would be part of the conversation?**

Sheryl: Yeah. We do offer this software and the videos for a licensing fee, but then now I've been negotiating with people about different ways of getting access to the workbook pages, because those, again, we've found that really the workbook is essential for developing spatial skills. I try to keep the cost down, but I know that in community colleges, cost is always a concern.

If people wanted to work out a licensing arrangement to get access to PDF files of the workbook pages… I think my mission in life now is to help students and teachers be successful in STEM, and especially the young women out there. I'm not saying I don't make any profit, but I don't make a huge profit. I try to keep the cost down, and I try to work with people in their situations to get them access to the materials so that they can go about helping their students develop their spatial skills.

Donna: Sure. I understand. You're trying to figure out a way to make this sustainable, and also fit into their budgets. That is great to know.

I am going to come to some of these questions for Dr. Sorby. The first one is, ***"Can this be considered more like a competency-based course where students can move along according to their skill level in a certain area or module?"***

Sheryl: Yes, so I should mention that one of the ways that this has been implemented, in particular at the University of Colorado Boulder is they have an introductory course, and they give everybody in the course the Purdue test. They tell them that in order to pass this class, you have to pass the Purdue test. That's just a requirement for passing the class. Because it's an R1 research institution, a large percentage of their students pass the Purdue test the first time they take it, and so they're done. They don't have to do anything.

But this group of a lot of women, and maybe students from low SES groups who don't do as well on that Purdue test, what they do is in the evening, they offer workshops. The workshops are primarily based on my curriculum. They have them go through the software. They have them go through the workbook pages and do all of that kind of stuff. I think they have a few other activities that are not part of my curriculum that they're doing.

Then about partway through the semester, they give them the chance to pass the Purdue test again. They might not have worked through the entire 15 hours. They might have only done eight hours at that point in time. They take the test, and if they pass it, then they don't have to go to these workshops anymore. In the evening, they just kind of keep going in their class the way it is set up.

Then for the students who are still struggling, then they work through more of the modules in the curriculum. I guess from that standpoint, yes, it could be a competency-based thing. Again, that's how they do this at this university where it's like, "Look, in order to pass this class, you have to have a passing grade on this Purdue test. If you don't start out with a passing grade, we'll help you get it along the way." I think I've answered the question. I'm not going to go on. We can go onto another question, unless you think I need to answer more.

Donna: No, no, no. I think that that is a good example of doing it in that competency based way. I like the way that students are checking in on their skill level by retaking the test, and some students are going, "Is this going to be enough?" And others will need additional content. That makes a lot of sense to me.

Another question that I'm seeing, ***"Is there research about cutting edge technology? Are these skills important for computer science courses or for a new area, like nanotechnology, for example? Is there any research about that?"***

Sheryl: There has not been as much, I would say, on things like nanotechnology, but in computer science, what is interesting is that if you look at the data that from my studies that I've done with engineering students, that some of the bigger grade improvements were in the computer science area. There have been studies in computer science that show that a person's ability to learn how to program is directly related to their spatial skill level.

I did a study with a colleague at Stanford University, and he had high school girls coming in who were coming in for, I think it was a two-week long summer camp on computer programming. What he found, he did a little study with the students, and what he found is that for the students from a high SES background, the spatial skills training didn't have an impact. They learned how to program just as well as the students how didn't have the spatial skills training.

But for the students from the low SES backgrounds, it was particularly important for them. The students from low SES backgrounds, if they had my spatial skills training, they had an easier time learning to program than if they didn't have the spatial skills training. I've had conversations with people from computer science about this, because they're like, "You don't need spatial skills to do this."

Then when I talked to them about our data looking at word problems, and I explained to them that it seems like the spatial skills enables you to kind of set up the problem and figure out how you're going to solve it, then they get it. **Then they say, "Oh yeah, now I see how that applies to computer science." It's not just do you have a widget and can you visualize it from one direction or another? It's that your ability to visualize this widget from one direction or another seems to be related to your ability to do these really abstract kind of things that you find in the world of computer science.**

Donna: That is so critical, because programming is really becoming almost something that you need to have if you are pursuing higher education.

Sheryl: Right.

Donna: If that's the case, and we're seeing such a difference based on socioeconomic backgrounds, once again, I see spatial reasoning being a really critical part of decreasing the equity gap in STEM. I myself have had computer science or computer networking instructors say to me, "No, no, no, there's no spatial reasoning." I would like to ask you, I'd love if you could maybe send me the information for that study. Maybe we'll put it in our Proven Practices Collection, along with some of your other work that we have in there, Dr. Sorby, because I think that's a really important piece.

Sheryl: Yeah, and I should mention too that, in fact, a colleague of mine has received a grant from NSF to look at the impact of spatial skills training on computer science performance. A year from now, we might have a lot more data on this, but I can send you the data that I do have right now.

Donna: That would be wonderful, and I'm hoping that we'll be doing another *STEM Success for Women Virtual Conference* next year. Not waiting three years, but doing it next year. I could potentially have that colleague come and talk with us about it. Now I have another question asking, ***"Does your course use any tools like computer-aided design software (CAD)?"***

Sheryl: No. We have our software that we've developed. Some of the things that you might do in the software would be similar to the kinds of things that you might see in CAD, but it's specific to just spatial skills instruction. Speaking of CAD, what we've found, and it's not just me, other people have looked at this too. A lot of times people think, "Well CAD helps you develop your spatial skills." What we've found is that a little bit, but the hand sketching seems to be really important.

For example, in some research I did a few years ago, we were teaching a CAD class, and we were teaching an engineering graphics class that was mostly sketching. We've found that the students in the CAD class, they improved on the Purdue test by maybe 4% between the beginning and the end of the semester, but the people who were doing the sketching were improving their spatial skills by more like 20% or something like that.

The CAD itself will minimally impact spatial skills, but not as much as the sketching. The other thing I want to say about CAD is that what we have found and what others have found as well is that in order to learn to use CAD, you need good spatial skills. If you have students with weak spatial skills and they're taking their CAD class, they're typically frustrated with what they're doing. They feel like they have to start over a lot. They feel like they take a lot more time. Their models are not as robust, so they end up doing a bunch of extrusions that they don't need to do. They create an object in 12 steps instead of three or something like that. The lack of spatial skills seems to be a real impact, in terms of your ability to learn to use CAD.

Donna: I have a question for you, and this is my question. **Because the sketching you've described is so important, we have coming up next Tuesday an interview with Cal Poly Pomona. It's about supplemental instruction. They are having students use iPads to do sketching. Does it have to be pencil and paper, or could it be on an iPad, and then therefore fully online?**

Sheryl: That was part of what we were doing with our research project, the community college one, is that there was a component doing some iPad sketching. The answer is yes and no. Yes, they can do the sketching on the iPad, but I saw this with some people who were using this sketching app, is that

because of the way it's programmed, if your line isn't perfectly straight or your line isn't this, then it'll come back and tell you you're wrong. You might have something that's essentially correct, but not correct. Then that just gets people more frustrated.

Yes, it is possible. The other part of it, though, is the data that I saw, the people who were sketching with the iPad were not improving by as much as the people who were sketching by pencil and paper. For example, typically in the class that I teach with the pencil and paper sketching, we might see an improvement from 50% to 75% between the first part of the semester and the end of the semester, whereas people who were doing the same course but sketching with an iPad were maybe improving from 50% to 60%. They were improving, but not by as much as the students who had done the sketching.

Now obviously the app can improve, and maybe it's better. This is data from a couple years ago, so in the world of computers, that's ancient, but the other problem I think with the app part of it is then all the students are required to have that. Especially in a community college, it's not as practical, I think, to tell all the students, "Oh, you need to get a tablet in order to do this class."

Donna: Right.

Sheryl: Because you can do things on your phone, but then it's so tiny that it's impossible to do it on your phone, right?

Donna: Yeah, yeah.

Sheryl: Yeah.

Donna: That's interesting. It's really interesting. Well, I have one last question, but it's a good one. One of our listeners says**, "It's amazing that the spatial skill level is so low in so many community college students. Is it possible that this could be behind the high failure level in remedial math in community colleges?"** She says, **"I've observed that students seem to have cognitive blocks to learning math that seem to have nothing to do with the mathematical procedures they're learning. Has anyone studied the impact of spatial skills instruction on learning arithmetic, algebra, and other developmental level math courses?"**

Sheryl: Yeah, so there has been work done in the elementary grades on spatial skills. The things I see the most are for really young kids, spatial skills are linked to the child's understanding of the number line. Then other people have found spatial skills are linked to your ability to do what they call approximate math, where you have to sit down, and you have to say, "Oh yeah, this number is about that," kind of thing. But there's a lot of work done in the elementary grades, and they show that, yes, there is a strong, strong component linking success in some of these early doing proportional reasoning, doing fractions, all of those kinds of things seem to be related to your spatial skill level, for young children especially.

I don't think anybody has looked at this specifically, like in kind of a foundational level community college math class. I think it would be a very interesting thing to look at. If somebody wants to look at that, we can talk about it, but in the elementary grades, certainly there's been a lot of work, in terms of the link between spatial skills and success in math.

Donna: I see this as a future NSF grant. ***This brings me to my last question, which is your contact information, best way to get in touch with you, because there's several people who want to get in touch with you for different reasons that have written. What's the best way for them to do it?***

Sheryl: I am actually an emerita faculty member at Michigan Technological University, and the reason I bring that up is that my Michigan Tech email is because I will have this email for the rest of my life. It's the easiest one to get in touch with me at, because I've been in other jobs too, and my email is always changing. That email address is sheryl@mtu.edu.

Donna: Great.

Sheryl: There are other ways to get ahold of me, but that's probably the most reliable. I think on my website at higheredservices.org, there's a "contact us" button. That will be forwarded to my sheryl@mtu.edu email address.

Donna: Great. This has just been a fantastic interview. I can't thank you enough, Sheryl. I also want to thank all the participants and the great questions, really excellent questions.

Sheryl: And thank you, Donna, for inviting me. It's been a pleasure as usual. Thanks everybody for listening and the great questions.