Tuesday, February 23, 2016. Maggie Johnson, Google.

MS. PERNAMBUCO-WISE: Good morning, everyone. For those of you whom I have not had the pleasure of meeting as yet, my name is Tekakwitha Pernambuco-Wise, and I'm the head of Sea Crest School here in the San Francisco Bay Area.

I'm honored this morning to present to you Maggie Johnson, who earned her Ph.D. from the City University of New York. She entered an industry when there were very few women in the technology field, and so was a pioneer for women in this area. She's currently the director of education and university relations for Google. She manages all technical training, content development, and information monitoring programs for Google engineers and operations staff, as well as Google's K-through-12 educational programs in STEM and computer science.

She also manages the university relations area, building research partnerships with faculty globally and Google strategic initiatives and online teaching and learning.

Prior to Google, Dr. Johnson taught for 15 years at Stanford University where she was a director of undergraduate studies in the department of computer science. Dr. Johnson has three children, all of whom attended Sea Crest School here in the San Francisco Bay Area.

I am pleased to present to you and to welcome Dr. Johnson to The Heads Network annual conference.

DR. JOHNSON: Thank you. I really appreciate the invitation to come and speak with you today. I've been thinking a lot about what to talk about because there are so many things to focus on for a group such as yourselves. Tekakwitha gave me some things to focus on, and those themes were really trying to think about how to help the young women in your schools to thrive as they grow into a rapidly changing dynamic world, and also to help them to acquire all of the skills and capabilities and instincts they need to become future leaders in that world, particularly in male-dominated fields.

Given those two themes, what I thought I would do is talk a little bit, at least at first, about some actions that you as heads of schools could potentially take to help young women thrive and grow into these future leaders. So let me just list these things first, and then we'll talk about them in a little bit more detail.

Thriving in a rapidly changing dynamic world. The operative words there are "rapidly changing" and "dynamic." The young women in your schools are growing into a very different world than I did or that many of you did. It's really so dynamic, and there are so many different things they're going to have to deal with that we never even thought of.

Some of the things that we can do to help them in this pursuit: First of all, we need to obviously help them build a strong academic foundation that consists not only of problem-solving and critical thinking, but also computational thinking. So they still need to learn math and science and history and all those things, but the focus can be much more problem-solving and these different types of applications rather than the facts and all the rote concepts that quite often are part of the traditional process.

The other thing is that we really want to teach students how to learn, so that they can teach themselves. I'm on my third career right now. And I might actually have a fourth one before I'm done. And I think for the students in your schools, they're going to be reinventing themselves all the time. It's something that is just part of what's happening in the world right now.

And lastly we have to foster creativity and innovative approaches. In this century, innovation is as critical a skill to learn as anything else, as is computational thinking and problem-solving that you have already covered in many of your programs. But innovation is just absolutely the key to success. So it's something that we have to think about how to teach.

On the leadership side of things, we want obviously to help them to learn to define a meaningful strategy and goals and then be able to make the long-term plans to meet those goals. This is, again, a skill. It's not an innate ability. It's a skill that can be learned.

We also have to help them learn how to build a team around those goals and rally them with enthusiasm and energy and also be able to manage with consistency and respect. So all of those things are all a part of these leadership development opportunities we want to provide.

And then lastly we want to build confidence and resilience, which for young women is absolutely key. There's a whole support system that needs to be put in place, particularly if they're going into male-dominated fields.

So given just that small list, what I would really like to do here is make this as tangible and practical as possible for you, so I'd like this to be much more of a discussion than a presentation. I know that you are all doing all kinds of interesting things in your schools along these lines. I have some ideas I'm going to share with you, but I would really like for you to be able to share also with each other so that all of these things can kind of come forward as possibilities. So if we can make this as practical and realistic as possible, I think that will be a good outcome at the end.

To begin, one really obvious observation is that the traditional educational process and pedagogy in the public school system almost runs completely counter to the kinds of things that we need our students to learn now. Think about the different aspects of this, you know, the sage on the stage in control of everything going on in the classroom, and the operative word there is "control." They need to control everything the students are doing, everything they're learning, everything they're thinking, all that stuff, and that is very much a part of the traditional way of teaching.

You have this packed curriculum controlled by standards which are driven by standardized assessments. You have learning via work sheets and memorization and drilling and all those kinds of things, again, in order to pass the standardized test and all this teaching to the test.

And finally, you have this focus on getting perfect scores. The most successful student is the straight A student, and failure to get those grades is failure. And that probably is the most debilitating one of all.

These are not surprising attributes. It's interesting that when you look at many of the preschool programs, they really foster creativity and curiosity and exploration, and as students move into the traditional educational process, that gets more and more constrained and more difficult for students to actually continue doing that.

Now, that's not to say that there aren't wonderfully creative and innovative teachers in public schools. We know there are. But the problem is, there are not enough of them and the kinds of teachers that are experimenting and trying to bring the kinds of skills and the kinds of things that our students need to learn into the educational experience is not consistent or comprehensive enough, even though it is happening in spots.

So this is one of the things that's really kind of interesting, how we as educators have to think about the shift from this kind of a structure to something that is going to help prepare our students in a much more realistic way.

One of the things that I would really like to encourage you to do, because you as heads of private schools have the ability and the flexibility and the freedom to experiment so much more than teachers do in traditional public school systems. And one of the things at Google, we're all about technology, but we're also all about scale. So if whatever we're doing isn't going to work for millions and millions of people, then we're doing something wrong.

One of the things I would encourage you to think about as you not only experiment with the things you're already doing but as we talk about some of the other experiments you might try, is to design for scale. And what that means is that if you are doing an experiment or doing some kind of a program in your school that is really working, can you find a way to package it up, put it in a box so that other teachers in other schools elsewhere can use it? That's something that you actually have to design for up front, and you have to think about how can you not only run this program but teach someone how to run it at the same time. So it's a little added layer, but if you do that, then you have this opportunity to shift some of the things that are going on in really meaningful ways. So I encourage you to think about, as you're doing your experiments and as we talk about experiments you might try, how can you scale the things that are successful and give it up to a much broader audience so it's going to have a bigger impact.

So this is a -- I won't say it's a statistic. Being from Google, I'm very data-oriented, and when I hear this, and I have heard this in many different education talks, I always question it because it's, like, how could you possibly measure this? I'm trying to find where this comes from and I can't find it. But I think instinctively we kind of know it's true. If you just look over the last ten years at the new careers that have come up, things like data sciences, things like bioengineer with the whole explosion of the human genome, there are a whole list of domains that did not exist ten years ago.

So if you look at grade school kids and project out, some percentage of them, it's likely, are going to be doing things that we can't even fathom right now. Now, whether it's 65 percent, who cares. But it's another compelling motivation for thinking about how to be educating our students in different ways that are going to prepare them much more effectively for what's coming.

One of the other things I want to mention here is that a lot of what I'm going to present to you -- I haven't been teaching. I have never taught in K-12. All my teaching was in higher ed. But we do a lot of work with teachers and various different programs through Google around STEM, particularly around computer science.

One of the great teachers that I had the opportunity to meet, and I'm borrowing really liberally from her ideas, is Esther Wojcicki. She's a very successful teacher. She teaches at Palo Alto High School, and has been teaching there for about 30 years. She started the journalism program there in the mid-1980s with eight students, still teaches today, and has 600 students, and is kind of a huge proponent of project-based learning, empowering students to teach themselves, being a coach and a guide and adviser who is helping them and empowering them do what they need to do. She has been very involved in that and made that a very successful part of her teaching, is very vocal and very out there talking to everybody to try and get everyone to try it.

She wrote a book last year called *Moonshots in Education*, and she's a good friend of mine. We worked together a lot on many of our education initiatives at Google. What you may not know, she's kind of the grandmother of Google. The founders, Larry Page and Sergey Brin, the very first set of servers that they created for a Google search engine were installed in her garage in Palo Alto, and her daughter Susan was one of the first ten employees and is now the CEO of YouTube. Another one of her daughters married Sergey Brin, so she really is like the grandmother of Google, although they're not together right now.

Anyway, the point is that she has been involved in Google from the very beginning. I'm borrowing a lot from her ideas and from her book in what I'm going to be presenting to you.

First of all, thinking about this solid academic foundation focused on problem-solving, critical and computational thinking. Let's talk for a minute about computational thinking. That's kind of a buzzword. You probably heard this. You may have your own definition for it. There are lots of definitions out there.

At Google we have a very specific definition and we feel it's a really critical skill for students in this century. The way that we define it is, it's a problem-solving technique that computer scientists use to solve problems. And it's all based around this notion of abstraction. Abstraction is when you take a really complicated real-world situation, kind of take away all the details so you just have the essentials,

and then you take those essentials and find a way to represent them in a computer, and then you solve problems about the real-world situation in the context of that model in the computer.

So this notion of abstraction is what computer scientists do every single day. That's what we spend all our time doing. So abstraction is really key. And computational thinking is this process of going from that real-world situation to that representation in the computer.

Let me give you an example that shows the four steps of the process. It's something that we've done many, many times with fourth- and fifth-graders, just a little 15-minute activity that we take them through that's really powerful for the teacher and the student and illustrates this process.

It's all around factoring. If you have to factor 18, there's a process you go through. So the first step in the process is pattern recognition. So we usually have the kids take two or three examples, like how do you factor 12? And they're, like, well, start with one. Well, that divides it. Two? That divides it. Three? You know, it divides four. You go all the way up to six. And then you help them to make the observation that, well, you don't have to go any further because anything greater than six is not going to divide it evenly.

So you take them through, like, let's do 18, let's do 24, and they start to see a generalization of that pattern that comes really naturally. Well, just divide everything up until N, and divide it by two, whatever N is, and you factored it.

And so you take that generalization, turn that into a little algorithm, and then you show them a little bit of Python. If you know anything about programming language, this is a very English-like programming language, and they end up with four lines of Python at the end of the process in about 15 minutes that would factor anything. Put in three million whatever, and it just spits out the factors. And they built it.

So this shows four steps, pattern recognition, pattern generalization, algorithm design, and then, obviously, representing it in a computer with the programming language. And whether or not they get to the last step, the first three steps are really critical. Again, it's a very powerful little thing because they're, like, wow, I built that little thing. I'll never have to factor by hand again.

But it's a great little exercise. And for you as teachers and administrators, it helps you to see that this process is really very important.

And for us at Google the reason why we feel it's important is, first of all, all the devices in the algorithms and the applications are getting more and more sophisticated and this notion of abstraction is just everywhere. For people in my generation, when I first saw a word processor it's, like, oh, it's an automatic typewriter, and that is the abstraction. A word processor is an abstraction of a typewriter. A spreadsheet is an abstraction of an accountant's worksheet that used to be all handwritten.

Students today don't even know what the abstraction is from. They just automatically abstract. They don't even need to make that connection back. But it is important to know that it's all abstraction. It's all representing something in the real world.

So for Google, it's important not only because the devices and the applications are becoming more sophisticated, but it's also this phenomenon which we call computer science plus X. And CS plus X means that more and more domains are requiring some amount of algorithm design and computer science to be successful in these domains.

And I forgot to bring the slide, but I have this little thing that we show where you can do a Google search on just .edu domains. You can limit the search to a particular domain. So it's just on .edu, so it's universities, basically. You do a search on computer science and double quotes plus nothing. Just do a search on that, and you get this long list of computer science and math, computer science and biology, all these double majors, all these places where you're majoring in biology, have to take the first two programming courses, all over the place. This is prevalent in universities all over.

And the idea is that in order for me to be successful in biology, medicine, economics, and so many different domains, I need to understand the tools that I'm going to use, and those tools are automated, they're applications, they're algorithms that are really sophisticated, and if I'm going to use those, I need to understand how they work.

So those first three steps I talked about are things that all students need. It is becoming more and more prevalent that they need to be at least able to design and

understand the algorithms that underlie the tools they're going to use, and the tools are becoming a part of everything.

So this is computational thinking and it's something we feel is absolutely critical for students in this century, along with all the other things that are equally important that also come into it.

So just going through some ideas here. Bring technology into the classroom every day. There are still many, many classrooms where students walk in and have to turn everything off and look at the teacher. And that's not the best way for students to learn how to use technology in ways that are ultimately going to make them independent life-long learners, and technology is going to be a part of that. So the more they can learn how to use technology to do a search and research and understand high-quality content from low-quality content on the web or all these various different providers, these are really important skills for them to learn so that they can become those independent learners later.

Now, the good news here, especially for Google is that one out of every three students in the US, private, public, are using the Chromebook. They have their own Chromebook. So it's moving in the right direction in terms of having every student have their own device that is used specifically to support their learning. And the teachers obviously have to embrace this, too, and it's happening, which is really good to see. It's been a long and arduous process, it continues to be somewhat arduous, but it is starting to happen.

I'm borrowing this directly from Esther. Be the guide on the side, not the sage on the stage. And the thing that is really, really difficult here for teachers is to give up control. There's a leap of faith that has to happen where you're going to say, "All right. You students and I are going to do this together. I'm going to learn with you, and we're going to partner together and collaborate, and I'm empowering you to take as much stake in your education as I'm taking stake in it."

This is something, again, that Esther has been very successful in doing. She tells the story about the first time that she had whatever they were, the little square mats. I can't remember what they were called. Like one of the very first Macintosh computers that came out. They were donated to her classroom. Before that point, everything was done with paper and cutting things out and making physical newspapers and things like that. And then she got all these computers and had no idea what to do with them, had no training, no nothing. She had about 12 students in the class, and she just said, "Let's open the box and figure out how to do

it together," and that was sort of the beginning. And these students just did it. They figured out how to run a network, they figured out how to get all the tools up and running so that they start to automate all the processes, and that is what convinced her that she could do this kind of thing and trust them to help take a stake in their own learning.

Relate education to the real world. I know a lot of these things are really obvious to you, given the things that you're doing in your schools. But especially for young women, the more they're doing projects that they feel matter to the community or to someone, the more it's really internalized for them, something that they really are going to take with them. So that's really an important part of it.

And then the last point is using all of the huge number of high-quality materials that are out there. Teachers who have tried to implement some of these project-based learning techniques say again and again that it's so much easier than trying to control everything that goes on in the classroom. You know, the minute you relinquish that control, and start to use all the things that are out there, the less you actually have to plan every single thing that goes on in your classroom from now until whenever, because it can happen in a much more free-form way. There are so many different tools and apps available and high-quality content out there ready to be used. So that's another point.

So before I move on to the second thing here, I just wanted to stop and see if anybody had any additional things you might want to share or things that you're doing in your school along the lines of moving these problem-solving kinds of activities forward in your own schools.

MS. BROWNLEY: We have gotten rid of final exams in the spring to create what we call end-of-year projects in the ninth, tenth, and eleventh grades, where students take what they have learned in the course of that year and create an experience and execute it. So for instance, we do mock trials around land use in Zimbabwe as part of our world history and English curriculum. And it's been fascinating to watch kids at the end of the year walking out of school talking about what they have done rather than wondering whether or not they got an A on the exam. It's amazing.

MS. JOHNSON: Great. Someone over here?

MS. KAUFFMAN: What's interesting is using technology in the classroom every day. I'm curious as to whether other schools are experiencing any of this, but we're Castilleja in Palo Alto, we know lots of the same people. We actually have parents

who are starting to push back on technology in the classroom and are really worried about their daughters using technology too much, to the point where they're not developing social skills and relationships. And I think it reflects their own ability to not control their daughters' use of social media. I think they're conflating technology and social media as one, because there are so many other applications that are not social media. But anyway, I just wondered if you or anyone else is starting to see that or hear that or feel that.

SPEAKER FROM THE FLOOR: Just a question. Are they concerned about too much social media, do you think? Is that what the motivation is?

MS. KAUFFMAN: I think they are. I think they're having trouble figuring out when their daughters are online and they say, oh, I need to do this for school, and they're using Schoology and Google Docs, that somehow the schools are contributing to the problem of their daughters never having their heads outside of the screen, because we're requiring it for school at the same time that parents are trying to limit their daughters' screen time, basically.

MS. JOHNSON: It's an interesting spectrum, because it's a pendulum. Before, it was like no technology in school at all, and then it comes over to being more technology. I think that there's something in the middle and it's natural to go all the way over to the other side before it balances.

But I think you're right. Parents have to take responsibility, too. These are kids, so a lot of their instincts are not exactly right yet, and not only the teachers and the administrators but also the parents have to help. So it's not surprising that you have gone that direction, but to try and bring it back has got to be a partnership between two.

MS. SCHECKELHOFF: I'm Terrie Scheckelhoff, head of St. Catherine's Episcopal Girls School, 1,000 girls in Richmond, Virginia. And along those same lines, I think anything that all of us can do together to help people like you and Google around -- I think we have to change the whole paradigm of you take exams and put everything away, make sure you drop your cell phone off in this basket, make sure you don't have your Apple watch on or your Google glasses and all. And I think we're in a world now that none of us enter any meeting without all of our technology and research at our fingerprints. So I have been having a conversation at my school -- we have 200 employees -- trying to sit down and say, what does that look like and what can we do collectively as heads of school on a national platform around saying, take everything you have, take every resource you

have into any kind of problem-solving or exam, because the exam is going to be one that you're not going to be able to look up the answer anywhere. You're going to have to synthesize, going to have to problem-solve in a different way. So how can we all work together and with your help and others at Facebook to help us create that kind of educational learning situation for our students?

MS. JOHNSON: If that's the only thing that comes out of this, then we've got something here, because it is a problem, you know, in terms of where we are on that pendulum swinging. And there's definitely an opportunity for partnership there.

SPEAKER FROM THE FLOOR: There's a high-end independent school in Minneapolis that quite a few years ago installed a Montessori preschool through kindergarten in their school. And this may be a method or way for schools to get to the projects you're doing. The Montessori methods have permeated the whole school. In the last couple of years, they totally redid their physical plant so they're project-based, and they're really able to do what they're doing because they had a gradual infusion of the method into the total school. It's very impressive to us.

MS. JOHNSON: That's great. Thanks. Okay. One last one and then we can move on.

SPEAKER FROM THE FLOOR: Ann Marie from Sacred Heart in San Francisco. And maybe you all got this very clearly, but could you just tell us the three steps again in order?

MS. JOHNSON: Pattern recognition, pattern generalization, algorithm design. Those are the three. If you do a Google search on "exploring computational thinking," you will find a website that has a ton of content that is similar to the factoring one I just gave you, all kinds of different ways to integrate this into various parts of the curriculum and what those steps are.

MS. PERNAMBUCO-WISE: One thing that we do at Sea Crest, we just finished our second annual innovators' symposium. We invited real scientists from the real world to come in and they have a conference day which is very similar to contracts, and it's at the middle school level. It was a couple of weeks ago, and Maggie was one of the speakers. It really showed the children how science and technology in the field relates in the real world. And was a very exciting day for the children to see real scientists and what science means for all of us.

MS. JOHNSON: It is. My 13-year-old daughter loves it, that one day, and it is way beyond computational thinking. She was handling brains, is what she talked about at dinner that night.

I think it's a really important point that when I look across here, everybody's on their computers, and I know you're listening to me. But it's such a part of any meeting I go into. It's not rude. It is a part of the way we do our work. And it's a transition we have to go through to get our students and parents to understand that that's the world they're going into, and parents and students have to learn that structure and discipline as to when you do it and when you go up for air and be with your friends, that kind of thing.

Moving on, then, we have to teach students how to learn independently and with their peers, become independent life-long learners. We talked a lot about this already. They're going into a world where they're going to have to be reinventing themselves.

When I was at Stanford for those 15 years we completely overhauled the curriculum three different times. And obviously, it's a high-tech computer science, so having to overhaul it is not surprising. But one of the things that we did -- and this is something that might be relevant to you -- we really deliberately set up kind of a meta thing across the sequence of courses that the students had to take that required the students to constantly be learning new things. So for example, the first computer science course they take, they learn a programming language called Java, which is fairly easy to learn. There's lots of scaffolding around it. It keeps them kind of safe. They learn that language, do a whole bunch of projects in it.

And then the second course is in C++, which is a completely different language, a lot of commonalities but pretty different in the sense that some of the scaffolding falls away, there's a little more danger when you start messing around with the hardware a little bit more, and that's the first two classes of the major.

Then the next one that they take right after that, after they have declared, is a ten-week course where they do three different projects in three completely different paradigms. And they're deep projects, team-based projects, but it's just like, okay, do this and then, like, slap, do this, so that they are constantly having to switch gears in order to learn whatever it is they need to learn in order to get that project done.

Then from that point on they're going on into the upper-level undergrad stuff, and every course they take they are learning something different. If you're learning operating systems, you have to write an operating system in a really low-level language because you do have to control the hardware. So it's constantly shifting the ground under them. And the process that they go through not only helps them to learn really quickly; it helps them to identify -- and we actually have a capstone course where we make this explicit -- it helps them to identify the commonalities between all those things we have thrown at them. There's a lot of common ground in between different programming languages, different platforms, and various things.

When I was teaching there -- ten years ago is when I left Stanford -- there was no cloud, and everything they do now is in the cloud. So it's completely different than the way we taught. Everything we taught them then was on your laptop. Now all the tools you use are in the cloud. It's a completely different paradigm and way of thinking.

So these kinds of shifts happen a lot in that particular domain, and the students who come out of a program like Stanford are ready to just learn new things. So I don't know whether that applies in some of the ways that you think about the sequencing and the things that you're doing in your own courses, but there can be this meta thing where you can really force them, as they go through this, to be resilient and to be flexible and to identify those common themes that will help them learn new things.

SPEAKER FROM THE FLOOR: I'm wondering how you deal with the bugaboo in our field, which is assessment, because I think that's the limiting thing that we're all faced with is our assessment models are not designed to promote that kind of learning experience for kids. So we're bound by the way we think about measuring competence and mastery, and I'm just curious, when you have a program like that that's so clearly designed to teach how to learn, how do you deal with the assessments?

MS. JOHNSON: I don't know how much relevance this is for K-12, but I don't think you all have to deal with the kinds of stuff that goes on in the public schools, the kinds of assessments and things that go on there. There's that GPA thing. Yes. I get that. So if I think about CS1, that's probably the easiest one, for that ten-week period there would be four highly scaffolded projects; there would be some quizzes, a midterm, and a final. So there's a lot of work and there's a lot of opportunity to get some sense of what students are doing. The project work was

kind of check-plus, you know. It was much more effort and how much that they were able to accomplish, because it was a whole sequence of things that they were asked to do, and if they made it three-quarters and that was great, or if they made it farther, whatever. So we were really very careful about not inadvertently discouraging women, for example, or students who haven't been coding since they were two years old, which you have a lot of at Stanford. So you want to make sure you're not discouraging the students who are new to the field. So the project work was more on effort, and then the quizzes were much more on sections and what was covered in sections, because there is some tangible kind of material you have to test on programming language kind of concepts. And then the midterms and the finals were, again, project-based. It was like, oh, remember that project you wrote? Well, what if you had to add this other feature to it? So it's taking what they'd already done and hopefully internalized, because the project work is really key, and the exams were always building on the project work. And then it was something they could do in a couple hours on paper.

So I don't know if that's helpful to you. I'm not a K-12 teacher, so I don't know. We have so much more flexibility in higher ed than you have.

MS. BROWNLEY: What a great provocative discussion. This isn't why you're here, so I just think about our schools, where it's not so much college and GPA but in trying to explain to colleges what project-based learning is about and whether our kids have learned how to learn, because that was the crash against APs as one way of having understandable recognition. I think about Stanford as a 5 percent admit rate. You know, how do we get them to see a kid's portfolio work?

MS. JOHNSON: It's going there. I think in certain fields it really is, and the new computer science AP is a portfolio-based assessment. So you're totally on the forefront and that's great, but it's not easy. It's a transition that we're all in the middle of, and I don't have the answers. But it's great that you're trying to push forward on these things.

MR. McKEE: Mark McKee, Viewpoint School in Calabasas. I wonder, in your role both at Stanford and now working with universities, so much of what we do ultimately is driven by things like the A-through-F, A-through-G requirements of the UCs, which once upon a time decided that it was important that the kids have three years of foreign language, for example. With this focus on computational thinking and CS, are you seeing any shift in higher ed dictating down to K-12 that we'll need to be teaching computational thinking or computer science as that kind of a requirement?

MS. JOHNSON: Yeah, I would say yes. I don't know what it replaces, because that's a bigger question. You definitely are seeing across many universities, especially the larger universities, that those first two courses I talked about, CS1 and 2, are required for so many majors now. And if those are required, they're going to have to take something else away. You can't just keep adding and adding. So we're going to see more of that. But I do see it happening, just to answer your question, but it's a zero-sum kind of thing.

SPEAKER FROM THE FLOOR: One of the things that I saw in higher ed was that some of these intro computer science courses weren't really intro, and it was exposing socioeconomic advantages or disadvantages for students. And you know, we're coming from schools that are, I think by design, offering courses of the great majority of the Americans and people outside of the country don't have the opportunity to learn, and these computer science courses and higher ed, particularly in these schools, are not really intro, and it was an enormous issue. So I was just wondering what you have seen.

MS. JOHNSON: You're absolutely right, and it is a huge issue. We're going to get into this a little bit because there's this whole diversity problem in high-tech which you're exactly hitting on here. Right now there's an explosion in computer science programs and in many engineering programs. So there has been a lot of awareness-raising about the jobs available, about computation, computing in the future and how important it is. So there has been a lot of awareness-raising over the last three or four years in K-12. It's working because the students are busting down the doors to major in computer science.

Over the last three years, year over year, there's been a 23 to 25 percent on average increase in enrollments and majors in computer science across the country. Every single college. It's a huge issue for those departments. I won't distract much here, but the problem is that even though there's that explosion in enrollments and majors, the number of women and under-represented minorities has gone down. And one of the problems is that the way that the departments are dealing with this is they put a cap on it. And if they put a cap on the number of majors, then you automatically are sending an implicit message that this is selective, and that's not the way to encourage women and under-represented minorities to get involved. So it's a huge issue.

But let's get through this first, and then we can go from there.

MS. EVINS: Just one question. Penny Evins, St. Paul's School for Girls. Is there any way that your research is trying to bridge the gap between the computational thinking, preparing for job life, et cetera, et cetera, and growing good people and making fuller and enriched lives and the character piece of how collaborating through computation creates a stronger moral compass or something that we in our hearts can feel that has meaning rather than just the outcome of preparing you for the job?

MS. JOHNSON: Yes, absolutely. I think that that's really critical. If you think of a Venn diagram, the innermost circle, the way we think about it, that's coding. There's a relatively small number of people that we need for software engineers. It's a big number in terms of what we have now. We have an issue. But that's what we think of at this core. And then outside of that is computational thinking. We think that there's a larger set of students who need to understand computational thinking than need to code. And then outside of that is digital literacy. Everybody needs to know how to use the devices and the core applications. And then outside that is what you're talking about. And that's really as critical as the rest of it.

One of the things that we struggle with all the time at Google and at any high-tech company is this image of people working in our field and all they do is spend ten hours in front of a computer, and they don't talk to anybody. I'm just in my cubicle and that's all I do, just code. And it couldn't be further from the truth. It is completely team-based, it is highly collaborative, you constantly have to be working with others, whether it's on your team or across teams. It's completely counter to what people think it is. And it's very much what you're talking about in terms of not only working with your teammates but also coming up with products and services that are going to help people be more effective and productive and useful in their own world. So it has to be a big part of that, too.

Fostering creativity and innovative approaches. I mentioned earlier, innovation is as key to success as computational thinking in this century and I'm often asked, especially by kids, how do you define innovation and how do you teach it? I guess the first distinction is creativity versus innovation. Creativity is coming up with ideas, brainstorming, whatever it is you're working on, coming up with different ideas. Innovation is where you take one of those ideas and actually try and make it work. And if you try and make that idea work, sometimes you're going to fail and sometimes it will be successful. And failure is absolutely an essential part of the process. It is not just something to avoid. It has to be a part of the process. And the reason for this is that if you think about what innovation really is -- and I'll try and be as explicit as I can -- you know, for a kid they have all this stuff kind of

floating around in their heads. They've got concepts and all kinds of different things that they have learned from your teachers, they've learned by reading, whatever it is, and it's all floating around in their heads. And as teachers we try and introduce these kind of vectors that allow them to line up facts and concepts in a way that makes it more meaningful to them.

So for example, photosynthesis. I might know the chemical equations about photosynthesis and I might know the cellular structure of a plant and I might know what happens in the atmosphere, but until I put those all together in a vector, I have just random things floating around in my head. But once I understand, oh, you know those chemical equations are actually what happens inside that plant that causes that atmospheric cycle, that kind of internalization of that vector is learning. That's not innovation. That's learning. And we as teachers are always trying to find these vectors that make it easy for students to internalize those kinds of thing.

Now, innovation comes up where you still have all that stuff floating around in your head but you put them together in really weird ways. Take all those things and create some kind of vector that's just, aha, I'm going to try this and see whether something happens. So you put them together in ways that are thinking outside the box, that kind of thing.

A great example of this at Google is Project Balloon. I don't know if you have heard of this. But we're just about to really expand on this right now. These are high-atmosphere balloons, balloons that will stay stable in the stratosphere, they have a little bit of equipment on them that provides for whatever is beneath it to get Internet access. So balloons, putting a little bit of equipment, trying to get them stable in the stratosphere, is an excellent example of putting a bunch of things together that nobody would ever think to put together and, believe me, they tried a gazillion things that failed before they came up with the right combination that would allow for Internet access anywhere on the planet. Because all you have to do is place that balloon, and everyone has Internet access below it. So a great example of how you take things that are commonplace and put them together in odd ways and come up with something that is innovative. And that's really the crux of it.

Now, how do you teach this? I think it's to provide students that opportunity to put thing together in unusual ways. And Esther talks about this thing called Moonshot Friday, and it's based on the notion of 20 percent time at Google. We still have 20 percent time at Google. One day a week every engineer has the opportunity to work on whatever they want. We encourage them to work on the product they're

working on and do something new and different within that context, but they have that day to do what they want.

We have a long list of products that have come from 20 percent time. For example, Gmail. That came from 20 percent time. And the atmosphere at Google is really interesting because it fosters this kind of innovation. If you have ever been there, the campus feels very academic, it has all kinds of little nooks and crannies where people can go and work together. There are whiteboards everywhere, and all kinds of things on whiteboards that you're, like, what is that? And it's always filled with various things. There are pool tables and games and food everywhere. It does everything it can to keep everybody there all the time, which for the 50 percent of new graduates that we hire, they do that. They stay there all the time.

The point is that it really does foster innovation by providing an atmosphere and that kind of opportunity to do this putting things together that don't necessarily match.

Now, Esther's idea, Moonshot Friday, same thing. From lunch to the end of the school on Friday, every single Friday, it's maker time. It's innovation time. And it's a place where at least for her classes, she makes it so that there are long-term projects that kids can do on every Friday afternoon. And it can start with just maker stuff, like a maker kit or some kind of project where, okay, put the paper clip and the rubber band together this way and see if it works, or whatever it is, so that they learn about innovation, putting things together in unusual ways, and they learn that failure is totally okay. Failure is absolutely an essential part of the process. So that's one way of thinking about bringing innovation into the school week and having it be a long-term thing that you can actually try.

I want to shift gears and talk about leadership. This is much shorter, and then we can take more Q and A and more comments. As we think about particularly the young women in your schools and fostering leadership capabilities, at Google and really any company, there are four categories of workers. And I'm really simplifying, but the four categories are managers who are leaders, so you have someone who not only defines the vision, defines the strategy and then the long-term plan for making it happen, but also manages the people and the work. So they do it all. So it's managers who are leaders.

Then you have managers who are not leaders. And this is a very common thing at Google. We have engineering managers who manage the work and the people and the career development and all the things having to do with having direct reports.

And then you have tech leads who are technical wizards and they're the ones who look two years ahead and say, "Oh, here are the features we need to be working on now." And those two together are partners for this team, and that's a really common structure for us. So managers who are not leaders, and that brings us down to individual contributors who are leaders. Those are tech leads. That's what I was just talking about.

And then you have individual contributors who are not leaders. And this is a great little picture that illustrates at least part of that. You have got a manager who is managing working people. And then you have got a leader who is actually down there doing it, so you have your tech leads, and then you can imagine somebody doing both, much harder. And then you have lots of individual contributors who are not leaders, who are workers. They're doing the work. And by far that's the majority of the people.

Now, the reason I bring this up is because in the real world, not everybody's going to be a leader. In fact, most people are going to be individual contributors, hugely productive, high achievers, wonderful workers, but they're not leaders. So it's important for you as administrators and teachers to recognize that not everybody in your school is going to be a leader, but what's really important in K-12 is for every student to have the opportunity to try it, because it is a learned skill. It's not innate. A lot of people are innate leaders, but you don't have to be. It's something you can learn.

So everyone should have an opportunity to try it, but not everybody's going to want to do it. It's not something that we should force. It's something that we should provide the opportunity for.

So the things we talked about earlier were learning to define meaningful strategies and goals and making the plan in order to meet those goals; being able to create a really healthy, dynamic team and drive the team towards accomplishing those goals. And then confidence and resilience, and I'll talk about that in a moment.

One thing I wanted to say here is this whole Moonshot Friday of having a period of time each week where you can have a longer-term project that students work on, maybe something important in the community or similar to what you were talking

about, where it's a capstone kind of thing, are really useful for having students be able to try these different roles. They can switch out of being the lead, and have the opportunity to see whether it's natural for them or whether it's something they like or whether it's like, you know, I'd much rather be the one doing the work. Totally fine. So it's just giving them opportunities to try it.

Now, the thing I wanted to just take a couple minutes and finish up with has to do with young women coming into the engineering technical field or any field where it's male-dominated. And this is this idea of confidence and resilience. It's a really challenging problem, because all high-tech companies are very focused on diversifying our work force right now, and this is because not only is it a social justice kind of thing because the demand is there, the salaries are there, and it's something that we really want to have much more equity, but speaking more self-serving, it's like if we're going as a company to create products and services that are truly accessible to everybody, then they have to be created by a diverse work force. If it's just Asian and white men creating all our products and services, there's going to be an inherent bias. There's no way to avoid it. So we have to diversify our work force. It's a really big challenge. Some of the things we were talking about earlier, the pipeline is growing and that's great, but we've got this choking of the pipeline going on right now, because there's a capacity issue in computer science departments, and even if there were no capacity problems, we are still losing the women and the under-represented minorities. So that's some of the ways it's being handled.

One of the things that we're focused on, at least at Google, is that there's research around the fact -- it's really quite intuitive, too -- that once you reach a certain threshold, around 25 percent, 30 percent, once we have, say, 30 percent women or under-represented minorities as a part of our demographic for our technical work force, all these issues start falling away because one of the biggest issues that a woman faces, say, they're on a team of five and they're the only woman, there's an implicit message there that you don't really belong here because you're the only one. And if there aren't enough women for them to talk to and enough women for them to build that support network for helping them have more confidence and resilience, it's really hard, and they leave. Even if they just perceive that the message is sent, it's enough for it to be real, and it may not even be sent; it's just something that's a really difficult problem. But we're working really hard to try to get to that 30 percent threshold, because once you have that, all of a sudden there are two or three on the team. They're just there, and then a lot of these issues just fall away. But getting to that number is really hard, especially when you're taking about 18 percent coming out of the undergraduate programs right now, you know,

there are just not enough. And the women, even in undergraduate programs, are really suffering, too, because if they're the only woman in a class, then again they're getting that message.

So the support network that they need requires mentors, it requires role models, it requires people who are like them who are successful that they can see and aspire to, and there are just not enough of them. So it's similar to what we have been talking about, all this transition of trying to move things forward toward the kinds of educational processes and pedagogy we need for the 21st century. It's the same thing for us. We're in the middle of a transition, but there's a lot of focus on it and we really feel very confident that we'll get on the other side of it eventually, but it's a hard problem.

Let me just say one last thing. I don't know how much time we've got.

MS. PERNAMBUCO-WISE: We've got about five minutes.

MS. JOHNSON: So given all the things you heard here from each other and the things that I presented, again, I would really encourage you to think about what tangible things you can take back and try, and do it in such a way that you can figure out how to package it up so others can try it, whether it's others here or whether it's other teachers just in general. It's not that much more work, and it just has the potential for really increasing the impact of the experiments and things that you're trying, so I encourage you to do that. Any other questions?

SPEAKER FROM THE FLOOR: Maggie, Google does such generous things in education in giving away Google apps for education and Google is a for-profit organization that is one of three or four different corporations that are really huge on the team right now. We're all running these nonprofit organizations with an educational mission. Can you help us think about how your organization that you said feels very much like a campus and an academic setting -- we're all in an academic setting, very much nonprofit, and should we worry about the for-profit mission of Google versus the nonprofit mission of our sector?

MS. JOHNSON: Oh, boy. That's an interesting question, because there's the for-profit aspects of Google, there's all kinds of different ways of perceiving why we are in the educational realm and why we work so hard in that domain. What I can say is that education is one area at Google that is probably the least connected to a for-profit world, and the reason I say that is because we fell into education completely inadvertently again and again and again.

So if you ask Larry Page five years ago before he had kids -- now he has kids, so it's different -- he always said, "Google is not an education company. That is not a domain, it is not a sector, it's not an industry I want to get involved in." I would say seven years ago, because the kids are older now and he's not saying that now but he said that very distinctly then.

And what happened over the course of maybe three or four years, first of all Google Apps came out, and Google Apps was designed for small business, it's designed for individuals. We had no idea that it would be so revolutionary in the classroom in the sense that it's like it's in the cloud so everybody can share it and everybody can interact and collaborate, and it's just right there. We had no idea. And then teachers started using it, it started taking off in the education sector and we were, like, "Just give it away. This is not a place where we want to make money because we can make money off enterprises."

So we fell into that. And then Chromebook, it's the same thing. Chromebook, small and medium businesses, created to develop this really hardy little computer for businesses and it took off in schools. Again, a complete accident. We did not plan for that. And it's great in schools. It's cheap, you turn it on and everything is installed and up to date. You know, all the things that we like about netbooks in general, but again, it was completely accidental. And now we're in it and Chromebooks are going crazy in the education market. But we didn't intend any of this.

And each time we reacted by just saying we don't want to make money in education; we have plenty of other ways to make money, and we view education as a nonprofit area within the company. Now, there are skeptics who would say, "Well, we're building the next generation of Google users by having them all on apps." Okay, why not? But we won't monetize, beyond selling Chromebook, but we have to sell the devices. Everything else -- Classroom is free, all those things. I don't anticipate ever monetizing those things.

I don't know if that answers your question, but it was a completely accidental thing for us to fall into it.

SPEAKER FROM THE FLOOR: Should we trust Google?

MS. JOHNSON: Yes.

MS. PERNAMBUCO-WISE: In the interests of time, we'll take one last question.

MR. BURNS: My question is, because this organization focuses on women in leadership and girls in leadership, obviously, moving up into womanhood, I'm thinking of your last point about the male dominance and how you could eventually achieve the 30 percent involvement of women in small groups. What are you doing, if anything, to work with the males to understand that they are both part of the problem and could be an innovative solution to working to develop a way for more women to be involved? In other words, the problem isn't going to be solved by the company. It could be solved by a mind-set, perhaps. So are you approaching any of that?

MS. JOHNSON: A really good point. At Google there's a lot of education that goes on around unconscious bias and trying to help everyone in the company to be sensitive to how you might be, in your own mind, biasing various observations and various assessments, whatever. So we really try and desensitize across everybody for that.

But the one thing that came to mind when you were asking the question, it is absolutely essential to focus as much on the men as the women, because they can be supportive and helpful and that's something that we really try, to raise that awareness.

We have this program that we're doing at Google. We've run it for about three years now. It's called an engineering residency. And it's a program where we're taking students who, for example, didn't have the opportunity to go through Stanford and get a CS degree -- and there are many, many, many students out there, all brilliant, tons of brilliant students in the smaller liberal arts colleges studying computer science, but they're not getting that kind of project-based intensive experience that you get at Stanford, but they're still brilliant and we know they're there and we know they're good, but there's a gap there in terms of getting them ready for working in a place like a high-tech company. So we go specifically to these programs and we offer them a residency program which is a one-year opportunity to come to Google and spend that year kind of filling those gaps that they weren't able to get from the program that they went through.

And the reason I bring it up is because we focus very much on diversity hiring there, so we hire women and under-represented minorities into the residency program. It's always about two-thirds to a third, so it's two-thirds diversity and a third that are your typical demographic. And the thing that happens -- and we run many cohorts through this now -- is that that third of the men, they're a minority that entire time. The 30 percent has switched on them for that year. And looking

at how they react to that and what they learn from it is really powerful, and we're trying to take what that experience is and make that more broadly available to the other majority at Google. But injecting that kind of a cohort, which we've been doing -- and we've done hundreds now -- into Google has had a huge positive effect, not only in getting us closer to that 30 percent number, but also the men who go into this through that experience have a completely different perception. So there's something really there. It's really important.

MS. PERNAMBUCO-WISE: I think we can all agree, it was well worth the wait.

MS. WADE: Thank you, Maggie. Very powerful, incredibly thought-provoking.

And now you have 12 minutes. Bring your bags and come right back. Can't wait to see you.