40,000 Hours to Create a Robot Gardening Business and other Futures for Education and Training. An Interview with Dr Bror Saxberg, VP Learning Sciences, Chan Zuckerberg Initiative.

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Abstract

JALT's editors Christopher Harris and Jürgen Rudolph spoke to Bror Saxberg, who is currently the Vice-President Learning Sciences of the Chan Zuckerberg Initiative (CZI), a not-for-profit organisation founded by Facebook CEO Mark Zuckerberg and his wife Priscilla Chan (a medical doctor). Amongst other things, CZI has the audacious goal of curing, preventing, or managing all diseases "in our children's lifetime" (Farr, 2018). In a wide-ranging interview, we began with Dr Saxberg's lifelong learning journey from pure research to being a 'learning engineer'. Other topics include: the promises and pitfalls of e-learning (including m-learning); the 'undead' lecture as an enabler for 'learning tourism' and the importance of practice; the importance of metacognition (that we know how to learn) in mastering multiple, difficult-to-automate skills and competencies in a lifetime of continuous learning in a world that changes at breakneck speed; how we can create top performers and maximise corporate potential via evidence-based training programmes; the paradox of knowledge (our ignorance increases with more knowledge); and key teaching strategies for a personalised learning approach and promises of neuroscience. We have divided the interview into ten parts.

1. From researcher to 'learning engineer' – from pure research to application at scale

Eds.: Thank you so much for agreeing to this interview. We very much appreciate your making yourself available. Your leadership in your previous role with Kaplan inspired us here in Singapore and around the globe to get into measurement of learning a lot more and consider fit for purpose, outcomes-based approaches from a teaching point of view, but I think it is fair to say that you are also a lifelong learner... Could you share a bit with us about your own learning journey with some of the world's most famous tertiary institutions like Oxford, Harvard and MIT?

Figure 1: Dr Bror Saxberg (Corcoran, 2017).

Dr. Saxberg: It's an odd journey, I started life as a research person. I used to do human and machine vision research at MIT's Artificial Intelligence Laboratory. That was back in the day when I was going between Harvard Medical School and MIT, because I was interested in how the brain processes and stores information and I was planning a good research career based on that.

After I finished my MD and PhD, I realised that the best labs were run by people who knew how to put together equipment, ideas, resources, funds and get them all to go in the same direction (laughs). And while poor labs were chaos, good labs had people who knew how to do this. Nobody was teaching graduate students or even young faculty members how to do that and I certainly wasn't going back to school after spending so long in school already. So I hunted around to see where I could learn this: I ended up at McKinsey and Company where I spent five years in New York. I figured those guys went in and solved problems like these for businesses all the time so what better place to try to pick up how to do this well?

A funny thing happened on my way through McKinsey because I really got interested in action at scale: by applying systematic approaches, thinking about organisational change issues and more you could make a difference in the real world. So when I finished my time at McKinsey in the mid '90's, I decided to jump into the middle of an edtech boom of that era, the CD-ROM revolution, to see if I could combine my technical capabilities with impact at scale. I managed to find a role as General Manager for a company called Dorling Kindersley, running their US Multimedia division. Ever since then, I've been on a series of assignments that are at the intersection of cognitive science, curriculum, assessment, instruction, technology, always at scale, always facing many users, not just a research setting. I continued that all the way through until I was lucky enough to work with you all at Kaplan for quite a few years.

So I started as a research person and turned into what I now think of as a 'learning engineering' person in terms of building things at scale.

Eds.: So did I sense that there was some frustration with the limits of the research part in terms of outcomes or application that the engineering part seemed to satisfy?

Dr Saxberg: I think it was less a sense of frustration with the research, but more an excitement about impact. In other words, I didn't get less interested in the research side, but rather the ability to affect 10,000, 100,000 or a million learners or more (like we're trying to do at the Chan Zuckerberg Initiative) was pretty exciting and was more motivating to me. It didn't reduce my interest in research: I was really engaged by the question of how best to apply research results at scale.

I'd started life as an Engineer anyway: my undergraduate life in Seattle was as an electrical engineering person as well as a math person, so I've always been interested in building. My research life was indeed pure research, but my time at McKinsey brought me back to thinking that building and having an impact out in the real world directly on lots of learners, like Kaplan does, was more attuned to my interests, so I made the shift.

Eds.: Wonderful. Our Journal of Applied Learning & Teaching that has only had one volume, has already managed to produce its own sub-themes of sorts and one of those is the lifelong learner, which is why we're so interested in your own learning journey because we all know teachers aren't always the best learners but you buck the trend...

Dr Saxberg: ... One thing I would say is that my whole journey has been a change journey just like for you all. Being enmeshed in technology, you can't help but be changing what you're doing and having to come up with new ideas and new ways of making use of that changing technology. So it wasn't hard to keep changing and learning because there was no choice really (Eds. laugh). You know the CD-ROMs of the mid 1990's are gone and you know the capabilities of computers have moved on, what is it, a thousand fold? So if you're going to be doing this kind of work, the technology-enhanced work, you just have to accept you will keep learning and changing and that's not going to slow down. You're completely right about lifelong learning!

2. Promises and pitfalls of e-learning and m-learning

Eds.: We were chatting before the interview about some of the recommendations you'd made as Chief Learning Officer of the Kaplan group about reading in this vein for our own learning, including Clark and Mayer's E-learning and the Science of Instruction. In the third edition of 2011, the authors make the point themselves that digital technology continues to evolve rapidly. What would you say are the promises and pitfalls of e-learning and perhaps also learning today compared to when the book came out seven years ago?

Dr. Saxberg: Well, there is a new edition of this great work from 2016, if you're interested; they've been updating it every two or three years, so you'll need to order another copy. Sorry about that (Eds. laugh)!

There are a few things that continue to be terrific about the e-learning world and mobile learning which hinge on the flexibility of those tools, and the ability to engage interactively with a wide variety of learners in many ways. It's not just video watching and multiple choice question answering – there are new environments such as simulations and virtual reality spaces that create a broader set of experiences.

I think one of the risks of e-learning can be isolation: if you don't consciously address it, then the way you might be learning is only on your own – that's not enough anymore. Getting this right is a work in progress: how do you get important working-in-team experiences coupled with the e-learning and mobile learning work?

More generally, not just about technology-enhanced learning, I think we've been undercooking all kinds of non-academic learning issues. One of my colleagues at CZI, Brook Stafford-Brizard talks about comprehensive student development. In addition to academic or workplace task development, you need to think about developing other aspects, things like a learner's own identity development. What do the learners think about who they are and what they can actually learn? If a person is running around with an identity that says 'I can't do math', they're going to be very different in a learning context or around the workplace than if they're neutral on the topic, or thinking 'Yeah, I'm a math-using human being. I use Math all the time.'

Issues around what identity a learner needs to develop, and what toxic elements of other current identities they might currently bring in are not things we usually think much about when we design training and learning experiences. Similarly, other non-academic, non-work-task aspects get short shrift, including social and emotional learning – the capacity to talk to other people, work with them, understand their and your emotions, seeing a problem from somebody else's perspective. These are important skills for the future. Arguably, these are the skills that are the least likely to be automated over the long haul.

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The sorts of cognitive and information processing and even mechanical skills that people have historically distinguished themselves by are ones that are increasingly able to be done by robots or other kinds of 'intelligent' appliances.

The good news is this makes it less likely people will be swotting tables of numbers and procedural work with pencils or calculators: the machines are pretty good at that stuff. But other issues will then require expertise: how do you explain a best solution to somebody else, how do you help somebody think through trade-offs for a solution that will work best for them, how do you think about somebody's life stage and current misery or joy and family situation – all are the kinds of skills that are going to last a long time as valuable skills for human beings to do with each other. I don't think we have enough progress yet with any technology to replace these, so we need a more explicit focus on making sure these very essential human skills get built out while we also work on whatever the current workplace skills evolve to, guided by information-rich appliances.

I do think technology has the possibility of giving even more possibilities for interesting training. Things like natural language processing of human voice recordings may help with some rehearsals and role play. Rather than having it expensively reviewed by a human expert, you may be able to get some initial feedback with an IBM Watson-like artificially intelligent agent, maybe not the best feedback, but some feedback quickly to at least get you started on improving as a learner.

Mobile devices are great, too, but phones have very limited screen size. This may be a problem for some instructional approaches, because some outcomes require the use of a full visual field, e.g., to lower cognitive load for a novice by providing more structure and information around the visual field. The tiny screen doesn't help as much on that front, but there are other terrific uses – the trick is to fit the learning purpose with the different technologies you have available.

Eds.: Yes, we're doing that at the moment for this interview, in fact. We have our questions on the right of the screen and then we have the live video recording of you and various other sources to guide us...

Dr Saxberg: Yes, and if you were trying to do this on an iPhone, not so easy, right?

Mobile can be fabulous, allowing learners to take advantage of times and locations for learning that pop up in their lives somewhat unexpectedly. We have to make sure that we are matching what's good about a technology to the kind of learning that we put through it instead of trying to force-fit all learning through any device even if it won't really work. The fact that you can work on a mobile device while you're waiting for a bus or when you're on the train or someplace else is great, but we have to design carefully for that brief moment with the limited visuals of those devices. The answer to 'Is now the moment to take a good look at that big art history textbook page?' might well be 'No', because you can't see anything of the big picture, you can see just the nose on a Picasso on your iPhone in sufficient detail, or a vague view of the whole painting, but you have no real sense of what the Picasso looks like. Not a good way to use mobile technology, so use the time and device differently. The trick is to match the technology with the learning event that gets you the outcomes that you're after.
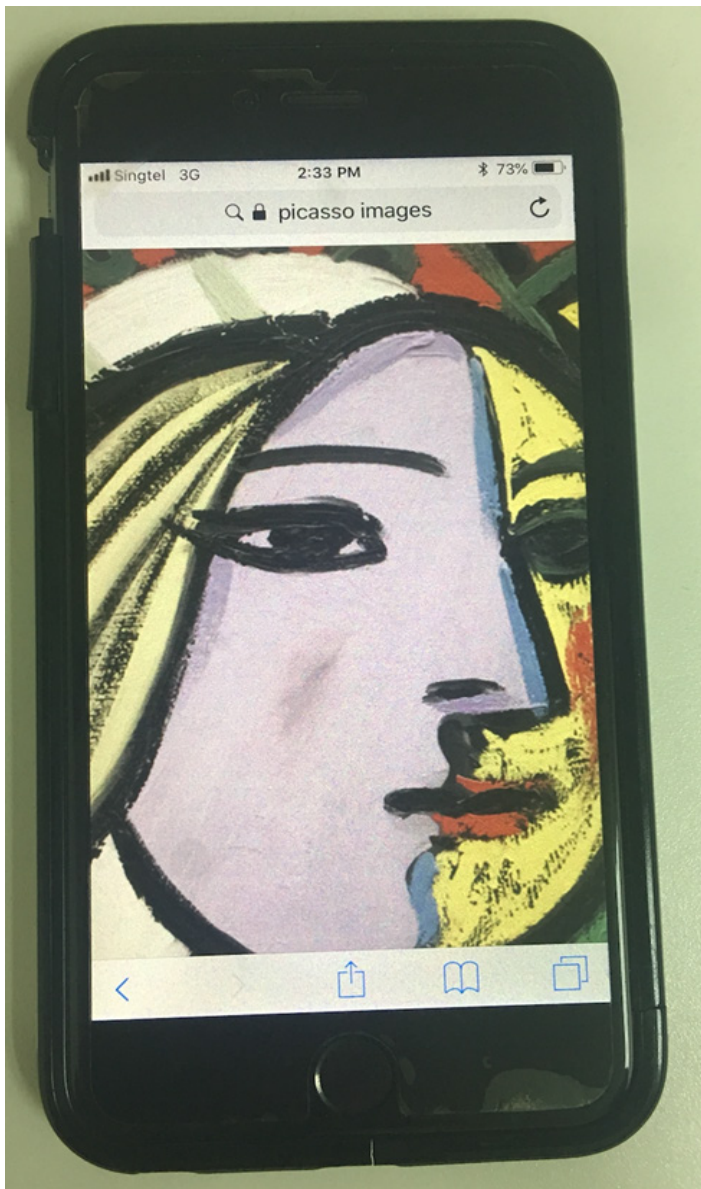
Figure 2: Looking at the nose of Picasso's Woman Before A Mirror on an iPhone.

> "The trick is to match the technology with the learning event that gets you the outcomes that you're after."

Eds.: So if I may summarise, designers of the future and instructors should be thinking about: how do we incorporate the concept of team into this, the social, emotional and empathic approaches that are essentially human things that are hard to replace.

3. Metacognitive knowing about learning and a longitudinal approach toward mastery

Dr. Saxberg: Yes, this is right. However, one other thing I have to add to any description of what designers, purchasers, administrators, and of course teachers need to be able to decide and do about learning materials is to understand more of the empirical evidence about how learning actually works. That allows us to design, purchase, and train for what we know about the limitations and capabilities of learning from evidence we have, rather than how we wish learning worked.

> "What teachers need to be able to decide and do about learning materials is to understand more of the empirical evidence about how learning actually works."

There is far too much learning designed for how we wished learning worked: if we listened to a great video from a fabulous lecturer, wouldn't it be great if that was enough to build expertise? Unfortunately, it doesn't work for almost all learners: if you don't engage in pretty detailed practice and feedback about a skill, most people won't acquire it. It's inconvenient that we can't just run a tape in front of people and have them gain skills, but that is the nature of human learning.

To get there, we need designers as well as teachers deeply understanding concepts like those in that *E-learning and the Science of Instruction* book you cited. Even if the evidence is frustrating, they should take it into account as they try to make the right trade-offs for learning. Designing learning, or anything else, is all about trade-offs and it is better to make evidence-based trade-offs than guess-based trade-offs.

Eds.: Yes, I was validating some lecturers for teaching roles the other day and you still get that problem of them never using evidence to check their gut reaction. There's a lot of assumptions about what their learners have learned. I would ask them how they knew that the learners in their class had achieved the outcomes the lecturer had planned. They would say 'I saw their body language was very positive', but no way of checking and assessing this objectively.

Dr Saxberg: Yep! They were not trying to gather real evidence of a mastery change – it is hard to do, but key. I suppose another piece of evidence that is hard to collect but should get easier as time goes on, is longitudinal evidence for mastery. It shouldn't just be the quiz at the end of a lesson and the assumption on the part of the faculty that, 'well my job here is done because most of the students got a high mark on this quiz.' In theory, we're not only trying to get people to get high marks on current quizzes, we're trying to get them to master complex cognitive skills for real-world use over time. So another really valuable skill for designers is to ask: "What's coming next that makes use of that skill that we intended this person to master?" and then go look and see if the earlier mastery is evidenced in that later exercise.

Writing is a good example of this. The essay practice you did in English class turned out 'great' and so now the theory is you've learned to write. How about that later history paper? Is it inadequately written? If a later piece of work that should be advanced by an earlier piece of mastery doesn't show that earlier mastery, then something is wrong.

An inconvenient truth about mastery is that you need to practice the transfer of it to a new environment; you can't

just write one good essay in an English course and say we're done mastering writing. You have to do several, and keep pointing to the general principles that you're using, to improve your writing. This will raise the odds that when you're in another new environment you'll be able to apply the principles in that new environment, too. It's a bit humbling

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but it is a really important part of being a designer that as we start to have better and better data systems capturing longitudinal information, we should look two years out to see how kids did on the written assignments against the same rubric that we assessed them on back at the start. Can we see that they're still writing in the way that we intended them to write? Or do we have to fix something because every time they write a lab report in Science they are terrible; we got it working in history, but why aren't they writing well in Science? This kind of longitudinal investigation allows you to realise you've got to go back and revise your early instruction in the writing course to make sure it generalises better. Sorry, long answer to a short question!

Eds.: Not at all, and I was just thinking about the Professor that always likes to teach both first and final year because they want to see what has stuck. What was sticky?

Dr Saxberg: That's a great attitude! I think it's rare among Professors to have a clue about long-term outcomes of their learners from early, large courses – quite hard for them. Hard enough to recognise the students!

Eds.: Well that always depends on the number of students. We often teach 400 in the semester, not at the same time, of course and we spend half of the time remembering half of names. The frustrating thing is actually in the beginning we only recall a few names and then by the last class we know most, but then we don't see them for a while and we've forgotten them all. Perhaps we should take your advice and do longitudinal name recognition?

Dr. Saxberg: Maybe some spaced recognition work? You know, Ebbinghaus' research from the late 19th century: some great things to do, to memorise names!

4. The 'undead' lecture as an enabler for 'learning tourism' and the importance of practice

Eds.: Absolutely. I think you've already touched a little on our next question, which is regarding your views of the lecture. Do you agree with Salman Khan, who provocatively claimed that YouTubeU beats YouSnoozeU? And, of course TED Talks have almost revitalised the public lecture. If someone like us approached you and asked how can we make our classes more interactive, what would be your advice?

Figure 3: Hermann Ebbinghaus (1850 - 1909; Brittanica, n.d.).

Dr. Saxberg: There's a couple of things here. I think lectures have an important place. They are terrific at setting a context, at demonstrating why a topic or an area has real value; they can be motivating to show that learners can succeed at achieving complex tasks by telling stories and showing examples.

However, there is an inconvenient truth: when you're working on complex cognitive skills you really have to have students dig in and produce something. Learners have to use the principles, use the techniques. It is never enough for complex cognitive work to just listen. You do not end up reliably being able to perform, and things get forgotten, if you're only listening.

This doesn't mean you have to blow up the lecture hall. Given your environment you can find something better matched to how learning works. There has been work done by a physicist at Harvard, Eric Mazur, who sorted out how to turn a 300-person Physics class into a pretty engaging, flipped environment by focusing on problem solving during class. He had students do problems, and added one piece of technology, a clicker system for students to declare their answers, which nowadays you can do with cell phones. He could then see what fraction of students got things right: if most students did, he would move on. If many got it wrong, students were directed to discuss with their neighbour for a few minutes, and then re-enter their own answer. Again, if everybody got it right, he moved on. If most students were still getting it wrong, he would stop and discuss with the whole class. He had sorted out personalised instruction to an entire lecture hall of students!

Figure 4: Eric Mazur with students in a Harvard University physics class (Chase, 2006).

People have tried this successfully with even simpler technology, such as coloured paddles for answers. It can be very simple but it changes the classroom and the allocation of time from just lecturing to spending most of the time on the things that the group are finding the most confusing. And, of course, once you have technology available in the after-lecture settings, you can set some adaptive individual work, via simulations or many other. But lectures are far from gone.

There's another very important role for the more traditional discursive lecture: to provide chances for 'learning tourism'. Such lectures can be fascinating, interesting, engaging things just by themselves. (TED talks are absolutely that.) Sometimes they do make you go off and learn more, but often you just had a great time, and the experience was so mind-bending that it makes you think about the world for 20 minutes in a new way. There is nothing wrong with this 'learning tourism', as long as you aren't confused into thinking a 20-minute talk about string theory has made you a string theory physicist!

Eds.: I think it's the same with MOOCs, the beauty of the MOOC is you can just go in for a couple of minutes and then you hate it and you didn't spend any money and you checked out. We agree: 'learning tourism' has a place.

5. Teaching and career-counseling in a world changing at breakneck speed

Dr Saxberg: Another example of a use for a long-form presentation could be for something like career counselling. It would be great to have a walk through or a day in the life of a person in a role, ideally narrated, to help folks with no idea about careers find out if this is an interesting day. I may not (yet) be trying to become a Nurse, but I want to find out what it is like to be Nurse. That seems a great use of narrative and storytelling with a longer form, lecture-like or video-like. From there, I can check if I am now interested enough to do that for real, having had a sense of it.

I don't think we do this systematically enough for students in our career guidance, especially for High School and even

College students. Often, it's only a random great teacher that happens to inspire you into becoming a chemist instead of a historian and that's no way to run a railroad! What if you would have been a really great historian instead of an average chemist? Maybe you would have really loved history, but you never had a great history teacher, nor any exposure to what professional historians actually do (very different from what students learning history typically experience). We need to figure out a more systematic way of exposing people to what it is like to be an X now?

Another career misconception example: car repair. Many in my generation think car repair is metal bashing: welding torches and crank shafts and oil everywhere, right? However, if you actually go into a modern car repair place, it looks more like a computer science lab. An awful lot of the work is actually driven by software, even AI, and I imagine robots will do a lot of the messy hard work in the future, leaving mechanics with clean hands, as opposed to thinking 'Ah it's all about the big pipe wrench banging away at the distributor cap. This'll do it! Always did it for my Grandpa; I bet it'll work for you too.' That will soon not be happening anymore.

Careers in general are no longer so fixed. Because of information-rich tools, jobs are going to start changing at the rate of Moore's Law (the exponential rate at which silicon chips advance their processing speed). What a nurse does today is very different than it was 20 years ago because of the tools available, and the repeated flow of information through systems, not just people.

Eds.: Yes, my wife and I had our third child last year after a six-year gap to the second child and what struck my wife was that when the midwives and nurses came into the room they went straight to the computer, but when she had our other children they went straight to her.

Dr Saxberg: Mmmmm, tricky: are we saying we've made progress with this? I'm not always sure. To your point, though, the notion of what it is to be a nurse is changing. Faculty run the risk of remembering a hospital ten years ago and won't have an awareness of what it's like now. We need more clarity on job needs that get revised as jobs change. Being a neurosurgeon is completely different in the age of robotics than in the days of heroic individual work in the 1970's and 1980's. A little scary, the stuff people were doing back in the day. . . good thing to have steady hands back in the day. Whereas now, we have MRI scans, we simulated the surgery six times, we have a robot set up to move slowly and carefully along a very tightly prescribed path. So, arguably, it's a totally different profession than it was. We need ways to retrain current practitioners, and to communicate to those who might be interested in these careers, to update folks to modern best practices.

Eds.: It's actually quite vindicating to hear you say that because we've been working with a start-up from the UK called Thinksmart that is really a learning tool that works on presenting authentic moments in the life of various professions as case study problems and allows users to try and select the appropriate solutions. These moments are higher stakes than the everyday, maybe once a quarter or once a year kinds of situations. All of the solutions for

the cases are plausible but the 'correct' one is that agreed upon by a panel of experts. So to rephrase what you said earlier about being able to expose learners to a variety of experiences, this seems to have some clout.

Dr Saxberg: Yes, and if you start this exposure all the way back when kids are 12, which is when they're beginning to be civilised and can understand a lot of work-related stuff, you can show them a lot of different types of work. By the time they are 17 or 18, they could have easily been exposed to and experienced hundreds of types of work and begun to get a sense of what might be a fit, especially if you're using automated tools to record: 'What did you think? Can you see yourself as this? And what did you like, didn't like?' You could begin to provide a navigation system that would change as the kids changed from being 12 to being 17, and could help them hone in on things that their parents or friends or friends' families would never have had any idea would have been a match for that kid.

This happens all the time across the economic spectrum, that families can't help kids imagine a wide array of careers. It's not just the impoverished, difficult circumstance, where nobody knows what a developmental neurobiologist does. Even in a higher-end environment where 'everyone' is a doctor, lawyer, accountant, or other professional, nobody has any idea what great jobs there are, say in working with big machines. I had a friend whose family were all doctor-lawyer types. Their middle child wasn't doing very well at school - he liked to work with his hands. His family was distraught: 'What's he going to do? Is he just going to pump gas? What will we do with him?' The other children were all 'properly trained' lawyers and doctors.

That kid eventually found his way and became one of the world's best maintainers of machines with wheels that are six feet tall (two metres) or higher. So he's probably gone out to Western Australia a number of times during the boom days of mining, and all over the world, doing interesting and specialised maintenance and repair work on some of these incredibly expensive, giant machines. He makes a six-figure income, and by every measure the lad turned out to be successful. But his family had no idea early on that there were jobs out there of that kind, that could create satisfaction for a kid who was mechanically inclined. Nobody in their social circles were in any way mechanically inclined.

This makes for a really interesting puzzle, to give all levels of families a much wider exposure to careers that might fit their children, as their interests begin to become more visible.

Eds.: Well, you've given us a really interesting potential solution to our employability question. Let's start a bit earlier.

6. The rise of the machines and difficult-to-automate competencies

Dr Saxberg: There's a really important question to be answered: what are the long-lived skills for human beings, the things that are unlikely to be automated away near-term?

A Harvard Business School Professor, Amy Edmondson, and I wrote a piece last summer for the McKinsey Quarterly where we tried to look at the increasing value to corporations of becoming very good at changing skills. One of the parts of the article was about which skills will pass the test of time in the presence of increasingly capable information-rich tools. An Australian venture capitalist, Christopher Selth, had a nice way of thinking about this: the purpose of people, ultimately, is to give meaning to each other, to our lives, decisions, and struggles. The kinds of skills that allow me to give meaning to you are very hard to automate away. If you are in a community theatre company, and your audience is a set of robots who clap and cheer at your version of Hamlet...really? I'm feeling good about my performance when a bunch of robots clapped? Not so much... but when it's real people who are crying in the front row, now that's meaningful to me.

> "The kinds of skills that allow me to give meaning to you are very hard to automate away. If you are in a community theatre company, and your audience is a set of robots who clap and cheer at your version of Hamlet... really? ...But when it's real people who are crying in the front row, now that's meaningful to me."

Or think about life stages. There's nothing like talking to another parent when you struggle with your own children: sharing the jetlag from the kids screaming at night, etc. As opposed to Siri on your iPhone saying "I'm really sorry to hear that. Would you like to listen to another song?": it's not going to do it for you. Another example from the business community that's been going on for decades is solution selling. For complex sales, the idea is that, instead of me trying to get you to do what I want, let me try to understand what you want to do, what will advance your career? Then I can figure out how what I am providing will help you reach your goal, not just mine.

Those kinds of skill and the communication that goes with them, we really should start in pre-school: "Why is little Bror again hitting little Juergen on the head with a truck"? (Eds. laugh.) One approach is for little Juergen to bash right back on little Bror. But another approach is for little Juergen to figure out 'What's going on with little Bror?' And maybe solve that problem instead.

We can teach kids to do that kind of thing, to think about a situation from the other side, and then find a solution. The more we start giving students in elementary school, middle school, and beyond ways to see the world through someone else's eyes, the more they have valuable skills to build on that are not going to be automated away, the better their future.

Eds.: Right, so you gave us some answers to the question asked about the long-lived skills for human beings, but on the subject of your article with Edmondson, you were

saying that there's increasing value for companies who are able to keep changing skills of their associates. Can you say a bit more about that in relation to the education ecosystem?

7. Creating top performers and maximising corporate potential via evidence-based training programmes

Dr Saxberg: This is one of the reasons why the corporate training part of Kaplan always intrigued me. I am increasingly convinced that there are trillions of dollars of corporate value trapped behind walls of inept corporate training caused by companies not understanding what makes top performers different from medium performers. As a result, they do not design their training to measurably move medium performers closer to top performers, leaving huge amounts of value on the table.

Companies can see (i.e. measure) the variance between median performers and top performers: sales people, project managers, nurses – pick whatever job you want. Top performers differ from median performers in how they add revenue, reduce error rates, reduce other costs, increase the lifetime value of customers, on and on. Because of Moore's Law mentioned earlier, information-rich tools are changing faster and faster which causes careers (and top performer decisions) to change faster and faster too. This means that the huge lake of trapped corporate value caused by the inability to move median performers towards top performance is getting deeper faster and faster.

It might take 20 years or half a century, but eventually there will be holes put in that multi-trillion-dollar wall (that is trapping the corporate value). Once there are enough examples of this kind of work (training and development people lifting, e.g., a $90 billion dollar valuation company by $15 billion, by spending $100 million on evidence-based cognitive task analysis of top performers with evidence-based learning design) and enough examples of CEO's who have made their bones on the basis of skill changes to their organisations, there will be a wash of other leaders at all levels that want to unlock their piece of the trillions of dollars of corporate value before their competitors do.

If they do this, imagine the kinds of questions these companies will then ask higher education! Because companies will now know how to train people to be top performers in a reliable, repeatable way, they will demand the same from graduates of higher education – they should be ready to be top performers in their field when hired.
There's a decent chance many in higher ed will say 'Naaaa, we're not going to do that because we've been doing what we do for centuries so why would we listen to you?' I think corporations will then say: 'We do know how to do this - we're going to hire high school kids and train them in the same way that we know how to train our other employees,' and sideswipe parts of the higher education system that don't change.

Imagine it: trillions of dollars of missed value to corporations are going to push upstream to change or replace higher education because corporations will take the stance that they can hire high school kids or first year kids out of college who know a little bit and put them in evidence-based training programs. Why should they hire a badly trained nurse from a university and try to retrain them, when it is more efficient to train them correctly with evidence-based methods to deliver top performance from the beginning? Since each employee, through information-rich tools, delivers ever more value with the best decisions compared to mediocre decision, this will pay off with increasing value over time.

If there's trillions at stake, the money will flow and people will figure out how to be rewarded for doing this better and better. My view is I'd rather get ahead of the raw economics, not wait many decades for this to happen on its own, but I see the economic pressure forcing this to happen no matter what. This is all a little cosmic gentlemen, but I'm just saying...

Eds.: Oh no, not at all. Actually, I would like to follow up a little bit on this because I think the three of us, we are great believers in education and, I still think, in higher education, although these are excellent questions that you're asking and, of course, evidence is extremely important. You're probably familiar with Martin Ford and his books, The Lights in the Tunnel and The Rise of the Robots and I think he's making some very eloquent and fair points that he's really very concerned about the future of work and that, basically in the next couple of decades, lots of people may lose their jobs and there may be underemployment, and also education may not be the panacea anymore, so he even considers something like a basic income that is paid to every citizen and so on. But I'd like to read a quote to you from another book, Home Deus...

Dr Saxberg: Yes I know that book.

Eds.: We were confident you would (all laugh).

Dr Saxberg: No, no, you just happened to pick things I've read!

8. The paradox of knowledge: our ignorance increases with more knowledge

Eds.: So, let me read this about the paradox of knowledge, which I found completely mind-blowing and that is something that I'm meditating on a little bit at the moment:

"Knowledge that does not change behaviour is useless. But knowledge that changes behaviour quickly loses its relevance. The more data we have and the better we understand history, the faster history alters its course and the faster our knowledge becomes outdated... Today our knowledge is increasing at breakneck speed, and theoretically we should understand the world better and better" (Harari, 2016, 58-59).

But actually when you compare 1,000 years ago in Europe and today, for instance, if you compared 1,016 AD, it was relatively easy to predict how Europe would look at in 1,050 AD, there would have been little difference, but in contrast we have no idea how Europe will look in 2050 (Harari, 2016). So what Harari is saying is, because we are

so knowledgeable, because things are moving faster and faster, paradoxically, we really don't know what's going to happen or, to use the four types of knowledge, we don't know that we don't know.

Dr Saxberg: It is a conundrum. I think, as we have always done, we in part will use technology to try to guide us and aid us and accelerate our understanding. There is a real puzzle here. When the economics of machine-driven work pushed humans to transition away from doing most of the physical work, there was a place for people to go to add value: if you could figure out how to get more and more people to do intellectual work, creative work, information-based decision-making at scale, then people added additional value. Their new work then leveraged all the machines that did the physical.

I still think there's a lot of room for human work, creativity and thinking even if implementation and complex information processing is increasingly carried out by various kinds of machines. Some of the folks who write about this paint a depressing picture of humanity split between an elite class with everybody else as drones. I just don't buy it.

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If you look at the changing nature of work and how people work together, how they draw on each other through gig economies and so forth, there's all kinds of new structures of human work that technology is enabling. As I said earlier, the critical capacity of people to give meaning to each other is going to remain valuable, even at a point where everyone is supported by robots, growing food and so forth.

It may take generations, and there may be serious dislocations along the way – not saying it's necessarily a smooth ride. People have been surprisingly resilient generation after generation at finding new sets of things to add value to. The number of new professions that have sprung up after years of technology already changing work is extraordinary.

9. Multi-skilling or the 10,000-rule multiplied

Here's another example of a path forward for people which is very dependent on better learning. When we talk about obsolescence, what we often focus on is one skillset "Oh my, being a tax lawyer in the US servicing middle income clients, you're in trouble." Your job is first outsourced to India, and then outsourced to IBM Watson.

What people forget is there's another way to think about adding value. One of the things learning science suggests is, with well-designed instructional environments, you can gain world class skills in about 10 years of half-time deliberate effort. This is the "10,000 hours" idea that you see in Malcolm Gladwell's work, or the original Anders Ericsson work. (It's half time for 10 years because doing this well is quite exhausting. Many careers show the same thing, it takes 10 years to be a fully licensed architect, lawyer, doctor, plumber, etc.)

If we're all living to be 90 and you start building competence when you're 20, you have 70 years to build world-class competence. So let's do the combinatorics: Imagine there are 1,000 different areas you can become world-class at and you pick one at age 20. 10 years later you pick a second one. 10 years later you pick a third one, 10 years later a fourth. Now do the math: 1,000 choices for the first, 1,000 for the second, 1,000 for the third, 1,000 for the fourth – you end up with a potential trillion different combinations of four different world class competencies to choose from! Not all are necessary – but that's a lot of possibilities – and more when you add the fifth and sixth decade!

Thought experiment: you start life as a gardener. Then you get a business qualification so you can run a great gardening business. Then you get a robotics qualification – you are preparing to be the world's first robotic gardening service. In fact, you probably need a law degree – those early robots are going to hurt some people, eh? By then, there won't be many human beings on the planet who are exactly right to build the world's first robot gardening empire, with world-class competence in gardening, business, robotics, and liability law! Four world-class competencies bouncing around inside one human head!

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That is a possible source of human value for the long haul. It wouldn't help to have four different expert systems, one for each area: you need to blend all these together in a creative way to try to build something new. You have the expertise in one head to make you quite unique on the planet. Combinations of world-class expertise can also allow humans to retain uniqueness and value over specialised, individual machines.

However, note that this requires we have highly reliable and effective skill-change systems, so when someone decides "I'm going to become a world-class roboticist," there's a place for him or her to go and a set of activities to give him or her the practice and feedback needed to reliably hit this goal. With machines doing a lot of underlying work to keep

bread on the table, we have time to do this – but we do need reliable systems for training that are tied to world-class expertise and evidence-based instruction to make this work.

No pressure on our education and training systems, but the fate of all humanity may hang in the balance. . . Uh oh, I've gone cosmic again, sorry. . .

Eds.: Yes so we know the one true competence is change, but how can educators embed that because so much of what we do is so planned and structured with soft landings and hard testing? How can we prepare the mindset that would know that every ten years I need to reskill?

> "The classic question we ask kids is 'What do you want to be when you grow up?' Now we should be asking, 'What things do you want to be when you grow up?' We want most kids to say many things, not just one."

Dr Saxberg: Well, a flippant, but maybe relevant answer, is to start very early. The classic question we ask kids is 'What do you want to be when you grow up?' Now we should be asking, 'What things do you want to be when you grow up?' We want most kids to say many things, not just one.
Maybe a little person wants to be a Princess and then a Neuroscientist. Well, fabulous, there's nobody better on the planet to be working on people's beautiful smoothness of face then a Princess Neuroscientist! Kidding, of course – a real Princess Neuroscientist would be working to bring the benefits of improved executive function to all her people. . . Seriously, though, instead of a dread focus on 'What's your career out of college?' we need learners to start imagining a sequence of careers and training, and plot out what order makes sense.

We've got to think about human development as a multi-dimensional trajectory where we work on changing people's identities at the same time as we're changing their skills. A key identity change is that we're supposed to have more than one expertise in life.

This is a real change. I don't know if it's true in Singapore, but in the United States, there are a lot of people with real, single domain expertise from decades past that can't get a job using this expertise now. Their identity is that they are an expert – unfair that their single expertise is no longer enough. We have to change that identity to embrace the ideas of continuous change within their expertise, and the need to add more expertise categories.

10. Key teaching strategies for a personalised learning approach and promises of neuroscience

Eds.: We notice that your work at the Chan-Zuckerberg Initiative addresses primary and secondary education, as well as post-secondary through the College Board work and other initiatives. This is a big stretch! What are key

Figure 5: Mark Zuckerberg (TV5 News, 2015).

teaching strategies for teachers to employ to enable a personalised learning approach? Do you find the quest for personalised learning in one of these arenas at all at odds with a standardised testing focus of the other; where do these concepts intersect?

Dr. Saxberg: The nice thing about learning science, at least as much as I've been able to understand, is that minds keep working pretty much the same way once you're in middle school and beyond. It is true that for the smallest folks in elementary school and earlier, there are some different things you have to pay attention to, different affordances you can take advantage of (like real respect for what parents pay attention to – that tends to fade in middle school and beyond. . .), much like the distinction between paediatrics and general medicine: some things work the same, some things are quite different.

In all cases, though, it is really important to pay attention to the differences minds have at the point where they are engaging in instruction for the same learning outcome. Two different students, looking at a white board on which is written "$ax^2 + bx + c = 0$" may have two very different reactions. One student thinks, 'Oh, no, this is a quadratic equation – I know she's going to ask me to factor this to find the roots. I hate factoring quadratic equations!' Another student thinks, 'Why are there letters and numbers on the same line?'

They are having identical sensory experiences, but completely different cognitive (and emotional) experiences: the first student's long term memory has immediately "chunked" the information on the white board (probably as the teacher is writing it) to recognise "quadratic equation" – and, from prior experience, has a negative reaction to it. The second student has no prior instruction on polynomials, or possibly even the use of letters to represent variables (a quite difficult concept for learners, it turns out), but also has no particular emotional/identity reaction, either – just confusion, maybe curiosity.

So we need to support teachers and learners in identifying what, exactly, learners have in long-term memory – both cognitive issues, and identity/emotional reactions – and how best to handle the very different needs for these minds. The question of what our actual long-term targets are is different, and key, to this. I would argue that we have to

become better at pulling backwards from current decisions of top-performers at work to what is needed to get ready to learn this. Years ago, when I started in engineering, a crucial skill was claimed to be working a slide rule. Educators persisted in training us on fluency in slide-rule use even as scientific calculators clearly made those skills obsolete – it was 'what we do'. A waste of time, for future top-performance – yet hours were spent on it!

Same with standardised tests: 1) we need to evolve our evidence-gathering across students to more quickly keep up with key performances that lead, ultimately, to high performance in many fields, as those requirements change, and 2) if the 'standardised tests' do not evolve, we are going to have to sort out how to prepare our students to 'get over them', where they remain mandarin-like obstacles to further training, without missing the preparation required for actual top-performance in the future, even if not reflected in 'standardised tests'. Very messy, possibly very inefficient – but if the real world requires it, we must help students do both well.

Eds.: What are the latest happenings in the neurosciences that are getting your dopamine levels rising?

Dr. Saxberg: A very tough question – I suspect I am not as up-to-date on deep neuroscience questions as I should be, so your readers should realise I'm not the ideal guide here! (And if any of your readers are neuroscientists, have them contact me if there's anything that excites them about practical implications of the neurosciences they've seen!)

I'll start with some hesitations. Neuroscience is a broad field, with many branches. Quite a few of these have been working for years on really fundamental mechanisms of learning – how do cells communicate? How do various brain structures connect cells together, and learn? Much of this, while promising for the future, does not directly suggest how to practically improve learning, e.g., for algebra instruction for 13-year olds.

That's okay – it's very reminiscent of what happened in medicine in the 1960's, when DNA became first recognised as fundamental to human development and disorders. For a long time, the basic research created explanations for what clinicians were seeing: various disorders, like Huntington's Chorea, were determined to be defects in very specific parts of a person's genome. From a science standpoint, fascinating – but from a clinician's standpoint, nothing new to do at the time.

Eventually, however, work on genetics, DNA, RNA, protein synthesis and more led to new treatments that prior biology would never have suggested. Huge benefits followed – and we continue to explore all that for human health. In the same way, I feel that a lot of neuroscience is very early stage – and may explain some of what we already know from cognitive science, as well as issues in development, e.g., the impact of toxic stress on cortisol levels that create biologically-based learning difficulties. There's still a paucity of results from neuroscience itself about what to do, in a school, at scale, to help – but this will come.

One fascinating area that I see on the cusp (in addition to paying much more attention to lowering toxic stress levels in communities and families) is work on what is called executive function: things like people's working memory, their ability to focus and resist distractions. There are very intriguing correlations between these lower-level capabilities and learning and life success, but a lot less clear causal connections between what you might do to lift these lower level capabilities (as measured currently) and gaining learning/life benefits. If we can start to show learning and life benefits for various interventions on executive function itself that are scalable (specific practice and feedback regimes using adaptive technology, perhaps), this could be very exciting. There is intriguing evidence about this for kids with ADHD (including late-stage FDA trials going on now in the US) and for seniors with dementia – just nothing (that I'm aware of) very convincing for normal folks.

We shall see – we are reaching an exciting period where our understanding of biological, neural and brain function is beginning to overlap with our understanding of cognitive progress in learning, emotional regulation, and identity. Fingers crossed – could be great new things to come, if we are careful to use good evidence, personalise our interventions to what individual learners have already experienced and mastered, and pay attention to what careers really need going forward.

Eds.: Dear Bror, thank you so much for the fabulous interview!

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