VIVEK WADHWA WITH ALEX SALKEVER

THE DRIVER IN THE DRIVERLESS CAR

HOW OUR TECHNOLOGY CHOICES WILL CREATE THE FUTURE

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PREFACE

Not long ago, I was very pessimistic about the future. I was worried about hunger and poverty, disease, overpopulation. I believed that the world would run out of clean water and energy and that we would be fighting world wars over scarce resources.

Today, I talk about this being the greatest period in history, when we will solve the grand challenges of humanity and enter an era of enlightenment and exploration such as we saw in my favorite TV series, *Star Trek*. Yes, I grew up dreaming of tricorders, replicators, and androids and wanting to be an astronaut so that I could join Starfleet Academy. Didn't all the people from my generation, of the '60s?

At Stanford, Duke, and Singularity universities, and now at Carnegie Mellon, I have spent the past six years researching the advances in technology that are finally making science fiction a reality. It truly is amazing what is possible, as I will explain in this book. But I have come to realize that reaching Utopia will take vigilance and effort: like the course of a game of snakes and ladders, our path is strewn with hazards.

My research has made me acutely aware of the dangers

in advanced technologies. These are moving faster than people can absorb change—and offer both unprecedented rewards and unpredictable hazards.

As a society, we can make amazing things happen; and the more we understand, the better our decision making will be—and the greater the odds that we head toward *Star Trek*. Today's technology changes are happening so quickly and are so overwhelming that all of us—including technologists—can benefit from access to new tools for considering and managing them. I wrote this book with the help of my good friend and writing guru, Alex Salkever, in order to provide such tools, because I believe in the power of choice and the greater judgment of involved citizens. We hope that it will help you deal with the challenges that new technologies raise now and in the future.

INTRODUCTION

It is a warm autumn morning, and I am walking through downtown Mountain View, California, when I see it. A small vehicle that looks like a cross between a golf cart and a Jetsonesque bubble-topped spaceship glides to a stop at an intersection. Someone is sitting in the passenger seat, but no one seems to be sitting in the driver seat. How odd, I think. And then I realize I am looking at a Google car. The technology giant is headquartered in Mountain View, and the company is road-testing its diminutive autonomous cars there.

This is my first encounter with a fully autonomous vehicle on a public road in an unstructured setting.

The Google car waits patiently as a pedestrian passes in front of it. Another car across the intersection signals a left-hand turn, but the Google car has the right of way. The automated vehicle takes the initiative and smoothly accelerates through the intersection. The passenger, I notice, appears preternaturally calm.

I am both amazed and unsettled. I have heard from friends and colleagues that my reaction is not uncommon. A driverless car can challenge many assumptions about human superiority to machines.

Though I live in Silicon Valley, the reality of a driverless car is one of the most startling manifestations of the future unknowns we all face in this age of rapid technology development. Learning to drive is a rite of passage for people in materially rich nations (and becoming so in the rest of the world): a symbol of freedom, of power, and of the agency of adulthood, a parable of how brains can overcome physical limitations to expand the boundaries of what is physically possible. The act of driving a car is one that, until very recently, seemed a problem only the human brain could solve.

Driving is a combination of continuous mental risk assessment, sensory awareness, and judgment, all adapting to extremely variable surrounding conditions. Not long ago, the task seemed too complicated for robots to handle. Now, robots can drive with greater skill than humans—at least on the highways. Soon the public conversation will be about whether humans should be allowed to take control of the wheel at all.

This paradigm shift will not be without costs or controversies. For sure, widespread adoption of autonomous vehicles will eliminate the jobs of the millions of Americans whose living comes of driving cars, trucks, and buses (and eventually all those who pilot planes and ships). We will begin sharing our cars, in a logical extension of Uber and Lyft. But how will we handle the inevitable software faults that result in human casualties? And how will we program the machines to make the right decisions when faced with impossible choices—such as whether an autonomous car

should drive off a cliff to spare a busload of children at the cost of killing the car's human passenger?

I was surprised, upon my first sight of a Google car on the street, at how mixed my emotions were. I've come to realize that this emotional admixture reflects the countercurrents that the bow waves of these technologies are rocking all of us with: trends toward efficiency, instantaneity, networking, accessibility, and multiple simultaneous media streams, with consequences in unemployment, cognitive and social inadequacy, isolation, distraction, and cognitive and emotional overload.

Once, technology was a discrete business dominated by business systems and some cool gadgets. Slowly but surely, though, it crept into more corners of our lives; today, that creep has become a headlong rush. Technology is taking over everything: every part of our lives, every part of society, every waking moment of every day. Increasingly pervasive data networks and connected devices are enabling rapid communication and processing of information, ushering in unprecedented shifts—in everything from biology, energy, and media to politics, food, and transportation—that are redefining our future. Naturally we're uneasy; we should be. The majority of us, and our environment, may receive only the backlash of technologies chiefly designed to benefit a few. We need to feel a sense of control over our own lives; and that necessitates actually having some.

The perfect metaphor for this uneasy feeling is the Google car. We welcome a better future, but we worry about the loss of control, of pieces of our identity, and most

importantly of freedom. What are we yielding to technology? How can we decide whether technological innovation that alters our lives is worth the sacrifice?

The noted science-fiction writer William Gibson, a favorite of hackers and techies, said in a 1999 radio interview (though apparently not for the first time): "The future is already here; it's just not very evenly distributed."[1] Nearly two decades later—though the potential now exists for most of us, including the very poor, to participate in informed decision making as to its distribution and even as to bans on use of certain technologies—Gibson's observation remains valid.

I make my living thinking about the future and discussing it with others, and am privileged to live in what to most is the future. I drive an amazing Tesla Model S electric vehicle. My house, in Menlo Park, close to Stanford University, is a Passive House, extracting virtually no electricity from the grid and expending minimal energy on heating or cooling. My iPhone is cradled with electronic sensors that I can place against my chest to generate a detailed electrocardiogram to send to my doctors, from anywhere on Earth.*

Many of the entrepreneurs and researchers I talk with about breakthrough technologies, such as artificial

*I have a history of heart trouble, including a life-threatening heart attack; my ability to communicate with my doctors in seconds instead of hours makes my life both safer and easier, and gives me the confidence to go hiking up mountains and to travel the world giving talks.

intelligence and synthetic biology, are building a better future at a breakneck pace. One team built a fully functional surgical-glove prototype to deliver tactile guidance for doctors during examinations—in three weeks. Another team's visualization software, which can tell farmers the health of their crops using images from off-the-shelf drone-flying video cameras, took four weeks to build.

The distant future, then, is no longer distant. Rather, the institutions we expect to gauge and perhaps forestall new technologies' hazards, to distribute their benefits, and to help us understand and incorporate them are drowning in a sea of change as the pace of technological change outstrips them.

The shifts and the resulting massive ripple effects will, if we choose to let them, change the way we live, how long we live, and the very nature of being human. Even if my futuristic life sounds unreal, its current state is something we may laugh at within a decade as a primitive existence—because our technologists now have the tools to enable the greatest alteration of our experience of life that we will have seen since the dawn of humankind. As in all other manifest shifts—from the use of fire to the rise of agriculture and the development of sailing vessels, internal-combustion engines, and computing—this one will arise from breathtaking advances in technology. It is far larger, though, is happening far faster, and may be far more stressful to those living through this new epoch. Inability to understand it will make our lives and the world seem even more out of control.

In the next few chapters, I will take you into this future, discussing some of the technologies that are advancing at an exponential pace and illustrating what they make possible. You will see how excited I am about their potential—and how worried, at the same time, about the risks that they create.

Broadly speaking, we will, jointly, choose one of two possible futures. The first is a utopian *Star Trek* future in which our wants and needs are met, in which we focus our lives on the attainment of knowledge and betterment of humankind. The other is a *Mad Max* dystopia: a frightening and alienating future, in which civilization destroys itself.

These are both worlds of science fiction created by Hollywood, but either could come true. We are already capable of creating a world of tricorders, replicators, remarkable transportation technologies, general wellness, and an abundance of food, water, and energy. On the other hand, we are capable too now of ushering in a jobless economy, the end of all privacy, invasive medical-record keeping, eugenics, and an ever worsening spiral of economic inequality: conditions that could create an unstable, Orwellian, or violent future that might undermine the very technology-driven progress that we so eagerly anticipate. And we know that it is possible to inadvertently unwind civilization's progress. It is precisely what Europe did when, after the Roman Empire, humanity slid into the Dark Ages, a period during which significant chunks of knowledge and technology that the Romans had hard won through trial and error disappeared from the face of the Earth. To unwind our own

civilization's amazing progress will require merely cataclysmic instability.

It is the choices we all make that will determine the outcome. Technology will surely create upheaval and destroy industries and jobs. It will change our lives for better and for worse simultaneously. But we can reach *Star Trek* if we can share the prosperity we are creating and soften its negative impacts, ensure that the benefits outweigh the risks, and gain greater autonomy rather than becoming dependent on technology.

You will see that there is no black and white; the same technologies that can be used for good can be used for evil in a continuum limited only by the choices we make jointly. All of us have a role in deciding where the lines should be drawn.

At the end of the day, you will realize that I am an optimistic at heart. I sincerely believe that we will all learn, evolve, and come together as a species and do amazing things.

With that, let the journey begin.

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Remaking Education with Avatars and A.I.

Let's imagine that I am a fourteen-year-old boy. (Some of us never really grow up!) I am sitting in class, feeling sleepy (as always). My eyes droop. It's after lunch, and I would dearly like to take a nap, but naps are not in the curriculum. The teacher rambles on. Or the video rambles on. Or the pages of the book I am trying to read float together. I am fighting to retain the information, drifting in and out. What did I just learn? I don't entirely remember. This lesson is boring. Or it's too hard to comprehend. Or it's taught in a way that seems strange to me. I want to learn, but I know that I won't remember half of this information. Worst of all, I can't hit the replay button. Now the bell rings, and my time has gone. The information has gone. I'm going to flunk the class, or I'll have to spend a lot of time catching up on my own.

This isn't purely imaginary; it is the reality that students in schools everywhere around the world live daily. There are few institutions as inefficient and broken as the traditional education systems of the world, because we treat education as an industrial good, a unit of knowledge served up to the masses in a one-size-fits-all box. We have made some attempts at personalization, but they have remained marginal at best.

In schools today, teachers must teach to the median—or, in many cases, to the lowest common denominator. Students must learn on a schedule and from a curriculum taking no account of their capabilities or preferences; some students may take twice as long to learn differential calculus but half as long to learn Spanish irregular verbs. The root issue is that the default units of education—the classroom, the class, the school year, the period, the semester, the quarter—are all arbitrary distinctions dating back to the earliest days of industrialized education.

My future school is the backyard of my house, and my classroom is a digital tutor with a virtual-reality headset. My avatar instructor is Clifford; my educational coach, Rachel. I am learning geometry via a videogame that teaches how the Egyptian pyramids were constructed. Knowing that I love the pyramids, the A.I. algorithms that guide my avatars deduced that pyramids would be an effective way to engage me in core topics in this critical field of mathematical knowledge.

Clifford has been with me for several years. He knows how I learn, what I like, and what turns me off. He speaks in a British accent that, when I created my avatar profile, I chose because I liked the sound of it. Clifford is always on duty, a button-push away. He doesn't need vacations, bathroom breaks, or lesson-preparation time. And he is more in tune with what is going on inside my mind and with my feelings than any teacher ever was in my actual youth. That's because he has access to almost unlimited amounts of information about me and the world. He can use the

powerful sensors in and around me (in my contact lenses, in my iPhone, embedded in the walls, and woven into my clothing) to gain intimate, highly useful knowledge about my physical state.

For example, Clifford recognizes when I am tired, by noticing differences in the dilation of my pupils and color differences in my skin that indicate lower oxygenation of my blood. He also notices when I get excited about things, by watching my eye movements closely and sensing my pulse rate. Clifford's vision is far better than any human's eyesight. He can interpret the subtle changes in my tone of voice that indicate whether I am understanding subject matter well or grasping at straws. He also learns to match my physical reactions to lessons with actual outcomes, in a constant feedback loop that leads him to improve over time as my teacher.

When I am sleepy, Clifford may suggest that I take a quick nap or go shoot hoops for fifteen minutes. When I am confused, he recognizes my lack of comprehension and doubles back to review the lesson with me, or he changes the exercises that I am working on in my tablet, to try engaging a different learning style. Sometimes it is videos; at other times, games or books; at other times, holographic worlds. Clifford communicates closely with Rachel for my geometry class. He is not in a hurry. There is no bell, no duration of a period. Clifford doesn't have to worry about whether my classmates are bored or sleepy, because he has only me to teach.

Rachel is a human being. She's my coach. She never lectures, or scrawls facts or equations on a blackboard. She

is there to listen and help. Rachel asks me questions to help steer my thinking in the right direction. She recommends reading and exercises to me, answers my questions, and teaches me how to work best with other children. She is charged with making sure that her students learn what they need, and she helps guide us in ways in which Clifford cannot. She also helps with the physical side of projects, things I make out of real materials rather than in my mind and in a machine. With Clifford as teacher and Rachel as coach, I don't even realize that what I am doing is learning. It feels like building cool stuff, playing video games, and living through history.

When Clifford found out that I love the Egyptian pyramids, for instance, he devised a lesson plan that used the pyramids to cover the geometry of different types of triangles, and the mathematics behind those ancient structures. We start with a guided virtual-reality (VR) tour of the pyramids, with augmented-reality overlays to connect the abstract geometry to the physical world. In this way, I can solve geometric problems that use rooms and facades of the pyramids to illustrate them. I feel that I am in the middle of history and following the minds of the Egyptian builders, the geniuses who planned and constructed these massive timeless monuments.

I take a lunch break, and then it's time for group fieldwork. Two of my friends from the neighborhood come over, or I go to their house. Clifford posts a holographic specification for building a pyramid with tongue depressors. We sketch out the design on our tablets, doing the mathematics

and planning its construction. Once our plans are set, our little group spends the next two hours painstakingly building the structure. The small pyramid comes to life before our eyes, a bridge to the greatness of Egypt.

The next day, Clifford starts to teach me some classic mathematical relationships bearing on triangles and pyramids. To translate these into a useful form, I write a computer program to calculate the mass and average pressure at its base of any pyramid given specifications including the dimension of the tunnels and chambers within it. I post my program on line. Other students and teachers grade the code's precision and structure (and whether it actually works). An A.I. system also tests my code and makes suggestions on how to improve it. As a final class project, my workgroup friends and I design a pyramidal play structure for a nearby playground.

On that final pyramid-design project, we work with our teaching coach, Rachel. She answers any additional questions we have and guides us through the project without telling us what to do. We build a model of the play structure as a reality check. Rachel tells us we may need to add safety nets on a section that is too steep for little kids. Although adolescents are smart and savvy, they may lack adult judgment and emotional sensitivity.

And that's what Rachel can teach us. Aside from a pittance for the tongue depressors, we pay nothing for this pyramid exercise. Clifford, having come into being in the same way that the free applications on our smartphones have, comes without financial charge. Rachel's coaching is

part of our public-education package—funded in the same way that today's teachers are. We use free Autodesk software on our tablet to capture a 3-D file of our creation so that we can turn it into blueprints for other cities and towns to use. And we enter the blueprints into a competition with the entries of thousands of other student groups designing play structures. The exercise is fun, functional, and educational, and results in a real finished work that might even have artistic and architectural merit. Most important of all, education ceases to become a chore or work and becomes a true joy, as it should be for everyone.

Back to the Future of Education

Surprisingly, this learning experience recaptures an ancient approach. Teaching started out, way back in time, as a one-to-one interaction between a tutor or mentor and a student. Then we moved toward the idea of school, class, and education, and it became a one-to-many process. In ancient Greece, this was a Socratic process, whereby a teacher guided students through the learning process by asking them questions. Back then, too, education was a privilege reserved for the elites.

Through the Middle Ages and the Renaissance, education remained a privilege, but the process of learning became more rote, with more memorization. The church broadened access to education, affording many students of lesser means the opportunity to study in exchange for entry into the religious orders. Indeed, church stewardship

of books of learning during the Dark Ages preserved invaluable knowledge from Roman times.

In the nineteenth and early twentieth centuries, a much broader swath of students took to the chalkboards. This accelerated with compulsory education in the United States and other countries. But the model of one-to-many moved further toward rote learning, and teachers' primary function became broadcasting information to the class, and an industrial education complex steadily emerged. Standard textbooks were constructed, pending approval from centralized school districts. Creative projects were minimized in the school system. Subjects such as arts and music, though essential parts of life, failed to make the grade in this industrial education system and were largely removed from the learning track beyond light nods in the general direction of fine arts. Schools were constructed and schedules set up that required students to sit in a chair for six or seven hours a day to receive the same lesson—regardless of their ability or learning style. They then went home and did largely the same homework as their peers, working from the same textbooks. Although this process did standardize education, it also failed to take into account the reality that not all humans are alike.

The Promise of Exponential Technology for Personalized Education

With the rise of the personal computer, and later, the laptop, came the promise that technology would remake

education and allow us to personalize learning again. Let's face it: one area in which technology innovation has thus far largely failed is education. First was the promise of One Laptop per Child; but proof that students using computers regularly for classwork and homework do better than those without has remained elusive. And in some major school districts, such as Los Angeles Unified, experiments in giving a tablet to each student have proven unqualified failures. Indeed, the jury remains out on computer-assisted education altogether.

Then there was the hope of online education. We'd all be learning from the Khan Academy or other online site. All the knowledge of the world would be accessible to everyone. And, to highly motivated students who could sit through lectures and quickly grasp concepts, it proved to be so. Unfortunately, those students represented a very small percentage of the total. Online education didn't lead to mass learning or competence.

Worse, researchers found that the people most likely to take advantage of online courses were those who need the least help: middle-class and upper-middle-class professionals. Early experiments at creating online learning communities—Massive Open Online Courses—struggled with high dropout rates and unexpectedly low test results. But none of this has kept venture capitalists from sinking millions into education-technology startups. The global education industrial complex is a trillion-dollar enterprise that remains poorly suited to serve us throughout our lives.

As an educator myself, I recognize the promise of remaking education with the help of technology. But why hasn't it worked? Why don't we have Clifford?

For starters, the technology is not quite there yet. It's coming very soon, but current solutions fall far short of the promise. Internet connectivity is not yet strong enough; the sensors are not ubiquitous enough; A.I. is not yet good enough. We're heading in the right direction, but a decade or so remains before we get Clifford.

When the emerging technologies do catch up with the vision, they will, with teachers providing guidance and coaching, supercharge learning by making it truly a one-to-one experience at every step of the learning journey. No more cookie-cutter courseware. No more lockstep class modules. No more struggling to keep up with the smarties or waiting for the slow kids to catch up. We are moving toward a technology-enabled era of learning in which every individual gets what he or she specifically needs and in which the pupils, with A.I. help, largely teach themselves. Again, these concepts are not new: Socrates also wanted his students to teach themselves.

The broad promise of this shift is breathtaking. When avatars, A.I., and connected learning can radically improve the learning process through digitization and personalization, then anyone in the world with an Internet connection can gain access not only to information and coursework (as we can now) but also to a top-notch education. The children of the richest and of the poorest will learn using the same tools and the same A.I., just as the children of the richest

and of the poorest use similar smartphones for communications and social media.

When the professional humans' role of broadcasting becomes one of guiding, the guides will be able to work with far more pupils, and to do it remotely, too. In fact, parts of this have been happening for years. British grandmothers have been teaching Indian kids using Skype. A number of Skype-based language and teaching businesses are operating right now. (Not surprisingly, this also works in reverse: Skype connects foreign teachers to American students to provide more affordable lessons and tutoring, giving the foreign teachers a good income by local standards.) There will always be benefits to physical presence, to being in the same room with fellow students and a teacher. But video-based learning and VR avatars can and will replace many in-class elements.

What's amazing, though, is that research proved more than decade ago that crude versions of this approach work. And they work even for the poorest of the poor with exceedingly modest resources.

The Hole-in-the-Wall and a Brief History of Online Education

In 1978, Sugata Mitra completed a PhD in physics at the Indian Institute of Technology, Delhi. The IIT schools in India are the equivalent of Stanford or Harvard in the United States, but with much greater competition for entry. Born and raised in India, Mitra's time at IIT gave him a

front-row seat at the computer revolution. He shifted his focus to I.T. instruction and went to work at NIIT, a leading computer-software and I.T.-training company in New Delhi.

Mitra sat in an office equipped with computers and air conditioning. But he knew that outside were slums teeming with young minds lacking quality education. His own job was to improve instruction in technology skills, including shaping curricula and marshaling textbooks to create a traditional educational process.[1]

Not too long after starting at NIIT, Mitra began to wonder whether this old model of knowledge transition could use an upgrade. Teachers were relatively expensive and not always sufficiently skilled, and many would not even show up to work in Indian villages. Personal computers had arrived, and Mitra knew they would soon hold far more knowledge than even dozens of textbooks. Furthermore, he believed that innate curiosity and the agile minds of children could direct their own learning process without a teacher, textbooks, or other trappings of the industrial education complex.

Then came the Internet, and Mitra had a chance to try an experiment. On January 26, 1999, Mitra carved a hole in the wall separating the NIIT building from a teeming slum in Kalkaji, New Delhi. Into the hole he inserted a computer with high-speed Internet access, equipped with a monitor and keyboard. Neighborhood children flocked to the novelty. Groups clustered around the system. In short order, they began, in groups, to quickly learn the very same

things that students went to school for: science, English language, and mathematics. They did that without guidance, without lesson plans, and without adult help. Upon testing the children, Mitra found that the self-taught scholars were learning as quick as, if not more quickly than, their school-bound peers.

I visited NIIT and Kalkaji in 2000 and saw this myself. I was touched by the excitement and enthusiasm of these poor children. Most of them did not speak English, yet they were surfing the Web and doing Yahoo searches (Yahoo being, in those days, the top browser). They were teaching each other what they had learned. They seemed really comfortable and happy using modern technology. For Mitra, and for everyone who visited, this was a revelation. In a nation of a billion people, half were illiterate; and here was a simple, low-cost experiment that was effectively educating dozens of children in one of the poorest neighborhoods of New Delhi.

Mitra realized that the hole in the wall was a door to enlightenment. He followed up by placing similar hole-in-the-wall installations in other locations to test whether his initial findings would hold. They did, and thus was born the concept of Minimally Invasive Education. Mitra believed that the students learned because their brains were wired to learn when given the chance. He noticed that a key component of the learning process was the group dynamic. Group learning has long been considered a core part of the curriculum in Western education, but not in India. Working together, he found, spurred creativity and

engagement. It made school fun. (This is also why group learning, virtual and real, will be essential even when every child has a teacher avatar.)

The Hole-in-the-Wall Education Project provided a fascinating and tantalizing glimpse of what might be possible for any child, given Internet connectivity and friends to learn with. Since then, Mitra has won a million-dollar TED prize, spoken all over the world, and launched dozens of "Schools in the Cloud" that focus on Minimally Invasive Education, a lightly guided curriculum designed to allow children to learn independently, in groups, while teaching each other.

The Flipped Future of EdTech and Personalized Learning

The many flavors of self-directed learning are baby steps toward a so-called flipped model of education. If you are not an education geek, you probably haven't heard this term. It describes something I alluded to earlier in the chapter, with Rachel, the teacher guide. In a flipped model, teachers no longer broadcast information, write lesson plans, and stand in front of classes lecturing; rather, the teachers become coaches and guides to students needing additional help. In a flipped model, students consume recorded lectures or online videos at their own pace, and often in their own time.

What this means is that human teachers will no longer be burdened with the boring work of preparing lesson

plans and administrative tasks, but will instead preserve their brains and skills for the harder work that requires judgment, nuance, and emotional intelligence.

The logic here is powerful. A huge chunk of how teachers spend their time could be replaced with pre-existing work, usually work that is actually better than the teacher could have delivered. Traditionally, for instance, teachers had reinvented, piecemeal, lectures and lesson plans. But why should every teacher in the country prepare lectures and lessons on a topic rather than rely on the very best educators in each topic either to deliver those lessons via video modules or to write lesson plans that can be used in any classroom? Using these, teachers find more time to spend one on one with students, coaching and providing individualized guidance. Ergo, the concept of flipped schooling: imparting the skills and knowledge initially at home, and running through exercises, projects, and discussions jointly outside the home.

Will this new educational system be an improvement on the old? To this I would answer an emphatic yes. Teachers are wonderful coaches. They can be wonderful broadcasters too, but the best teachers bring the greatest value to their students by coaching, not by broadcasting. Technology will allow them to focus on what they do best and on what is best for their students.

Smart entrepreneurs have grabbed this opportunity with a vengeance. Now online lesson-plan marketplaces such as Gooru Learning, Teachers Pay Teachers, and Share My Lesson allow teachers who want to devote more of their

time to other tasks the ability to purchase high-quality (and many lesser-quality) lesson plans, ready to go. With sensors, data, and A.I., we can begin, even today, testing for the learning efficacy of different lectures, styles, and more. And, because humans do a poor job of incorporating massive amounts of information to make iterative decisions, in the very near future, computers will start doing more and more of the lesson planning. They will write the basic lessons and learn what works and what doesn't for specific students. Creative teachers will continue, though, to be incredibly valuable: they will learn how to steer and curate algorithmic and heuristically updated lesson creation in ways that computers could not necessarily imagine.

All of this is, of course, a somewhat bittersweet development. Teaching is an idealistic profession. You probably remember a special teacher who shaped your life, encouraged your interests, and made school exciting. The movies and pop culture are filled with paeans to unselfish, underpaid teachers fighting the good fight and helping their charges. But it is becoming clearer that teaching, like many other white-collar jobs that have resisted robots, is something that robots can do—possibly, in structured curricula, better than humans can.

The jury remains out on how technology can be effectively integrated into education beyond its role in delivering information differently. My feeling is that this uncertainty is largely characteristic of early-stage technology development and will be addressed by the rapid improvements in A.I. that we are seeing uniformly in all disciplines. Many

other problems that have resisted A.I. progress—voice recognition, driving cars, writing music—are now seeing rapid improvements, and so may avatars and A.I.-driven education. Letting computers construct personalized, customized instructional materials, though it may reduce the mystique and magic of the craft of teaching, may perfect the entire educational process as a repeatable, affordable process of mass personalization. Ultimately, we're talking about capturing the knowledge, trapped inside the brains of gifted teachers, of how to reach students, and turning it into software-based A.I. The machines will watch the teachers and learn from the best. And the teachers will use the machines to bring the best individual experience to each child.

EQUAL BENEFITS?

So does this avatar-driven future of education have the potential to benefit everyone equally? I'm convinced that it will—eventually. In the shorter term, though, this new way of teaching children (and adults) will disproportionately benefit the wealthy and the developed world. Already poor schools' access to technology resources falls well short of rich schools' access. Poor schools have far fewer computers per student than rich schools do, and those computers are more likely to be broken or poorly managed. Poorer people and people living in rural communities are less likely than richer urban dwellers to have high-speed broadband access, and to use the Internet (yes, millions of Americans still

don't use the Internet)—and, for the most part, they pay more for high-speed broadband.

The core mechanism necessary to realize data-driven flipped education—reliable, very-high-speed Internet connections—remains too unevenly distributed among the rich and the poor in the United States and in much of the rest of the world. Two developments will eventually make such unevenness less important. The first is that connection speeds will increase everywhere. The second is that our handsets will become increasingly capable of hosting A.I. operations without recourse to online assistance.

Moore's Law prevails yet again. The good news, then, is that this gap should largely disappear within the next decade, leveling the playing field for all. The relatively rich will probably get early access to these technologies, but availability should quickly spread down the pyramid as the technology and its delivery mechanisms improve.

And, as education is the greatest enabler of autonomy, this will be a big win for everyone on that score.