Good morning,

I am really glad that this conference is taking place here, because other than the war in Ukraine, the most important issue that I have been dealing with for the last 20-25 years has been the issue of IT and education. Broadly STEM – science, technology, engineering and mathematics – and its education as a key to the future.

Of the two most important educational experiences or choices in my life, the second one was my choice of university, which I made for the wrong reasons but which ended up being very good for me. But the most important event, which given the time was quite extraordinary, was that when I was 13 I had a math teacher who was doing a PhD in mathematical education. She decided to do an experiment, which was that she taught in 1968 13-14-year-olds how to program in Basic. Most of you probably do not remember that it was all very primitive back then because you would write your programs out on tape on a teletype and then you would get a big modem and a telephone and connect to the main frame some 50 miles away. And then you would run your program – and it would not work. I did learn to program and I thought it was fun. I did not think much about it, I have not really been a science student, but eight years later when I was in university I saw an ad for a programming job and I got it.

These early experiences have had an influence much later in my life because I realised that not being a science person, I could program. But even more importantly, I have never been afraid of technology. I have never been afraid of math and science, and not because I am a great math student. If you get an early education in mathematics, then it is just like a language. If you do not get a language by age 13-14 you can always more or less get by with studying hard, but you never get rid of the accent. And if you do not learn to play a musical instrument by 13-14, you will never truly be great. What is important to know is that you need to start early. And as I conclude, we also do not need fear. I think that is one of the biggest problems we have in education today.

But let me get now to Estonia where, I assume, some of you have never been. About 20 years ago we were at a unique juncture. Estonia had re-established its independence in August 1991. In 1993 I was the ambassador of Estonia to the United States. Our big problem was how we would catch up after 50 years of Soviet occupation and enforced backwardism. You see, back in 1938-39, before we lost our independence, we had more or less the same level of development with Finland. Maybe GDP per capita was slightly higher there, but not much.

When we became independent, the difference in GDP per capita between Finland and Estonia was more than 10 times. So we had a big problem: how would we catch up? We did not have the infrastructure development of the countries that were on the right side of the Iron Curtain. We did not have a lot. We did have one thing, which was pretty good technical education. Which I think played a role later on. We did not see the fall-off in science and math studies that we had already seen in Western Europe in the 1970s and 1980s.

At the same time there was a unique juncture. In 1993 Marc Andreessen created the first web browser, called Mosaic, which probably some of you remember. That was extremely important for people like Estonians, countries like Estonia, because we learned fairly quickly that we could do a lot on the level playing field that the new infrastructure opened for all countries. I think one of the first national or government webpages ever put up was put up in 1993 in Estonia. Now it is such a boring and dull a place, but back then someone had the good idea of creating it. Another thing we also discovered was the importance of legacy technology or not being stuck to the legacy of technology. I fought one battle from afar with the Estonian government – from afar, because I was in Washington as an ambassador. I heard a ridiculous idea that the city of Helsinki had installed a new telephone exchange and in 1992 they wanted to give the old analogue 1979 telephone exchange for free to Estonia. We were quite poor that time and everyone said now we can get newer telephones because our telephone system was the old model from 1938. But I thought, no, no, you cannot do that, because you cannot get stuck with legacy technology. That was a lesson that the British and French learned after the Versailles Treaty when they confiscated German industrial plants and got for themselves all kinds of technology from the 1900s or 1890s that they then installed in their countries in the 1920s while the Germans went ahead and built brand new machines. So I fought that battle and a couple of other people here helped, so we ended up not taking the free telephone exchange, but instead we ended up having to make a major investment and actually digitising our telephone system. That was one of the best decisions the government made.

The real importance of IT came to me at last from reading a Jeremy Rifkin book called "The End of Work", which was a protest book against modern technology, automatization, computerisation, arguing that all of it would lead to massive unemployment. He gave one example there about a Kentucky steel mill that was bought by the Japanese. This was the time of the early 1990s when Japan was buying up everything in the world, so the Japanese bought this plant that employed 12,000 steelworkers and produced X million tons of steel a year. They completely automatized and computerised the plant. After that they still produced X million tons of steel a year, but instead of having 12,000 employees they had 120. Which, of course, from Rifkin's point of view was a terrible thing to happen. But if you are Estonian and your population is 1.3 million, which is basically half the size of Copenhagen, then the idea that you can increase massively the functional size of your economy through digitisation, computerisation and automatization, is a wonderful thing that we should embark on. If you want to have a society where you are not bound by your population, but bound only by the intellectual energy and intelligence of people, then you must approach education. And what you really need to do

is STEM – subjects like science, technology, engineering and mathematics – and you need to start doing it early.

The next idea we had was computerising all the schools. So by 1997-98 all the Estonians schools were online. At the time being online often meant dial-up, being online meant not having very good computers, but it did plant the seed of something. Students, though they did not learn to program, they did get access to computers. As always happens, there are always three or four or five students out of 100, who start figuring out what is going on with the computer and teach themselves how to program. As an example, right around the corner you can see the R&D headquarters of Skype where the graduates from this university here and also Tartu are working. They are people who, because of their family background or education, started playing around with computers at a very early age.

In order to get any real development you need to have skilled people in science and mathematics and you need to start teach them early. If we look at the PISA tests, we see huge differences in scores of countries in mathematics, science and reading performance. In the last PISA test, done in 2012, of the 65 countries tested, the first seven places in math were from countries in Asia. Estonia, however, did rather well also. We were 11th in the world in math and reading and we tied for 4th to 7th place in the world in natural sciences with Japan, South Korea and Finland. So there must be something right that is going on with our education. In Europe the two countries that do the best in PISA test today are Finland and Estonia, but the so called "old Europe" is behind. We see that with proper education you can overcome all kinds of seeming discrepancies and divisions between countries.

I would say that a good educational system in STEM subjects and openness to technological progress has helped these two countries. Because I cannot think of any other reason, except for perhaps that because Estonian and Finnish are bizarre Finno-Ugric languages the logic of those languages makes us better in math, but frankly I do not believe that. What we have done here is try to use as fully as possible everything that can be afforded to a society through digitalisation. For example no one gets prescriptions anymore on paper. So if you go to a doctor, they put everything on computer. PKI or public key infrastructure, digital prescription, online voting, banking online – all of it is something that has taken place in our country because we are a little less fearful. It has probably less to do with the educational system, and more to do with just the willingness and the early adopter mentality.

This ICT revolution in Estonia has lasted for a generation, but I have worries that we are not going far enough. If you recall, I started off with Rifkin's book "The End of Work", which was published 20 years ago and where he talked about the steel mill. Well, there is a Luddite book

out – it came out last year – which basically repeats this idea. The book is by Andrew McAfee and Erik Brynjolfsson, called "The Second Machine Age". It advances the same idea that in fact we are going to lose our jobs. The issue today is that we have been living at such an accelerating pace of change in IT that now it really is beginning to work. Today we are at the threshold of having self-driving cars. Maybe it will take another five years; maybe it will take ten years for the self-driving cars to come to Estonia, because they cannot handle the weather here. Nobody could think of self-driving cars 20 years ago, but today we can. What does that mean for the society? Well, certainly the taxi industry is going to change even more than it has changed thanks to Uber (or should we pronounce it Über?). What about trucks? Who is going to be a truck driver?

Maybe not yet, but 20 years from now there will be a scenario that the skills we need to live in the early 21st century may become completely useless. This would lead in turn to other changes, meaning that there will be people who can do things in a highly technological world and people who cannot. And the people who cannot will have a rather limited set of options for employment. What can those options be? A lot of them will be in very low-paying jobs. But being, for example, a science teacher – that would be good! Thus, we have to think a lot about how we are going to make sure that in our case Estonian society – and in your case your own countries – will do well in the future where, on one hand, we have accelerating change – it really is accelerating – and on the other hand we have a major drop-off in the interest of students in technology or mathematics – anything quantitative.

The reason I said the change is accelerating comes down to the so called Moore's Law. Mr. Moore came up with a hypothesis in 1965 arguing that every 1.5 years the computing power of a chip or a transistor will double and the cost will remain the same. What does that mean? That means a genuinely exponential rate of growth. When I was at the European Parliament last October trying to argue that Europe has to do something about its education and its economy to deal with the digital economy, I said to the politicians there, that keep in mind that after 4.5 years (that is also approximately the election period) the cost of computing in 4.5 years will remain the same, but your computers will be two to the third times more powerful. The crux was when one parliamentarian said, "What is two to the third?" proved them! So, we do have a problem! This question reflects a lack of understanding of people who make decisions in our lives. When a parliamentarian has to say, "What is two to the third?" then it is going to be hard, more difficult to get serious change in societies – if your politicians do not have the math education that should be part of basic understanding. Two to the third should not be too much for adults to understand.

So we do have some major challenges and these challenges will determine whether our societies will be successful in the future. Given this accelerating rate of change, we need to focus our education on math and science, and to do that at an early age. By the time children

get to the university, it is too late. If you do not start early, you will have universities filled with people studying public relations, all kinds of other things, but you will not have people who know what two to the third is, and we will end up seeing a greater and greater stratification of society based on your ability in quantitative realms. I mentioned the study of math at the universities, but we also need to address the issue of early education in mathematics.

One key issue that we see – aside from the fact that girls seem not to do as well as boys in mathematics – is the fear of mathematics. As a matter of fact some studies have shown that the fear of mathematics affects performance even more than actual knowledge in mathematics as you can raise scores by eliminating fear, so there is a psychological component. Equally important in the psychological component is the fear of failure, which is maybe even inherent in mathematics, because there are right and wrong answers. You know, I can write essays on all kinds on subjects and as long as it is grammatically right, I usually get a good grade. The problem in mathematics is that there is a right answer and there is a wrong answer. So, you can fail. You get the right answer or you get the wrong answer. We need to affect the psychology of teaching to the point that students do not fear failure, because fear of failure is, I think, one of the primary stumbling blocks to genuine progress. We can see that in the United States, at least in Silicon Valley, where failure does not any longer have a stigma like it does in other fields. You CAN fail. If you fail, you start over and do it again or, if you are younger, you do the math problem again until you finally figure out how it works and get the right answer. So, too, with the technology and technology industry where failure is not a sign of failure, but rather a sign of being creative and trying out ideas and then starting over. We need to bring that spirit into math and science education and we need to do that at an early age. And we need to make sure that in the future all of us, or at least far more people, are literate in STEM subjects.

So I will end here as I have been going on far too long. I wish your conference all the possible success and urge you to think about how to get kids learning math and science – and liking it – at an early age. And do, do teach kids how to code! Please!