Roger and Susan were both talking in various ways about learning from text in different types of environments, and I want to talk today about learning from visualizations. Now, this does relate to learning from text, because very often there are diagrams in text, and those need to be spatially interpreted. I think one of the things that we can really make some headway on is, when people are reading, do they look at diagrams, and how do they interpret them and relate them to the text.

I want to talk about sex differences, because they’ve been very much in the news, and there’s certainly speculation and I think, a widespread belief in the popular media that the fact that men are better visualizers, and I want to begin by saying that I do think that that’s a fact. But there’s this speculation that the fact that men are better at visualization than women accounts for sex differences in participation in science and math at the highest levels, and furthermore that it’s biological, and furthermore that there’s nothing we can do about it. I believe these sex differences are real-- they’re not in every aspect of spatial reasoning, but they’re very pronounced in mental rotation, which many of you are familiar with. And also, in the water-level task, knowing that still water is invariably horizontal, and as a function of that, in mechanical reasoning, which is a very location-oriented kind of task, that’s often used in helping people to select locations. These sex differences used to be thought to appear only at adolescence, but more recently we have become aware that they are evident as early as four years of life.

Now, this is a good slide because it does remind us that there is a lot of overlap; to say that there are differences does not imply that every boy is better than every girl. But at the same time, the differences are very large-- there’s at least a half a standard deviation, and usually more like two-thirds of a standard deviation. This is clearly relevant to various kinds of scientific education.

Geoscience education I illustrate here, just in a sort of base-validity way, by showing you some of the kinds of diagrams that people in geoscience are asked to interpret, but I could have picked engineering, I could have picked chemistry, I could have picked physics. All of these kinds of disciplines draw very heavily on spatial visualization.

In other studies of gifted samples, we found that early spatial ability, in this case in middle school, predicts later vocational choice. So, we have here both SAT Verbal and SAT Mathematical scores on the x and y coordinates, but what I want you to pay attention to isn’t the x and y coordinates, it’s a challenging visualization-spatial task, which is the fact that there’s a third dimension, a z coordinate, where there arrow points to the right if you’re a high spatial painter in middle school, you’re more likely to select this area to get a B.A. degree in. If it goes to the left, you’re less likely, and you’re a lower spatial ability person if you select those areas. So you can see that high spatial middle-schoolers eventually get the A’s in the physical sciences, math and computer
science, and in various types of engineering. So we have here sex differences; they’re early, they are related to science, technology, engineering and math education.

‘Are they biologically caused?’ is almost always the next question that people ask. But the reason people ask that is because they assume that if a difference is biologically caused, it must be immutable. And that is a false conclusion. There are many, many kinds of differences that have biological causes and that are affected by environmental input. And, if that were not so, all of modern medicine would be bogus, right? You come, you have a headache, you take an aspirin, it doesn’t prove that your headache was caused by a lack of aspirin, in fact, your headache may be caused by some genetic vulnerability, but it can be affected by giving aspirin. There are many, many examples of this kind. Now, I do want to just briefly say something about the case for biological differences. It’s often thought to be a very powerful case, and in fact, Larry Summers was apparently very influenced by his ill-fated comment prepared for him by Steve Pinker that covered these topics. So blame it on Steve. Sex differences are supposedly culturally universal; this is more or less true although there are some limits on this generalization. There are systematic relationships with pre-natal hormone levels…well, there’s some evidence of that, but it’s really not as strong a case as it’s often portrayed as being. There are systematic relationships with current hormone levels…this is sort of true, but it’s a flaky finding, and furthermore, in my view, it doesn’t make a lot of sense in a biological setting, because if it’s supposedly adaptive for men to have a higher spatial ability, then you would also have to say that its adaptive for women to have higher spatial ability when they are pre-menstrual and menstruating. And I have no idea why it would be especially important for women to have a higher spatial ability at that point in the menstrual cycle. So, even if it is related to hormone cyclicity, which is not proven, it’s not clear the hypothesis from the evolutionary-adaptational case.

As you go on and on, this whole line of work is embedded in socio-biology and what I’ve been trying to emphasize here is that either the evidence can be questioned, or the coherence of the story can be questioned, which I think is also very important. But my main message to you today, isn’t that. Let’s have there be sex differences, let’s have them be biologically caused, let’s have them be really crucial to learning science, technology, science and math content. Do we care? And what I want to argue is that we don’t care, because we know that these abilities, spatial abilities along with other abilities, are not fixed, that they are remarkably malleable, that they benefit from experience, and therefore the question has to be, ‘what are the male and female reaction ranges? How much can we decrease females’? How much can we decrease males’ spatial abilities? Can we get them over a threshold such that you have enough that you can succeed in learning and understand content? And I do believe, although this is an empirically testable question that I think has not been adequately tested, that there are threshold tests here. You need to have good ability. It’s not true that if you have more and more and more, you’re better and better and better. At some point, if you have enough. There are other things that effect your ability to read a biology lab, like, do you have leadership skills, how hard are you willing to work, are you actually interested in biology? For women, there is childcare and lifecycle support or family issues, so at some point we get to a threshold and we have to ask simply, ‘can spatial skills be increased?’
And here, I’d like to say that the answer is unambiguously ‘yes!’ And it’s not just ‘yes!’ it’s massively ‘yes,’ I should have put many, many more exclamation points after that ‘yes.’

This graphs shows a recent study that is currently under review, that I did with Melissa Terlecki, and it shows the increase after either practice, which is just taking the test again and again and again, or training (some played Tetris, that was their training,) we paid them every week to come in and take the test, and for the Tetris group to play Tetris for an hour a week, and we solicited high men, high women, and low women. Now ‘high’ ended up being lower in spatial ability, but the way we screened them was by their playing of video games and computer games, because that itself…we just thought it would be a crude screener for spatial ability and it turned out to be so. Note that we couldn’t find hardly anyone, one or two per semester in hundreds and hundreds people taking intro psych courses…men who didn’t play video games. They are not out there. Men play a lot of video games, and I think that’s very important in creating these kind of differences.

First of all, everyone gets better. Even the ‘high’ men get massively better. This is several standard deviations worth of getting better. Secondly, both ‘high’ men and ‘high’ women get better fast at the beginning, they start to slow down in their growth at the end of the semester, but they’re not at the ceiling and they’re still growing. This shows how underdeveloped these skills are, even in people who are the best who show up in intro psych. What I think is the most important aspect of this graph is the ‘low’ women. They increase, but at first they increase more slowly than the two ‘high’ groups. Later, they increase more rapidly than the two ‘high’ groups. So, consider, you’re a ‘low’ woman, you don’t play video games, you’re rotten at the stupid mental rotations test, which people make you take again and again and again, you struggle with it, you know you’re getting the wrong answers, why are you coming back? Answer? ‘I’m getting money!’ We get you over the hump, we get you halfway through the semester doing something you’re terrible at, and not getting much better at, and lo and behold, you start to get better at a fairly rapid rate. So I think this illustrates something very important about what you need to do with educational curricula, which is to get people over humps. I collapsed the ‘practice and training’ because there wasn’t a reliable difference between the Tetris group and the ‘just take the test’ group, although I think with more power there would be. But what we do know is, there were significant differences such that Tetris led to transfer. So, when you did other spatial tests other than the mental rotation test, either right at the end of the semester or three or four months later, the Tetris group does do better than the practice group, so Tetris improves transfer. We found that these tests were durable, I could have said that in regards to the prior slide, so that hasn’t been adequately assessed, but the effects do survive three to four months of no further input from us. So, I have a very simple message here, and that is to say that reading is important, but so is spatial visualization, and we must really work to increase it in all students. Thanks.