Not All That Glitters Is Gold

Can Education Technology Finally Deliver?

Arran Hamilton
John Hattie

A JOINT PUBLICATION
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In 2008, Professor John Hattie published *Visible Learning*, a synthesis of more than 800 meta-studies covering more than 80 million students. The book revealed which education variables have the biggest impact on learning and created a new mindset that has swept educators around the world. Applying the Visible Learning® methodology means that students are taught to know what they need to learn, how to learn it, and how to evaluate their own progress. Using the Visible Learning approach, teachers become evaluators of their own impact on student learning. The combination causes students to drive their own learning. Since 2008, Professor Hattie has teamed with highly influential educators to expand the Visible Learning canon with books, including *Visible Learning Into Action, Visible Learning for Teachers, Visible Learning for Mathematics*, and *Visible Learning for Literacy.*

Visible Learning+™ is the model of professional learning that takes the theory of Professor Hattie's research and puts it into a practical inquiry model for teachers and school leaders to ask questions of themselves about the impact they are having on student achievement. Visible Learning+ is a result of the collaboration between Professor Hattie and Corwin to help educators translate the Visible Learning research. Through a global network of partners, Visible Learning+ professional learning is implemented in over 20 countries in North America, Europe, and the Pacific.

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Professor John Hattie is Laureate Professor at the Melbourne Graduate School of Education at the University of Melbourne and chair of the Australian Institute for Teaching and School Leadership. His areas of interest are measurement models and their applications to education's problems, and models of teaching and learning. He has published and presented over 1,000 papers, supervised 200 thesis students, and published 31 books, including 18 on understanding and applying the Visible Learning® research.

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Introduction

When we were both children, we enjoyed reading the works of Hans Christian Andersen, and our mutual favorite is the story of *The Emperor's New Clothes*. Published in 1837, it tells the now-familiar tale of a fashion-conscious emperor who changed his outfits by the hour. Enter stage left, two "weavers" who promise to construct for the emperor the most exquisite garment imaginable from golden thread. But there is one catch: the outfit will remain utterly invisible to anyone not worthy of their current job or of simple mind.

The weavers, duly commissioned, then set out to do absolutely nothing. They sit in their weaving chamber, likely passing the hours with endless rounds of cribbage and charades. Whenever anyone checks on their progress, they rush to their looms, miming the action of weaving but, of course, without any actual cloth or golden yarn.

When the emperor sends his wisest official to inspect the cloth, the latter is left in a quandary. He can see absolutely nothing, but to admit it is a declaration that he is unfit for office. So he duly admires the cut of the (nonexistent) cloth and the array of textures and the golden stitching, reporting as much back to the emperor. On fitting day, the emperor, too, can see absolutely nothing. But facing the same dilemma as his wise official, he goes through the motions of being dressed in the golden "outfit" and confers the "weavers" with honors for a job well done.

Act 2, and the emperor parades through the streets of the capital in his new golden "suit." The people gather and, not wanting to be thought of as fools, clap and cheer the emperor on. But they have their doubts. Only a small child has the courage to voice what everyone else is thinking: that the emperor is wearing no clothes. In his heart, the emperor knows the little boy is right but is too embarrassed to admit it. He continues the procession, and his officials make even greater effort to bear the weight of his nonexistent golden train.

Since its publication 183 years ago, the story of the emperor's new clothes has often been used as a metaphor to describe any fiction that people have been induced to think of as fact. Sometimes, like the story, the golden threads that people are asked to admire do not actually exist; instead, the audience is manipulated into believing they do, through psychological gaslighting. More commonly, the thing exists and even glistens, but isn't made of the 24-carat bullion that the weavers claim it to be. In other words, it glitters but isn't gold.

In this paper we explore whether education technology also fits that second definition. EdTech is real and tangible, unlike the emperor's new (and invisible) clothes. You can see it, touch it, and use it. But we ask whether its impact is a fiction masquerading as a fact, or pyrite professing to be gold. And in the world of COVID-19, where schools across the planet have closed or are operating at reduced hours, this is an even more important question: because technology is fast becoming the only game in town. Whatever the potential limitations, virtual schooling is clearly better than no schooling.

Even before COVID-19, the perception from teachers, students, and parents was often that education technology is game-changing and transformative to student learning (Abrami et al., 2006). But, unfortunately, much of the evidence collected from rigorous studies suggests that it is at best average and more likely well below, as a mechanism for unlocking student achievement (Hattie, 2015). A major message is that technology has had less impact on the current model of schooling than many hoped for, expected, and advertised. But it could have major effects on alternative models of schooling, and herein lies excitement. The major message right now is that the medium (in-class, distance, hybrid) is far less critical than the quality of the teaching.

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Because of COVID-19, currently some fascinating and global natural experiments in distance learning are underway as children are forced to engage with their teachers, their peers, and learning materials through mobile devices, tablets, and laptops at home. This is an experiment that would never have got through any university ethics committee. But in the next 2–3 years, as we are able to systematically review and number crunch the impact of this Great Distance Learning Experiment on student achievement, we will have an even richer dataset on what works best in education technology and how we can make it work better.

The current (pre-COVID-19) research is, however, extremely underwhelming when we look at the impact of technology in schools where teachers and students are both physically present in the same environment. The purveyors of education technology often take the lackluster findings from empirical evaluation on the chin. It's hard to argue against the overwhelming data. But they often also suggest that the unflattering data relate to their older and discontinued products, that the technology has now moved on, and that their newer (but as yet unevaluated) releases and prototypes are "game changers."

We've heard it all before. But what if this time they're actually right? In this paper we explore the evidence, and on our journey we will traverse the following waypoints:

Waypoint	Overview
1	**The World of Yesterday** This chapter makes the claim that the general definition of education technology is too narrow and that we have all lost sight of the wide range of gadgetry in our schools that was introduced before the invention of the circuit board. We have also failed to measure the impact of this older technology—instead treating it as part of the furniture.
2	**The World of Today** This chapter reviews the evidence of the impact of current and recent education technology and concludes that while this has been positive it has also been underwhelming. We highlight that some of the more effective EdTech includes intelligent tutoring systems and the use of video capture/micro-teaching to enhance teacher performance.
3	**The World of Tomorrow** In this chapter, we review current and projected trends in education technology and make some predictions about what we think may be beneficial in unlocking learning gains for students in the near future.
4	**The World of the Day After** The final chapter looks at the long-term implications of technology on both education and wider society. It makes the case that when technology finally starts delivering, it really could change absolutely *everything*.
5	**Conclusion** Here we tie up loose ends and bring proceedings to a close.
Appendix	**60 Years of Research on the Impact of Electronic Technology on Learner Outcomes** This appendix summarizes and interprets the findings from 233 meta-analyses of more than 15,000 studies into the impact of education technology—involving more than two million participants.

CHAPTER 1

The World of Yesterday

Close your eyes for a moment and think about all the different types of education technology. Do you see tablet computers, interactive whiteboards, learning management systems, smartphones, virtual/augmented reality, and software packages that help students with their math and literacy or that offer adaptive testing?

If you thought of these things, we suspect you are with the majority. They are certainly the first thoughts that came to our minds, which is why we listed them here. But the generally accepted definition of what constitutes technology is much wider than this.

The term *technology* itself was not commonly used in English before the turn of the twentieth century. Back in 1937, the American sociologist Read Bain defined it as including "all tools, machines, utensils, weapons, instruments, housing, clothing, communicating and transporting devices and the skills by which we produce and use them" (p. 860). And this definition is still in common usage. Ursula Franklin (1999) gave an even broader definition: "the way things are done" (p. 80).

If you accept these definitions, anything that we humans do that involves manipulating or enhancing things that exist in nature is technology. The process and activity of harnessing fire, systematically planting and harvesting crops, building shelter, and establishing and operating a system of laws—these are all forms of tech.

In Table 1 (see the next page), we provide an overview of the evolution of major categories of education technology "devices."

In our opinion, the most important piece of education technology ever invented is writing, which emerged around 3,200 BCE. When it was first developed, there were sceptics who thought it would lead to intellectual decline. The Greek philosopher Socrates is said to have scolded students who had not taken the time to memorize a text by heart and had instead merely made notes summarizing the main arguments! Socrates' fear, apparently, was that writing would rot the brain and diminish our capacity to remember.

A little later than writing came candles, enabling people to read at night. Then the printing press, leading to the library and then the textbook. Then came the postage stamp and the postal system, enabling distance learning correspondence courses. The advent of this technology enabled the University of London to pioneer international degree programs in the late 1850s. Next, we get the radiator and electric fan—both important because it's difficult to concentrate in extreme temperatures.

In the 1870s, the overhead projector was born. But it took until 1957 for the U.S. Congress to pass the National Defense Education Act, which included funds to place overhead projectors in many school classrooms. This is not an untypical lag between the invention, adoption, and mass deployment of technology. Change takes time, although adoption cycles are getting markedly shorter.

The gadgets that appear under the dotted line in Table 1 are the things that most of us tend to think about when we refer to education technology: pocket calculators, computers, the Internet, SMART Boards, tablets, videoconferencing, and learning management systems. All of these came online starting in the late 1960s, after the shift from valve to transistor technology and then to the integrated circuit board.

When we unpack the educational technology that emerged from the digital transistor revolution that started in the late 1960s, we see waves within waves (see Table 2).

Table 1 A Brief History of the Evolution of Education Technology

Writing: 3200 BCE	Electric fan: 1882
Abacus: 500 BCE	Radio: 1896
Candle: 500 BCE	Television: 1925
Blackboard: 1100s	Pocket calculator: 1967
Printing press: 1440	PCs in schools: 1977
Library: 1651	World Wide Web: 1989
Textbook: 1687	SMART Board: 1991
Pencil: 1795	Virtual reality: 1991
School bus: 1827	Smartphone: 1992
Postage stamp: 1840	Videoconferencing: 1994
Radiator: 1857	Tablet computer: 2000
QWERTY typewriter: 1868	Open source learning management system: 2002
Overhead projector: 1870	

Note: Most of this technology was invented for use outside of education and only later applied to schooling. When we think about EdTech, for many, only the items below the dotted line come to mind.

Table 2 The Digital Wave

Wave 1 1970s–1980s	**Electronic content distribution** Simple digital computers with transistor circuit boards Distribution of learning content through tape/diskettes rather than through printed publications Emergence of first-generation tutoring programs offering basic drill and practice to teach content in a closed-end linear fashion
Wave 2 1980s–1990s	**Technology as a collaborative learning tool** Non-networked machines but with increased access to rich multimedia via CD-ROM Increasing access to computing equipment in schools; technology used by learners as a tool for content production, manipulation, and collaboration
Wave 3 1990s–2000s	**Adaptive algorithms and big data** The Internet and networked computers For students, increased access to adaptive virtual tutoring systems that identify their specific learning needs and provide targeted instruction For teachers, greater access to data and diagnostics on student achievement to allow data-driven decision-making Enhanced interfaces via touch screens, augmented reality, and virtual reality

We think it's fair to say that most of this technology was invented for broader use, with *edupreneurs* then identifying potential applications in education settings. To us, what's fascinating is that most of that early technology has become part of the educational furniture without much thought about its impact. We can't find any systematic reviews on the impact of graphite pencils versus chalk and slate, chairs and desks versus the floor, or the steam radiator versus log fires. But they are all leaps in education technology, and at one point someone would have been championing them.

As Higgins, Xiao, and Katsipataki (2012) remind us, with almost every new technology, there is a high level of excitement in the early days—supported by either qualitative research or anecdotal evidence. Once the new technology is fully embedded, there is then often more systematic evaluation, which is frequently underwhelming. At that point, the technology ceases to be new and is a fully adopted part of the fixtures and fittings that no one gives a second thought about. And the question of overall impact remains elusive.

CHAPTER 2

The World of Today

Digital Technology Is Everywhere

Reliable data on global public spending on education technology are difficult to come by. Our best estimate is that of the USD $3.5 trillion globally that governments spend on education each year, approximately USD $140 billion is on products, services, and interventions that could be delivered digitally (Hattie & Hamilton, 2020a). What percentage of this currently is being delivered digitally is hotly contested, but it is clearly increasing. We are witnessing digitization/dematerialization of vast troves of educational resources, as well-known curriculum and content developers move away from printed books to Netflix-style content subscriptions.

We are also witnessing a higher ratio of digital gadgets to students than at any other time. Data suggest that more than 72% of children in the developed world now use a desktop, laptop, or tablet computer in schools (Organisation for Economic Co-operation and Development, 2015) and that 95% have Internet access at home (Schleicher, 2019). This proliferation in access is largely driven by declining unit costs for computational products. Back in 1965, Gordon Moore—the co-founder of Intel—noticed that the number of transistors per square inch on an integrated circuit had doubled every year since their invention, and he predicted that this trend would continue into the foreseeable future. It has, and this is known as Moore's Law.

Moore's Law has enabled an explosion in the processing power of digital computers and a corresponding decline in price. The level of processing power that would have cost tens of millions of dollars in the 1990s can be purchased for a few hundred dollars today, and that power now fits in your pocket, rather than taking up the space of an aircraft hangar.

Evidence of Deep Impact Is (Almost) Nowhere

There are many things that have achieved global proliferation outside education—like fast food and fast cars. But just because something is widely available and widely used does not necessarily mean that it is good for us.

In education, we need to set the bar very high and ask: What is the actual impact of all this technology in the classroom? Serious research into the effectiveness of education technology started in the 1960s and has continued ever since. A good portion of that research is qualitative—it involves giving students and teachers access to technology and observing and asking them what they are doing differently and about their perception of impact. Overall, the qualitative research has been relatively positive. This tells us that there are strong *perceptions* that technology enhances learning outcomes, but this could quite easily be the result of a novelty or placebo effect.

There has also been a large amount of quantitative research, which is less interested in whether students and teachers "feel" and "believe" that the technology has improved outcomes and more interested in whether, for example, student test scores have improved on standardized assessments as a result of implementation. This is the difference between whether a thing looks like it is doing something and whether it really is.

To date, there have been more than 15,000 individual quantitative studies on the impact of technology on student learning outcomes, involving more than two million participants. Generally, these studies report a statistic called an effect size (*d*), which is a kind of universal translator that tells us whether an intervention packs the punch of a gorilla or a mouse. These studies, in turn, have been consolidated into 233 meta-analyses, which draw together and aggregate the findings from the broader base.

Table 3 draws together the findings of these meta-analyses and lists them under twenty-nine influences. The wider Visible Learning® project—which summarizes data from 1,700 meta-analyses and covers the impact of teacher, home environment, student disposition, and a range of other variables—sets $d = 0.40$ as the benchmark for above-average interventions. This is because the mean average effect size of absolutely any education-related influence on student achievement is $d = 0.40$, so anything above is better than average.

Table 3 The Effect of Technology on Student Achievement

Influence	No. of Metas	No. of Studies	Confidence Rating (1–5)	Effect Size (*d*)
Audiovisual methods	8	452	3	0.36
Clickers (feedback)	3	132	3	0.22
FaceTime and social media	3	72	3	–0.07
Gaming/simulations	27	1634	5	0.34
Information and communications technology	50	2859	5	0.51
Intelligent tutoring systems	5	299	4	0.51
Interactive video	6	372	4	0.54
Micro-teaching/video review of lessons	4	402	3	0.88
Mobile/touch devices/tablets	8	368	4	0.48
One-to-one laptops	1	10	1	0.16
Online and digital tools	9	344	4	0.33
Presence of mobile phones	1	39	2	–0.34
Programmed instruction	8	1889	3	0.23
Technology in distance education	2	28	2	0.01
Technology with elementary students	6	264	3	0.44
Technology with high school students	9	681	4	0.30

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Influence	No. of Metas	No. of Studies	Confidence Rating (1–5)	Effect Size (*d*)
Technology with college students	16	2636	5	0.45
Technology in mathematics	19	898	5	0.33
Technology in science	6	391	3	0.23
Technology in reading/literacy	15	652	5	0.29
Technology in writing	3	70	2	0.42
Technology in other subjects	3	96	2	0.55
Technology with learning needs students	4	114	3	0.57
Technology in small groups	3	193	3	0.21
Television hours	3	37	3	–0.18
Use of calculators	5	222	3	0.27
Use of PowerPoint	1	12	1	0.26
Web-based learning	4	163	3	0.33
Webinars	1	15	1	0.33
Total No. of Influences	**Total No. of Metas**	**Total No. of Studies**	**Mean Average Confidence Rating**	**Mean Average Effect Size**
29	**233**	**15,344**	**3.17**	**0.30**

Source: Visible Learning Meta[x].

Key for rating
Potential to significantly accelerate achievement
Potential to accelerate achievement
Likely to have positive impact on achievement
Likely to have small positive impact on student achievement
Likely to have negative impact on student achievement

Let's start with the good news. Only three of the twenty-nine types of technology-related interventions that have been heavily researched appear to have a negative impact:

- **Overconsumption of television outside of school hours.** The impact of this appears to be much more detrimental to adolescents than to younger students, perhaps because the former are more likely to be given homework that TV watching interferes with.
- **Use of social media as a teaching and learning tool.** This has the potential to distract learner focus and to be used as a conduit for cyberbullying.

- **Presence of smartphones in the classroom.** Again, this is because of their ability to distract students from learning.

Of the remaining twenty-six types of education technology intervention, none reverses learning. However, when we look at the total number of interventions that are above the d = 0.40 effect size, only eleven make the cut (i.e., just over one-third). Ten of these fall within the light blue zone and have the potential to accelerate achievement.

The data suggest the following:

- **The use of technology is likely to be more beneficial for elementary and college students.** However, why this is the case is still not fully understood.
- **Intelligent tutoring systems and interactive video generate some of the highest impact.** The data on intelligent tutoring are particularly robust for math, where several systems administer adaptive tests to identify learning gaps and then provide targeted artificial intelligence content to address these (more on this in the next chapter). The research on interactive video shows enhanced learning outcomes in, for example, science, where the content can be used to convey the infinite nature of the universe and to enable students to explore and understand the interaction between particles at the atomic/subatomic level and at the periodic level (e.g., covalent bonding).
- **Technology has above-average impact with students who have special learning needs.** Setting aside the clear benefits of medical devices like hearing aids, eyeglasses, and insulin delivery systems, the research suggests that intelligent tutoring systems in math and online guided reading programs for literacy have strong benefits for learners in need of remedial support.
- **There are benefits to using technology as part of the process of feedback.** For example, the outputs from digitally delivered adaptive tests can provide educators with a holistic picture of each student's specific learning needs. It is important to note that the same outcomes can be achieved with manual analysis of paper-and-pencil assessments, but this is more labor intensive.

Only one technology-related intervention sits in the dark blue zone, with the potential to significantly accelerate achievement. This is the use of video recording technology, whereby teachers can film and then collaboratively review their lessons (this is sometimes referred to as micro-teaching—more on that below). Analysis and review of these video recordings are used to enhance teachers' self-efficacy, collective efficacy, and the implementation of high-impact teaching strategies like feedback and success criteria.

None of the other EdTech-related interventions fall into the dark blue zone, which has disproportionate potential for high return on investment in terms of improving student learning outcomes. And this is unfortunate, because the Visible Learning research points to many things that a teacher can do in a classroom to unlock an effect greater than d = 0.70, which is the threshold to get into the dark blue zone.

The current mean average effect size for all technology interventions is d = 0.30, which is an improvement on the average effect size from research conducted in the 1960s (Kulik & Kulik, 1987). But the needle has not swung significantly upward since the 1970s, when the available education technology was still very rudimentary. How many of you remember those terminals with green screens and attached tape decks? Apparently, they generated similar learning gains to tablet computers and the Internet.

Micro-teaching/Video Review of Lessons

The Visible Learning research tells us that feedback is one of the higher-performing interventions in unlocking student achievement. But *feedback* is a suitcase term that needs to be

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unpacked a little further. Effective feedback strategies are two-way. They involve teachers feeding back to students on where they are at in their learning and where to go next. Good feedback also does the reverse. It enables teachers to collect information from students about the impact that they are having on learning. In other words, it's about the importance of feedback to enhance teacher performance.

There is a strong role for technology to play in this, and that role is already supported by the research. Micro-teaching is the process of teachers video recording their lessons and reviewing these with their colleagues at a sort of film night. Systematic research into the effectiveness of recording and reviewing lessons started in the 1970s, and since that time there have been more than 400 individual studies and four meta-analyses, generating an overall effect size of 0.88. This makes it an extremely high-performing intervention.

As ever, the devil is in the detail, and (as with all innovations) how micro-teaching is implemented significantly impacts whether it is successful. Sharing video recordings of yourself with other teachers requires a strong trust culture in the school and a commitment from all parties to use the data for collective evaluation and improvement. This links to self- and collective efficacy, that is, teachers individually and collectively believing that they can improve student outcomes and working relentlessly to do so. This is another high-impact strategy, perhaps the highest of them all (collective efficacy d = 1.36, albeit with a relatively modest research base). Our hunch is that the video analytics technology is more of an enabler among already highly efficacious teachers.

The strongest approaches to implementation of micro-teaching involve video footage being collected on a regular basis, with the video being stopped and rewound over and over, so that teachers can home in on specific micro-practices and review them. The Visible Learning approach is about teachers seeing learning through students' eyes, so it makes sense for the recording to be of the learners as well as the teachers.

When micro-teaching was first conducted systematically in the 1970s, it tended to happen in laboratory settings because the cost of video capture equipment was high. The technology of that era was also not very portable. Although this incrementally changed in the next few decades, the barriers to easy implementation were still relatively high.

This has now changed. There are already several easy-to-use micro-teaching hardware and software platforms, such as IRIS Connect or Visible Classroom, which enable teachers to unobtrusively record themselves and their learners simultaneously. Some of these platforms also allow for remote in-ear coaching in real time. Many also allow teachers to use a range of rubrics to record time-stamped information about their observations and to share both their videos and annotations with their peers for collective feedback. In our work, we regularly use IRIS Connect, not only because of the quality of video capture and analysis, but also because of the trust-based features that allow teachers to decide who they share their recordings with. Without trust, no one will record their lessons.

There is also innovative work being done in live lesson transcription, where teachers dial in to an external application that provides them and their learners with real-time transcription of the lesson and a data dashboard summarizing teacher talk time and teacher questioning.

Can We Completely Trust the Research on Education Technology, and What Should We Do With It?

One of the principal criticisms of these meta-analytic studies is that they tend to lump all the different kinds of technologies into a single category called *education technology* or *information and communication technology* (Hattie & Hamilton, 2020b; Higgins et al., 2012). In other words, the resolution, or dots per square inch, with which we can see the impact of technology through meta-analysis is not high enough. Visible Learning MetaX (www.visiblelearningmetax.com) attempts to address this by reporting on twenty-nine subcategories or influences, but we accept that even this is a major simplification. Therefore, **we include an appendix to this paper that contains a narrative summary of each of these twenty-nine influences.** We hope this will be of help to educators in selecting appropriate interventions and to product developers in identifying enhancements that might accelerate learner achievement.

The research tells us little about the benefits of process automation through use of student information systems. For example, back in the 1960s, before use of computers was widespread, setting school timetables was a labor-intensive process that often took teams of educators several weeks of combined effort to get right. Now timetabling can be done in minutes, at the touch of a button. While there is no evidence that this results in direct gains for learners, it frees up the time of teachers and leaders, which can theoretically be used on activities that do enhance student achievement.

Another challenge is that there have been considerable changes in how different categories of education technology are defined over time. Terms like *computer-assisted instruction* and *computer-based instruction* have become less common in both the literature and the marketing materials of technology companies and have been replaced with semi-overlapping terms like *adaptive algorithms, virtual tutoring systems,* and *intelligent tutoring software*. This can make the aggregation of data across studies and across time complex. We need better and more universally agreed-on definitions of the different categories of education technology, and we sketch out some characteristics in Table 4.

A final confounding variable is the increasing speed of technological advancement (Hirumi, 2002). By the time researchers have caught up with a definitive evaluation, the exercise is largely academic (because the world has already moved on) or the technology has become so ubiquitous that it is accepted without question. Does anyone care whether overhead projectors are more effective than chalkboards or whether tablets are more effective than laptops? The first two are obsolete, and tablets are now so widely adopted that no one really thinks about them.

We accept that education technology is the new furniture and that it is here to stay. We do not advocate turning back the clock to the time before the integrated circuit board existed, but we do advocate selecting technology wisely and not assuming it is a silver bullet that will transform *everything*. Electricity and running water, for example, are useful for a school to have, but they will not transform learning outcomes alone. We have both visited contexts where, by necessity, schools managed to thrive without either. The same goes for digital technology. We suspect that sometimes the insertion of new technology can be a distraction from the core business of teaching and learning. If you talk about the technology, it probably does not make much difference; if you talk about enhanced teaching and learning, then maybe we'll start listening.

When new technology is embedded into schools, it is (almost) never inserted into a previously unused portion of the school day. Unless the technology is being used for administrative process automation,

Table 4 Toward a Better Typology of Education Technology?

Purpose	User	Learning Design	Interaction	Control	Interface
Process automation/ efficiency	Teachers	Static content transmission	Linear	Computer-controlled	Keyboard and screen
Provision of information/ knowledge consumption	Students, with supervision	Content interaction	Adaptive	Teacher-controlled	Touchscreen
Enhancing learning and skills	Students, independently	Content interaction and feedback	Asynchronous	Learner-controlled	Voice/audio
Measuring learning and skills	Parents	Content production and manipulation	Synchronous	Hybrid	Biometrics
Needs diagnosis	System leaders	Adaptive algorithm that evaluates its own effectiveness and adapts	Human–machine		Augmented reality
Data collection and reporting	Community	Adaptive testing	Human–human		Virtual reality
		Simulation	Machine–human		Haptic feedback
		Games	Human		Biological implants
					Avatar
					Chat bot

In Table 4, we have attempted to categorize some different aspects of education technology. We start with the **purpose** or end goal of the technological intervention, which can range from the automation of a "back office" process, to enhancing an individual's learning and skills, to measuring progress in the acquisition of new learning and skills.

We then move to technology **user** type. Is the intended audience teachers or students or parents, for example?

Next comes the **learning design**. Is the technology designed to be passively consumed, or is there a process of interaction and also feedback? Alternatively, is the technology designed as a tool to support the production and manipulation of content?

After learning design comes **interaction**. Is it, for example, linear—with each user receiving exactly the same experience—or does the system adapt to the identified needs of the user?

The next question is who has **control**. Is it the technology that drives the user experience, or the teacher, or even the learner?

Finally, how does this **interface** with the technology? Is it, for example, through keyboard, voice control, or touchscreen? Judging from the fact that effect size has not radically increased since we transcended the era of keyboard and screen, we surmise that the interface may be less important than the learning design and interaction.

The current research also tentatively suggests that where technology is used for knowledge consumption/content transmission, the effect is low. But where it is used for knowledge production and collaboration, the impact is higher.

There are no rows in our table because the research evidence is not currently granular enough to point to an optimal "golden thread" from one column to the next. Our hope is that future researchers build on/enhance this nascent typology of technology and that they then use it to map these "golden threads." That is, if the purpose of the technology is X, it is more likely to be effective when used by audience Y, with learning design Z, and interaction types 1, 2, and 3. The research does not tell us this yet, but it's an exciting next destination of travel!

there is a clear time-cost to implementation in the classroom. This includes the upfront support required by educators to learn how to use the new technology effectively and the existing classroom practice that must be either stopped or watered down to create space in the lesson. If the thing that's stopped was something that had a relatively low impact on student achievement, like perceptual motor programs (d = 0.08), no problem. But if it replaces time spent on effective interventions like conceptual change programs (d = 0.99) or cognitive task analysis (d = 1.29), this may be highly counterproductive.

Unsurprisingly, teacher training in the use of technology is also key (Archer et al., 2014). During the COVID-19 shutdowns, we saw many education systems deploying technology solutions, but not the same investment in using them by teachers to enhance learning. Many of the poor outcomes occur because teachers are given new gadgets and don't know quite what to do with them. Then either they lack willpower, because they don't see the point of change, and put the device/app in the real or metaphorical cupboard (perhaps rightly) or they implement with low fidelity. Even where training is provided, too often this is limited to a single day, without any ongoing coaching or mentoring and without reviewing how the technology will be integrated into the existing instructional approach or how that approach will be revised.

It is interesting to ask how ubiquitous the use of teaching technology is throughout initial teacher education programs. How may teacher educators demonstrate their ease at using technology for teaching and learning for teacher education candidates? It is our observation that technology is rarely used other than for paralysis by PowerPoint, learning management for delivering lectures, note-taking, and grades, so perhaps it is less surprising that technology has barely touched how we teach. Indeed, most teacher educators still communicate with initial teacher education students via email, a 1990s technology surpassed by Twitter, WhatsApp, and other more commonly used communication applications.

Finally, we want to stress that there are natural limitations to the effectiveness of even the best digital technology. Even if the technology becomes so advanced that it speeds up access to appropriate content; sequences that content based on learner needs; and provides appropriate interaction, challenge, and feedback—the biological limitations on human working memory mean that there is only so fast the brain can go. It's a little like setting up a new library and sending a convoy of trucks full of books, but having only one librarian to receive, catalogue, and stack them onto the shelves. Unless the technology is used to enhance the biological capabilities of the human brain (which is riddled with ethical considerations and discussed in Chapter 4), there quickly comes a point where no further efficiencies can be made.

Larry Cuban (2003) concluded that technologies will never be used in any transformative sense until we change our teaching methods. At best, we will use technology to consume more facts and knowledge, and we will use the Internet instead of the encyclopedia, use PowerPoint and Word instead of slate and paper, and complete practice tasks online instead of on worksheets. As before technology, we prioritize knowledge consumption. It will only be when we move from using technology as a newer form of knowledge consumption to seeing technology as an aid to teaching for enhanced knowledge production that there will be an effect.

We end this chapter with a two-part thinking framework that will help you get to the heart of whether a particular piece of education technology is likely to improve or detract from your school or system's current school improvement journey.

Part A: Before investing in new technology-based approaches, ask yourself these key questions:

1. **What is it that you are trying to improve?** Why are you trying to improve it, and what's the worst that could happen if you did nothing? In other words, is this the most important improvement agenda for you to pursue right now?

2. **What are *all* the different ways you could address your high-priority improvement agenda (i.e., both with and without use of technology)?**

   The Visible Learning G.O.L.D. method provides a useful toolkit to help you frame these questions with precision and suggested protocols for evidence collection. You can find out more about G.O.L.D. in our sister publication, *Getting to G.O.L.D.: The VISIBLE LEARNING® Approach to Unleashing Education Improvement* (2021), available at https://www.visiblelearning.com/content/gold-papers.

Part B: Assuming you then identify a specific technology-based solution/partial solution, ask yourself these questions:

1. **What evidence supports the effectiveness of this new technology?**
   a. Have there been any independent evaluations?
   b. How many schools were involved in the research, and are there data on the link between implementation and student achievement?
   c. Is your local context similar to that where the research was conducted?

2. **What are you going to have to stop doing to make time to adopt and successfully embed the new technology?** What will the impact be of stopping your existing practice, and is there any danger that you could be replacing something that's effective with something that will have less impact?

3. **What support are your teachers and students likely to need in order to implement the new technology effectively?**
   a. Can you commit to providing this?
   b. To what degree can the product developer support you in effective implementation?

4. **What is the direct cost of implementation per student?** Are there other things you could invest in that would generate a higher return on student achievement and at a lower cost?

5. **How does the proposed technology link to other effective approaches and help you amplify them further?**

6. **How confident are you in your answers to questions 1–5?**
   a. What data do you have at your disposal?
   b. Where can you find additional sources of information?

As Viviane Robinson (2018) says, "Reduce change to increase improvement." So if still in doubt, exercise extreme caution.

CHAPTER 3

The World of Tomorrow

In the preceding chapters, we outlined the history of technology in education and reviewed the (underwhelming) evidence of impact. We also acknowledged that the rate of technological innovation appears to be continuously accelerating and that it is quite possible that future EdTech might have a more profound impact.

In this chapter, we take a speculative journey into the world of tomorrow, and for our purposes we define tomorrow as the period up until the end of the current decade (i.e., 2030). Our first prediction is that, as with previous waves of EdTech innovation, the breakthroughs are likely to come from other fields—with edupreneurs then harnessing and applying the new technology to education.

Table 5 lists some of the current and prototype innovations that we suspect are ripe for educational applications.

The technology outlined in Table 5 has some tantalizing implications, which we discuss next.

Table 5 Technological Innovations Ripe for Educational Applications

Innovation	Description
Biometrics	This is the use of measuring devices to monitor human biological functions. This is not a new technology; the first polygraph machines measuring blood pressure, heart rate, and galvanic skin response were invented almost 100 years ago. However, the hardware is being miniaturized. It can now be worn as a watch, woven into clothing, or stuck to the skin in the form of a cheap and unobtrusive derma patch. It can also be combined with audio surveillance of breathing and speech (to assess emotional state) and digital camera surveillance of both pupil dilation and the exact location on a screen that a learner is looking at. Headbands can also monitor brainwaves.
Smart lenses/ glasses	Well-known global electronics companies such as Samsung have already patented smart contact lenses that can apparently project data straight into eyes and also record video. Less invasive spectacle versions have also been developed (e.g., Google Glass), but unit costs remain high.
Facial motion capture	This technology maps and renders the contours of the human face. It was originally utilized for CGI animation and is being miniaturized, widening the use potential.
Haptic feedback	This is the use of vibration, forces, or motion to communicate with people. Current uses include mobile phone vibration and the rumble of video game controllers. However, we expect further miniaturization, including the embedding in clothing fabrics and either vibrating gloves or derma patches. There is also potential to use this technology in reverse, that is, to use micro movements of muscles to control devices.

(Continued)

(Continued)

Innovation	Description
5G	This is fifth-generation cellular technology, with much higher data transfer speeds and bandwidth, enabling more data to be collected/transmitted from/to more devices and at faster speeds.
Deep learning AI	This is a field within artificial intelligence (AI) that focuses on developing machines that can do things that have traditionally required human intelligence. Deep learning is a subset of machine learning where either neural nets or software equivalents are structured like the human brain into nodes that can recalibrate (aka learn) based on performance feedback. The technology is currently being used for facial recognition, language translation, chat bots, and driverless cars.
Transcranial magnetic stimulation	This involves firing highly targeted magnetic pulses at very specific cranial regions, which allows the pulses to hit specific clusters of neurons in the brain. However, recent research suggests that this currently has zero impact on enhancing student learning outcomes (Horvath, 2019; Horvath, Forte, & Carter, 2015).

Immersive Virtual Meetings and Virtual Schools

Videoconferencing has been widely available for more than a decade. While this technology allows people to communicate face-to-face, in real time and from the comfort of their respective armchairs, it is still rather limiting. There is less interpersonal connection and it feels much harder to collaborate with talking heads on a screen than with three-dimensional people with whom we are sitting around a table.

However, the combination of smart lenses/glasses, facial motion capture, haptic feedback, and 5G will theoretically allow for much more immersive and realistic experiences within the next 10 years. We foresee a time when, through wearable devices, it could literally *feel* like you are in the same room as the other participants. Graphics engines will re-render people's bodies in a digital space and capture and re-render precise facial expressions in 3D, and when someone touches you on the shoulder in the digital realm, you will literally feel it via the micro vibrations of your haptic shirt. And there will be no audio lags, because 5G broadband will enable seamless data transfers.

Here are some of the implications for education:

- **Greater use of virtual professional development for teachers**, with both facilitators and participants beaming in together from different parts of the world.
- The possibility of **creating virtual schools and campuses** that enable people in remote and rural locations to have access to high-quality education. There could also be benefits in developing countries where governments cannot afford to build schools or universities. Instead, they can bypass the cost and move delivery into the digital realm.
- Building a **simulated classroom** where initial teacher education students can explore, teach, gain feedback prior to entering a real classroom, or try new ideas before testing them (often blindly) on students.

Some of the negative implications might include increased physical isolation if people choose to collaborate entirely digitally and the challenges in switching and distinguishing between the digital world and the real world.

Biofeedback Dashboards for Educators

The Visible Learning research highlights feedback as a high-impact strategy for teaching and learning. This includes setting explicit learning intentions, using appropriate questioning techniques to elicit feedback from learners, setting appropriate assessment tasks, and providing learners with clear guidance on what to do next. However, from the work of Graham Nuthall (2007) we know that as much as 80 percent of what goes on in a classroom is hidden from the teacher. No matter how experienced educators are—in eliciting, interpreting, and responding to learner feedback—they cannot (currently) look inside the heads of their students to see whether neurons are wiring and firing.

However, as biometric devices become both less obtrusive and cheaper, we can foresee a time, in the near future, when students arrive at school wearing a Wi-Fi-enabled derma patch. This would continuously stream biological data that are interpreted by deep learning AI to make inferences about which students are bored, engaged, and struggling (e.g., because the cognitive load is too great for them to handle).

The early versions will likely report data to teachers on a handheld tablet dashboard, with different color codes for different learning states. Eventually, if smart lenses/glasses become mainstream for use by teachers, these systems will be able to project augmented reality "auras" around each learner—in different colors, corresponding to their specific learning state. So as a teacher scans the room, the learners who are focused and on task could, for example, have green lines projected around their bodies, with other colors representing different learning states.

The key research question, of course, is whether the bio-data that can be captured from derma patches can tell educators anything meaningful about learner mental states. And we will not know this for sure until early systems are trialed, evaluated, and refined. This highlights the benefits of being a late adopter.

As this technology takes off, it will also raise serious questions about who has access to the data, the potential misuse for social monitoring/surveillance (e.g., the plea from some parents to know the information in order to check whether their children are attending and teachers are teaching), and the fact that the data could be used for product marketing by pinging carefully timed adverts to smartphones to respond to changes in people's bio-signs.

The Rise of Robo-Coaching?

With the increasing automation of "routine" jobs like financial stock picking and medical diagnosis, policymakers are more often suggesting that education needs to equip children with skills that computers do not have. The oft-mentioned contenders include an overlapping basket of so-called soft skills or dispositions like willpower, resilience, grit, growth mindset, self-regulation, mindfulness, openness to feedback, adaptability, emotional self-control, conscientiousness, openness to experience, tolerance, intercultural fluency, codeswitching, welcoming ambiguity, agreeableness, tact, and diplomacy.

Putting aside the definitional challenges of these overlapping constructs, there is currently a great deal of interest among education policymakers, educators, and industry in how we can best support students to unlock these traits. The Visible Learning MetaX data on learner dispositions suggest that students who are anxious are likely to have much lower levels of achievement (d = –0.44), those with higher levels of concentration will have higher levels of achievement (d = 0.54), and ditto for deep and strategic motivation (d = 0.57). However, we still lack high-quality and replicable interventions that can be used consistently by educators to address and enhance desirable traits and reduce those that could be negative. The research also suggests that of the small number of programs that vaguely appear to push the needle, when the intervention ends, the participants start to backslide to their previous dispositional settings.

Some of the most interesting research we have come across is in the area of *nudges* (Thaler & Sunstein, 2008). The basic premise is that most people generally want to do the right thing, most of the time. But they may end up doing things that are harmful to their interests—if doing the right thing is actually much harder/more time-consuming or if getting sucked into repeatedly doing the wrong thing requires only a one-time minor slip-up. The basic idea behind nudging is that if we know what the barriers or frictions are to keeping people on the right path and we can remove them, we will encourage greater levels of positive behavior.

A concrete example is student dropout. Researchers can already identify the times of year and demographics most at risk by analyzing big datasets. If at-risk learners (and sometimes their parents) then receive automated SMS messages immediately before those trigger windows, the students can be nudged to stay enrolled. One example of this is research undertaken by Bergman and Chan (2019), where they recorded a 28% reduction in student course failures when well-crafted SMS messages were sent to parents at pre-identified points. Similar research has been undertaken with college students, with nudge SMS messages being sent immediately before the start of freshman year and at the end-of-semester/term breaks, because these have been identified as critical windows when students wobble and decide to leave the education system.

With advances in biomonitoring, deep learning AI, and smart lenses, we see no technical reason why it wouldn't be possible to replicate the success of SMS nudges on a bigger scale and build them into 24/7 robo-coaching apps. Imagine the following scenarios:

- **You are a 16-year-old girl on your way to school. Just before you get to the school gates, you waver and decide you would rather go meet your friends at the mall.** Your Robo-Coach has access to the messages you exchanged with your friends the previous evening, it can sense your elevated heart rate as you stop to consider the alternative course of action, and it notes from your GPS location and lack of speed that you have stopped at an unusual place. From the combined data, it assesses an 87% probability that you will not attend school, and it interjects with a timely and personalized nudge (in a soothing vs. commanding tone; male vs. female voice; using an emotional vs. factual plea, etc.) to push you through the school gates.
- **You are a teenage boy who struggles with anger management, and this is impacting your relationships with your peers and teachers.** Here, Robo-Coach might use audio surveillance data to identify trigger topics and situations, and it might also make note of pre-aggression arousal markers in your bio-signs. When Robo-Coach predicts a high probability of an aggression response from you, it might pre-prime you with alternative phrases you could use to defuse the situation or suggest you take a timeout to do guided breathing exercises.

The same principles could be applied to all manner of situations, including overeating, smoking, not taking sufficient exercise, and not listening to other people's opinions. The Robo-Coach might also help you gather data on your personality profile; identify traits that you want to enhance; and then support you through, for example, a self-authoring program to help you explore your past, present, and desired future. It might then track the changes in your big-five personality traits, much like how contemporary smartphones track steps walked and kilometers run—to help you keep on track.

The clear dilemmas with Robo-Coach are that it requires users to submit to 24/7 digital surveillance, it smacks of paternalism, and there is a profound danger that as the technology becomes more advanced, users become mere cyphers that mindlessly follow the instructions of their digital overlords—because the personalized advice and feedback received is so good that it would be foolish for anyone to make their own decisions about anything, let alone the potential for hacking and distributing of personal information (see Selwyn, 2019).

Next-Generation Intelligent Tutoring Systems

In Chapter 2, we outlined the aggregated effect sizes for twenty-nine current education technology interventions. One of the areas that achieved an above-average effect size was intelligent tutoring systems (d = 0.51). Not all tutoring systems are made equal, but many of the currently effective ones deploy variants of the following approach:

- **Conducting an initial diagnostic.** This presents students with an adaptive test that assesses which areas of the curriculum they know, understand, and can do with ease versus those with difficulty and not at all. A more powerful use of such assessments is to use them for predicting future performance more than merely summarizing past performance. For example, this system could track student progress in an area, match this progression with similar students in the database, and then recommend the next best learning step that these similar students have used to maximize their learning.

- **Mapping out a learning pathway.** Based on the outcomes of the standardized assessment, the software then maps out each student's individual learning journey (i.e., where they are now and where they need to get to next, across the whole of the curriculum).

- **Providing just for me, just in time, and just right feedback.**

- **Providing appropriate learning content.** The software then selects appropriate learning episodes (i.e., content bundles) from its bank of thousands of individual items.

- **Monitoring and adapting.** As students work through the selected learning episodes, an algorithm monitors their progress and determines the probability that each student has understood the learning. If the algorithm concludes that there is a high probability that the student has understood the learning episode, it moves on to the next part of the learning journey. If it concludes that the student is stuck, it provides scaffolded support. If the student is still unable to complete the learning episode, the algorithm switches to something different or reduces the level of difficulty.

Thus far, intelligent tutoring systems have shown the most promise in math and science (VanLehn, 2011). This is probably because, at least at the school level, there are objectively right and wrong answers for most questions in these fields. So it is easy for a binary system to measure whether a student has achieved the required standard. This is much more difficult for, say, history, where there are multiple ways a learner could tackle a prompt such as this: "The hubris of Kaiser Wilhelm II is the single most important cause of the First World War. Discuss."

However, we predict that intelligent tutoring systems could become more useful and powerful in the future, for the following reasons:

1. With advances in wearable biometric devices, it will be possible to monitor every student's heart rate, glucose level, blood pressure, galvanic skin response, and, eventually, brain waves. It will also be possible for intelligent tutoring systems to monitor a student's eye movements to determine where they are looking on screen and to listen and process both their breathing rate and speech. The algorithm will be able to tell
   a. whether the student is fatigued and should stop or, conversely, when they are most alert and primed for learning;
   b. whether the learning episode is providing desirable difficulties that accelerate learning;
   c. when the "aha" moment occurs and help students and teachers determine when is the right time to move from learning "more" information to relating ideas and building deeper comprehension; we have detected the "aha" moment from facial recognition software with much power and impact, and students love seeing themselves in replays when they relate ideas together (Berckley, 2019);
   d. whether (more controversially) it should administer transcranial magnetic stimulation (via a headband) to fatigued areas of the brain to enhance learner concentration and promote deep learning (although there is so much hype vs. evidence about these methods).
2. It is likely that deep learning technology will accelerate the ability of algorithms to process natural human language over the next few decades. If software platforms like Wolfram|Alpha and Watson continue to advance at current rates, it is not beyond the realm of possibility that they could meaningfully process a student's oral or written response to the causes of the WWI question posed earlier, assess this against a rubric, and provide feedback to the student about what to do next. This would widen the value of intelligent tutoring systems way beyond science and math applications.

There are also interesting implications for the future of testing. In most education systems, standardized high-stakes tests are a key part of the learning diet. But we suspect that in the world of tomorrow, these tests may become obsolete. As intelligent tutoring systems collect real-time data from students about their learning, this will be useable formatively by the machine to identify what to do next. It will also be useable summatively to report to universities, employers, and other stakeholders what a learner knows and can do. This will mean that the era of high-stakes testing could be brought to an end, to be replaced with unobtrusive continuous assessment.

The End of Foreign Language Learning?

In the mid-1960s, when William Shatner and Leonard Nimoy first appeared on our screens as Captain Kirk and Mister Spock, it was fascinating that every alien they encountered spoke perfect U.S. English. At the time, this was explained away through the plot device of the universal translator. This magical device intercepted alien speech and translated it. Presumably it also reanimated the lips of non-English speakers.

Technologists have been attempting for some time to bring the universal translator to life. In the

1950s, even before the era of *Star Trek*, researchers at Georgetown University had made some basic progress with Russian-to-English translation. They predicted that the whole problem could be solved in less than a decade. In the ensuing decades, progress was much slower than expected.

The predominant technique used by machines involved use of brute force algorithms that quickly looked up each word and its major synonyms in the target language and then used a statistical technique to identify the translation of best fit. The challenge, of course, is that the machine translators struggled to deal with semantic ambiguity and double meaning. For example, the sentence "Bush filed a suit for piracy" can be interpreted in many ways. The most literal translation is that an organic shrub placed a suit of clothes into some sort of filing system and that it intended to use the suit at some point in the future to buccaneer on the high seas. The more probable definition is that a person called Bush embarked on a legal case against a person or organization that they thought had breached intellectual property law.

However, with the advent of high-power portable computing and accurate speech recognition software, several organizations have now released translation apps that can be used via a combination of smartphone and earbuds. The smartphone can also be used to take photographs of images in a foreign language, which the software translates into the target language. These translation applications have been moderately successful. Right now, they appear to struggle with making meaningful translations of any source communication that is rated as higher than A1/A2 on the Common European Framework for Languages (CEFR). This is the level of French/German/Spanish where you are able to ask for directions, order food items, and have a basic conversation with someone about their family. And they struggle completely with complex technical or academic prose.

The approach that the current wave of translation software employs is difficult to know for certain, as it is a commercial secret, or rather a range of secrets held by different developers. But it is likely that a combination of methods is used, including statistical machine translation and example-based translation, which translates by analogy. Where deep learning algorithms are also employed, we have every reason to suppose these machines will get much better. Perhaps it will take another 20 years, which is about the age at which a skilled native speaker achieves C2 of the CEFR in their home language (i.e., they are able to process academic/cognitively demanding material).

You are probably thinking that, on the one hand, this sounds feasible but, on the other, it will still be too clunky to use in everyday environments like business meetings, romantic lunches, and dinners with friends. But the parallel advances in augmented reality and lip-syncing (via deep fake AI) offer some intriguing possibilities. Scientists at Washington University have already developed a real-time facial motion capture system that can scan the mouth, lips, and face on a target and reanimate them (see also the work pioneered at the University of Auckland on the Physiome Project http://physiomeproject.org/). We can imagine a future where everyone wears augmented reality smart lenses or glasses, and as we talk to someone in a foreign language, we receive a near instantaneous cloud-computed translation via an earpiece or implant, coupled with simultaneous augmented reality lip-syncing.

If our prediction is correct, this will be very disruptive. Why would anyone bother to learn a foreign language when they can rely on such high-quality translation? We speculate that this could result in the end of foreign language teaching, an enterprise that employs hundreds of thousands of people around the world. But it could also usher in a wave of greater global cooperation. As Peter Singer (2011) explains in *The Expanding Circle*, local and global cooperation is engendered best when both parties feel connected to one another. Language differences have always created a "them" and "us" barrier, and we can perhaps look forward to an era when everyone is "us."

Could Teachers Be Replaced by Robots?

About a year ago, one of us (John) delivered a conference keynote mentioning our experience of seeing a class taught by an anthropomorphic-looking robot teacher. The students seemed to like the robot as it was nonjudgmental—they could ask it the same question multiple times and it did not get frustrated, it did not know that they had been naughty yesterday, and it did not know if they had a diagnostic label (e.g., autistic). The day after the conference, the United Kingdom's *Times Education Supplement* published an article that created a Twitter storm: "We prefer the robot to the teacher," students say.

The message of John's keynote was about being aware of teacher relations and how they affect students, but it does raise the question as to the place of robotics in a world that is rapidly changing. Neil Selwyn (2019) has written a provocative book titled *Should Robots Replace Teachers?* and shows the advances in the field, and the possibilities. It is probably the advances in artificial intelligence that will make the difference, and already there are many AI programs available and used in many schools.

In our work, we have used text mining and analyses to instantly analyze teachers' dialogue and provided information back to teachers. There are earpods and eye gaze–tracking cameras that can be linked to AI and physiological measures of degrees of concentration among students. There are sensors and depth cameras that can track behavior, simulate approval or disapproval of certain actions, and create social bonds. For example, when a robot was dancing with preschoolers and lost power, causing it to lie on its back, the children fetched blankets and food and generally cared for the stricken device.

Selwyn does raise the ethics question about AI, robots, and programs having so much data on each student, and the potential misuses (e.g., after seeing reports on their child's concentration, parents complaining about why the teacher is not making them stay more on task; linking the data to commercial products; using the data against teachers). He concludes by noting the cost-effectiveness of humans to computers, that real people have many yet-to-be-replicated features (thinking, touch, having an expressive body to aid in cues about learning).

It would be a missed opportunity to not ask how these advances could assist learners. The mix of robots, AI, and real teachers is happening now and is likely to become the mix in the classroom. Given the inordinate amount of time students spend on social media, the links between students learning around the world as well as the opportunities to discuss, remediate, and hear aloud how others are thinking within and beyond the regular class open many possibilities.

CHAPTER 4

The World of the Day After

In the previous chapter, we argued that advances in biometrics, deep learning AI, smart lenses, and haptic feedback have the potential to significantly enhance technology's impact on learning outcomes. Of course, whether this theoretical impact is actually achieved can only be known once the edupreneurs have built their apps and researchers then evaluate the impact on learning. We look forward to including new categories of education technology in the Visible Learning MetaX over the coming years and in presenting and interpreting the effect size data—so that app developers can know thy impact.

However, none of the technological advances we predict over the next decade will do anything to alter or improve how learners' brains process, store, and retrieve data from the outside world. But we suspect that over a longer time horizon this might change. In the sections that follow, we make some (highly speculative) observations about the potential impact of new technologies on both learning and the economy between now and 2100.

Genetic Engineering

A dirty secret in our business of education is that intelligence is highly hereditable (Wiliam, 2018). Comparisons of twins (identical vs. fraternal; separated at birth vs. raised together) suggest that genetic factors account for more than half of intelligence. We know, too, that IQ correlates strongly with student achievement (Roth et al., 2015).

This means that the more we do to (successfully) improve the quality of schooling, the more likely that any remaining differences in student achievement are entirely due to genetic variation in both IQ and dispositions like grit or growth mindset. But what if we could do something about this?

Technology that genetically edits the human genome already exists. The CRISPR (Clusters of Regularly Interspaced Short Palindromic Repeats) process and its newer cousin Prime Editing are the genetic equivalent of taking a reel of cinema film, cutting a piece out, and then gluing in another piece of footage in its place. CRISPR has already been used in China to reduce susceptibility to HIV in newborn babies.

However, putting the ethical considerations to one side, it is currently considered far too challenging to edit the complex array of more than 1,000 genes that interact in order to enhance hereditable traits like intelligence or working memory (see, e.g., Plomin & von Stumm, 2018). And it will likely take several decades of (ethically questionable) experimentation and computer modeling to develop AI-led targeted/bespoke gene editing that could allow newborn babies to have high IQ, high physiological fitness, low susceptibility to illness, and a life expectancy of several hundred years. However, it is possible that by 2050 this technology could be widely available.

Brain–Computer Interfaces

Since the inception of digital computing, the ways that humans have interacted with devices has gradually evolved. Early computers filled large rooms and required you to travel to them. Over time, the devices miniaturized to such a degree that you could carry one in a backpack or briefcase (laptops) and, more recently, in your pocket (smartphones). The next step in this evolutionary process is likely to involve widespread use of smart lenses/glasses, as we discussed in Chapter 3. This will mean that digital interfaces are literally attached to our skin on a semipermanent (but removable) basis.

The obvious long-term step is for computers to directly interface with the brain. One of Elon Musk's ventures, Neuralink, has developed injectable micro-mesh that can be implanted in the brain and transmits and receives signals directly from neurons (Musk & Neuralink, 2019). This type of technology is still in its infancy: it requires brain surgery, the mesh is susceptible to degradation over time, and it currently connects only with clusters of neurons rather than individual neurons.

Another approach that is also being considered is the use of injectable nanobots (Shanahan, 2015). The idea is that these would swim to the brain and then position themselves like limpets at the various neuronal junctions in order to both receive and transmit information. However, it will likely be several decades before high-quality implants have been perfected that are no more painful/invasive than having a shot in the arm. With currently available technology, we still have to contend with brain drills!

We suspect that the path to brain implants is likely to be extremely slow. In the shorter term, it will more likely be about utilizing smart headbands to read brainwaves so that we can open electric doors, turn on lights, type emails, and operate equipment with our minds (Royal Society, 2019). In the longer term, cortical implants may help us learn faster—to the point where we can download new skills like horseback riding, Kung Fu, or Arabic within seconds from an app store. The technology might also provide an auxiliary buffer to our working memory and offer the possibility of "telepathy" through brain-to-brain Bluetooth pairing.

We suspect this will just be taking off in the next 30 years, given that people will understandably be extremely reluctant to embed electronic devices in their brains. However, by 2100, the practice might be widespread and there may no longer be any need for schooling or retraining in adulthood. Learning may become like getting software updates.

Assessing the Wider Impact of Technology on Society and Education

In the 1960s in the United States, President Lyndon B. Johnson established the National Commission on Technology, Automation and Economic Progress, which issued its report in 1966. It reviewed enhancements in living standards and concluded that "technological change would in the near future not only cause increasing unemployment, but that eventually it would eliminate all but a few jobs, with the major portion of what we now call work being performed automatically by machine" (p. xii).

Almost 50 years on and the predictions of the National Commission have not yet come to pass. But there has been a recent resurgence in the belief that they might. Contemporary futurologists are particularly interested in the growth of computer algorithms and the rise in artificial intelligence. Technologists frequently make the distinction between the following:

- **Artificial intelligence (AI):** technology that can undertake narrowly focused/domain-specific pattern recognition tasks and do these with greater speed and lower error rates than humans. This type of technology does not know what it does or why. It just blindly follows instructions.

- **Artificial general intelligence (AGI):** technology that has a fuller range of capabilities and for all intents and purposes is "conscious" of its surroundings. It thinks about what it does and about a wider range of related and unrelated questions, just like us.
- **Artificial super intelligence (ASI):** much the same as AGI, but at a faster rate than we can comprehend and about many things in parallel. This might be equated to the collective intelligence of every human being that has ever lived and will ever live. The futurologist Ray Kurzweil (2005) calls this god in a box.

The consensus among computer scientists is that all three will come, eventually. But estimates are widely divergent for AGI and ASI. Most researchers think that when one comes the other will quickly follow, but the estimated timescales range from 2030 to another 300 years (Bostrom, 2016).

AI, on the other hand, has already landed. We have algorithms that are as good as and often better than us in the following areas: facial recognition; stock picking; legal case law review; music composition; medical diagnoses; writing news reports; market research; driving; call center operations; searching for patterns in large datasets; and playing games like Chess, Jeopardy, and Go.

Back in 2013, Oxford academics Carl Frey and Michael Osborne wrote a seminal paper called *The Future of Employment.* It made projections on the level of susceptibility to automation for more than 700 current occupations in the United States. The startling conclusion was that 47 percent of current jobs are ripe for automation. And this isn't contingent on the distant discovery of AGI or ASI. Current AI already has the capability to do much of the work already undertaken by humans—we just need to train it to do so. This thesis was seconded by Martin Ford (2016) in his groundbreaking book *Rise of the Robots*.

While training AI takes time, it is a one-time endeavor. If we need extra help in medical diagnosis in new locations, we just need to make additional copies of the master algorithm and upload them to servers in those new locations. We don't need to train the software from scratch over and over.

At the 2016 World Economic Forum in Davos, the central theme was the role of humans in this fourth industrial age of automation. The broad conclusion was that we humans would add more value to pursuits involving creative and critical thinking skills and by "riding with the machines" to generate outputs that neither party could achieve alone. Indeed, some prominent educationalists have argued that unlocking and nurturing creativity is the key to ensuring the economic prospects for our own grandchildren. But we have watched with awe the creative powers of existing AI in independently

- composing pretty good music,
- producing art that is pleasing to the eye,
- redesigning the nozzle on the detergent bottle,
- rediscovering Newton's laws of motion after being given a pendulum to manipulate for a day (MIT Eureka Machine; the same discovery took us humans centuries the first time around), and
- writing their own computer code—and we wonder why so many think teaching students coding is worthwhile so they become second-rate coders to self-coding machines (see Harari, 2018).

In the short term (i.e., the world of tomorrow), we agree that creativity, critical thinking, and soft skills will be key to the next generation's capacity to ride with the machines and remain economically productive—and robo-coaching may help children and adults unlock it.

In the longer term (i.e., the world of the day after), we are less sure. There is a very real prospect that technological advancement is becoming what the philosopher Daniel Dennett (1995) calls a *universal acid*. This is something that, when unleashed, eats through literally everything and leaves nothing unchanged.

CHAPTER 5

Conclusion

In this paper we have explored the impact of education technology on enhancing learner outcomes—past and present. We have also made some (speculative) observations about how technology *could* impact both education and wider society in the future. Our core message is that when we look at both the past and present, the technology has been a great deal like the emperor's new clothes—while the gadgetry exists and glistens, its threads are not yet truly golden. In the COVID-19 world, we recognize, accept, and (even) embrace the fact that leveraging technology is the only game in town.

However, 60 years of evaluation data show no major quantum leap in the impact of technology on learner outcomes. Most of the current technological interventions in schooling remain average or below in their ability to enhance student learning—when the technology is used in schools and classrooms. The notable exceptions are intelligent tutoring systems (slightly above average, but select carefully) and micro-teaching/video review of lessons by teachers (well above average, but requires willpower to implement effectively). We wait with excitement to add the findings from the COVID-19-induced Great Distance Learning Experiment to the Visible Learning database. Our hunch is that this experiment will give us more granular data about the best ways to use existing technology effectively.

Our two-part thinking tool, presented in Chapter 2, will help you decide whether the issue or challenge that you face in your local context is best solved by technology, but it is most relevant to contexts where schools are open and operating under business-as-usual conditions. It will also help you consider the evidence of impact for the technology you select and how you will design your approach to implementation to ensure that your latest investment is not left untouched.

But we look on with fascination and wonder at the latest advances. As that technology continues to improve, will the splendor of the emperor's clothes one day become much more visible and the threads more golden? In the next decade or more, we expect to see smart lenses/glasses, biometrics, deep learning AI, universal language translators, 5G, facial motion capture, and possibly also transcranial magnetic stimulation being used in schools.

The late adopters will likely reap the greatest rewards, and their choices will be guided by systematic impact data rather than anecdotes and testimonials from the people in white coats who seduce the early adopters. The moral of the story is to be like the skeptical little boy rather than the emperor or his "wise" advisers. Although, admittedly, we owe everything to the innovators and early adopters, we make progress because of what is collectively learned from their mistakes.

As we peer further into the future and consider the types of education technologies that could be widely available by the turn of the next century, we begin to take more seriously the hyperbole from technology producers that "this time it's *really* different." New technologies like genetic engineering, brain microchips, and artificial general intelligence are technically feasible and could be utterly transformative to our business of teaching and learning. These have the potential to renovate not only our brains (e.g., via genetically enhanced IQ and downloading new skills from the app store) but also the entire nature of the economy and the purpose/value of education (through AI doing more and more of the heavy lifting).

In the same year that Hans Christian Andersen published *The Emperor's New Clothes,* he released a sister work called *The Little Mermaid*. This tells the story of a young mermaid who falls in love with a handsome prince. With the help of a sea witch, she takes human form—and at great cost—so that she can be with her true love. But the prince marries someone else.

Perhaps the moral of the story is to be careful what we wish for. When education technology finally delivers, it has the potential to impact the nature of absolutely everything. Because if, like Neo from *The Matrix*, we can literally access new knowledge and download new skills from an app store, physical schooling could eventually completely disappear. Thankfully, we are still a long way from this prospect. But watch this space.

Appendix

60 Years of Research on the Impact of Electronic Technology on Learner Outcomes

Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
Audiovisual methods	8	452	5,135	0.36	3	**Likely to have positive impact** Visual-based instruction involves the use of a wide range of visual media such as TV, video, film, slides, overhead projection, and so on. Findings show that providing information in a visual and engaging way does have an effect, but it is overall relatively small. Many of the studies captured here are pre-computer-assisted instruction and prior to digital instruction methods. The research shows a positive impact of experiencing instruction through a range of media and visual/audio methods compared with more lecture-style methodologies, which were often the control method.
Clickers (feedback)	3	132	26,095	0.24	3	**Likely to have positive impact** Clickers (audience response systems) are an interactive technology that enables teachers to pose questions to students and immediately collect and view the responses of the entire class. This is a relatively new area of research, and most of the

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						data come from the tertiary sector. Clickers provide teachers with the opportunity to check student understanding of key concepts or to poll for their opinions and reactions. It is less about the use of the electronic clicker than about the teacher receiving feedback about the impact of their teaching and engaging students in discussion and thinking about the topic they are learning.
FaceTime and social media	3	72	122,808	–0.07	3	**Likely to have negative impact** Various forms of social media are being used as pedagogical tools. They can also be used to assist in homework and seeking knowledge, but there can be privacy issues and negative consequences, including cyberbullying. These meta-analyses explore the relationship between intensity of use of social media and both student achievement results and psychological well-being. Of the three meta-analyses, one found small positive effects and the other two found negative effects.
Gaming/ simulations	27	1,634	159,081	0.34	5	**Likely to have positive impact** Typically, games/sims involve use of a digital model or game (e.g., role-playing, decision-making) with an aim to engage students in learning through mimicking real-world problems. The research findings are variable. However, with the large number of studies and

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						meta-analyses conducted over the last few decades, it seems safe to conclude that engaging in such programs will likely lead to a positive impact on student achievement.
Information and communications technology (ICT)	50	2,859	125,084	0.51	5	**Potential to accelerate** These studies explore a range of different ICT usage types and contexts—for example, computer/tablet/mobile, use by teachers/students, used for content creation/transmission/data analysis, and so on. The diversity of studies and usage contexts explored makes the identification and replication of effective strategies challenging, though.
Intelligent tutoring systems (ITS)	5	299	22,700	0.51	4	**Potential to accelerate** An ITS is defined as a software-based system that provides customized instruction and/or feedback to learners, generally without requiring the involvement or input of a human teacher. These are second-generation computer tutoring systems that have built in a more responsive and adaptive approach than earlier computer systems. All five of these meta-analyses were conducted in the last several years, and the research begins in the mid-1980s for these types of systems—so this is still an evolving area.
Interactive video	6	372	4,800	0.54	4	**Potential to accelerate** Interactive video methods are a combination of computer-assisted instruction and video technology. The use of

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						visualizations, video information, and interaction with the programs can convey key information and messages very effectively. Lots of variables exist, and the design of the instruction is crucial to success.
Micro-teaching/ video review of lessons	4	402	N/A	0.88	3	**Potential to considerably accelerate** Micro-teaching is where teachers examine aspects of a lesson or group of lessons by reviewing collaboratively with colleagues. This can involve the detailed analysis of specific pedagogic approaches (e.g., questioning skills, teaching strategies). It may also involve, as in many of the studies included in these meta-analyses, video recording a lesson and then examining an aspect of practice. The main implication regarding micro-teaching is that teachers need to receive ongoing feedback about their teaching and engage in ongoing reflection to improve student results, and when they do it can be very impactful.
Mobile/touch devices/tablets	8	368	19,735	0.48	4	**Potential to accelerate** Overall, the research suggests that there is a positive effect on student achievement through using such devices in learning, with the potential to accelerate learning. However, several moderators affect the extent of the impact. Most obvious is how the teacher has designed the learning episode to incorporate these

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						devices in a useful way. The effect appears to be greater for handhelds than for laptops; usage in inquiry-based learning appears more effective than usage along with lectures, self-directed study, cooperative learning, and game-based learning; informal educational environments appear more effective than their formal counterparts; and medium- and short-term interventions appear to be superior to long-term interventions.
One-to-one laptops	1	10	N/A	0.16	1	**Likely to have small positive impact** This refers to schemes or programs that emphasize the ratio of laptop computing devices to students being 1:1. One-to-one laptop schemes are being advocated in some education systems as key to improving the use of technology in schools. Currently only one meta-analysis (Zheng, Warschauer, Lin, & Chang, 2016) has examined the impact these schemes have on student achievement. The researchers found wide consensus in the studies that use of laptops promotes 21st-century learning skills. In addition, they found improved outcomes in writing, mathematics, and science learning—albeit small effects. Issues remain around equity of access and the moderators of teacher and parent knowledge and understanding in how to maximize the benefits of having access to the 1:1 laptops.

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
Online and digital tools	9	344	67,226	0.33	4	**Likely to have positive impact** There is no single definition for online learning. This is a broad category that includes learning with the assistance of the Internet and a personal computer. The term *e-learning*, or *electronic learning*, is used interchangeably with *online learning*. The term *digital tools* refers to the use of things like e-reading devices. The studies in these metas range from kindergarten through tertiary, but there are more effects in higher education than K–12. This is because most of the more rigorous studies, which had experimental and control group design, were only conducted in tertiary or higher education. This means that many of the less rigorous K–12 studies are excluded. Nonetheless, the overall findings suggest that use of online/digital tools, when combined with face-to-face instruction, can be slightly more effective than face-to-face instruction alone. It appears that variation in delivery methods rather than any particular medium by itself contributes to slightly improved learning outcomes for students. The practices with the strongest evidence of effectiveness include mechanisms to prompt students to reflect on their level of understanding as they are learning online. Where the online learning environment has the capacity to individualize instruction to a learner's specific needs, this also improves effectiveness.

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
Presence of mobile phones	1	39	148,883	–0.34	2	**Likely to have negative impact** This influence represents any measure of mobile phone use, whether considered normative or problematic, that quantifies the extent to which a person uses a phone or feels an emotional or other dependence on a phone, or categorizes the types of uses and situations in which phone use occurs.
Programmed instruction	8	1,889	N/A	0.23	3	**Likely to have positive impact** This mode of instruction, first designed by psychologist B. F. Skinner in 1953, provides students with immediate feedback and enables them to work at their own pace. It includes students working alone at their own speed, through a graded sequence of controlled steps. After each step, students test their comprehension by answering an examination question or filling in a diagram.
Technology in distance education	2	28	2,941	0.01	2	**Likely to have small positive impact** The studies aggregated here measured the effect on student learning of using computer-assisted technologies for distance education versus more traditional means of distance education. Overall, the findings show zero difference. These studies are only up to the early 2000s, so it is possible that the more modern and interactive forms of computer-assisted instruction may have a greater impact.

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
Technology in mathematics	19	898	237,607	0.33	5	**Likely to have positive impact** As with the other technology influences, this one has separated out and aggregated the studies measuring effects of different technologies on mathematics learning. The results are varied and difficult to generalize. The best way to use this influence would be as a benchmark for assessing any new mathematics-based technology implementation to check that product developers achieved greater impact than this average overall effect.
Technology in other subjects	3	96	4,433	0.55	2	**Potential to accelerate** This influence is a catch-all for the effects of learning through the use of different technologies in subject areas that have not been pulled out as separate influences in their own right. A wide range of technology contexts and subject areas are pooled here.
Technology in reading/literacy	15	652	134,321	0.29	5	**Likely to have positive impact** This influence groups together effects relating to the impact of computer-assisted technologies on reading/literacy. The studies and the types of tools or mechanisms that were compared are varied, as is the range of effects. As with other technology-based influences, the message is that caution needs to be applied when looking at any individual program for reading, and school leaders

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						should examine the evidence of impact very closely, especially when factoring in the associated costs. In any case, the use of the tool or device is never sufficient in itself, and the effectiveness is improved with good teacher training and carefully designed programs that include support with when and how to use the different tools.
Technology in science	6	391	10,240	0.23	3	**Likely to have positive impact** The effects grouped together here measured the impact of using different technologies (usually computer-assisted instruction) on improvements or gains in science achievement. There are a wide range of effects for many different types of technology interventions, so caution needs to be applied in interpreting this influence.
Technology in small groups	3	193	11,317	0.21	3	**Likely to have positive impact** The studies aggregated here measured the effect on student learning of using computer-assisted technologies in small groups versus individually. The findings show that using technology in a small-group context has a small positive impact compared to using it individually. These effects are moderated by a number of factors, however, and are likely to be more effective if students work in pairs, have knowledge of working cooperatively, use cooperative working

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						strategies, are supported in how to use the technology, and work with others of similar ability rather than a wide range of abilities.
Technology in writing	3	70	2,343	0.42	2	**Potential to accelerate** This influence reviews the impact of the use of computer-assisted technologies on writing achievement. The majority of these studies looked at the use of word-processing (or similar) technology and how this improves student writing. Overall there is a positive impact in using computer technology to assist students with planning, writing, proofing, editing, and revising their work. Improvements are particularly noticeable in students writing more on computers than if they were handwriting. They are also more likely to edit and revise their writing when using computers than with handwriting, as it is less onerous to make changes. Publishing pieces that look professional is a motivating factor for students. As with many interventions, the use of technology in writing is more impactful for students with learning disabilities.
Technology with college students	16	2,636	74,943	0.45	5	**Potential to accelerate** In this influence—as with the technology in elementary and high school levels—we have separated out the effects from many studies that measured the impact of computer-assisted technology implementations

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						on the achievement of students in higher education. As with all research, there is a wide variety of results across all these studies. The research suggests that use of technologies that require students to collaborate and work with at least one other person is generally more effective than individual practice and that combining human tutorials with simulations and/or drill and practice is more effective than replacing human tutorials with just computer-assisted instruction. In addition, there is the question of impact versus cost. Computer-assisted instruction has been found by some researchers to be cost-effective when compared to conventional instructional implementations in higher education, but this remains a not very well-researched question.
Technology with elementary students	6	264	N/A	0.44	3	**Potential to accelerate** These meta-analyses aggregate the findings of studies that measured the effects of using computer-assisted technologies in the teaching of elementary-age students. Different technologies have different levels of impact, and the impact varies by age of learner. The research suggests that technology interventions have the highest impact on students with learning disabilities, relatively high impact on elementary students, and lower impact on secondary students.

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
Technology with high school students	9	681	34,211	0.30	4	**Likely to have positive impact** This influence signals the likely impact of implementations using computer-based technologies on the achievement of secondary school–age students. The results across the studies are highly varied, and many different forms of technology implementation were measured, so the best way to view this effect size is as a benchmark to compare any future technology-based intervention. Schools and school systems should ensure that any new intervention has a higher impact than this average effect to justify scaling it up and always monitor and evaluate the impact it is having.
Technology with learning needs students	4	114	10,223	0.57	3	**Potential to accelerate** These studies examined the impact of students with a wide variety of cognitive learning needs engaging in some form of computer-aided instruction. Overall, computer-assisted instruction tends to have a positive impact on the achievement of learning needs students. The studies range across several learning areas, grade levels, learning needs, and forms of content-assisted instruction (CAI).
Television hours	3	37	1,022,000	–0.18	3	**Likely to have negative impact** In general, the more children watch television, the more likely this is to have a

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						negative effect on their school achievement, but there are many other more important influences. Watching only 2 to 3 hours of TV a week has no negative impact at all. The adverse effects were found to be greater for girls and those with high IQs. Younger children appear to be able to watch more TV than older children without negative effects on achievement outcomes. Interestingly, there can be prosocial effects of watching TV that are higher than any negative social effects (e.g., peer relationships are enhanced when children are watching the same TV programs and are able to discuss their shared experience). Note that with the proliferation of high-speed Internet and personal devices, television watching appears to be reducing. We expect that future meta-analyses may explore the link between Internet usage and student achievement.
Use of calculators	5	222	N/A	0.27	3	**Likely to have positive impact** These studies measured the impact of the use of calculators on student mathematics achievement. With one exception, the meta-analyses show a low but positive effect of calculator use on math skills. Calculators are most effective (a) when they are used for computation, drill, and practice work and for checking work; (b) when they

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						reduce the cognitive load for students; and (c) when there is a clear pedagogical purpose for using them.
Use of PowerPoint	1	12	N/A	0.26	1	**Likely to have positive impact** PowerPoint is the Microsoft program that allows integration of text, images, video, sound, color, animation, and other elements into electronic presentations. Studies here mostly measured the impact of PowerPoint, but evaluations of other desktop presentation programs (DPPs) are also included. The research provides limited support for the use of DPPs for either student perception or achievement, but many variables across the different studies were not able to be controlled for. And with a relatively small number of studies in this area, teachers and policymakers should exercise caution in generalizing the findings.
Web-based learning	4	163	22,554	0.33	3	**Likely to have positive impact** Web-based learning refers to learning that uses the World Wide Web (WWW), or the Internet or web-based tools, as a means and a method for delivering learning and instruction. The use of the Internet is relatively recent in terms of educational research history (i.e., the WWW was invented in 1989).

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Influence	No. of Metas	No. of Studies	No. of Participants	Effect Size	Confidence Rating (1–5)	Analysis
						The potential of web-based instruction will likely improve as pedagogical approaches in how to teach students to maximize the benefits of the web improve and as better design of curriculum and approaches to web-based learning develops. Existing research suggests there is potential for a small benefit to students engaging in web-based learning as compared to regular classroom instruction.
Webinars	1	15	591	0.33	1	**Likely to have positive impact** Webinars are online seminars conducted via web conferencing and usually include interaction. Webinars occur synchronously with a live audience.
Total No. of Influences	**No. of Metas**	**No. of Studies**	**No. of Participants**	**Mean Average Effect Size**	**Mean Average Confidence Rating**	
29	**233**	**15,344**	**2,269,271**	**0.30**	**3.17**	

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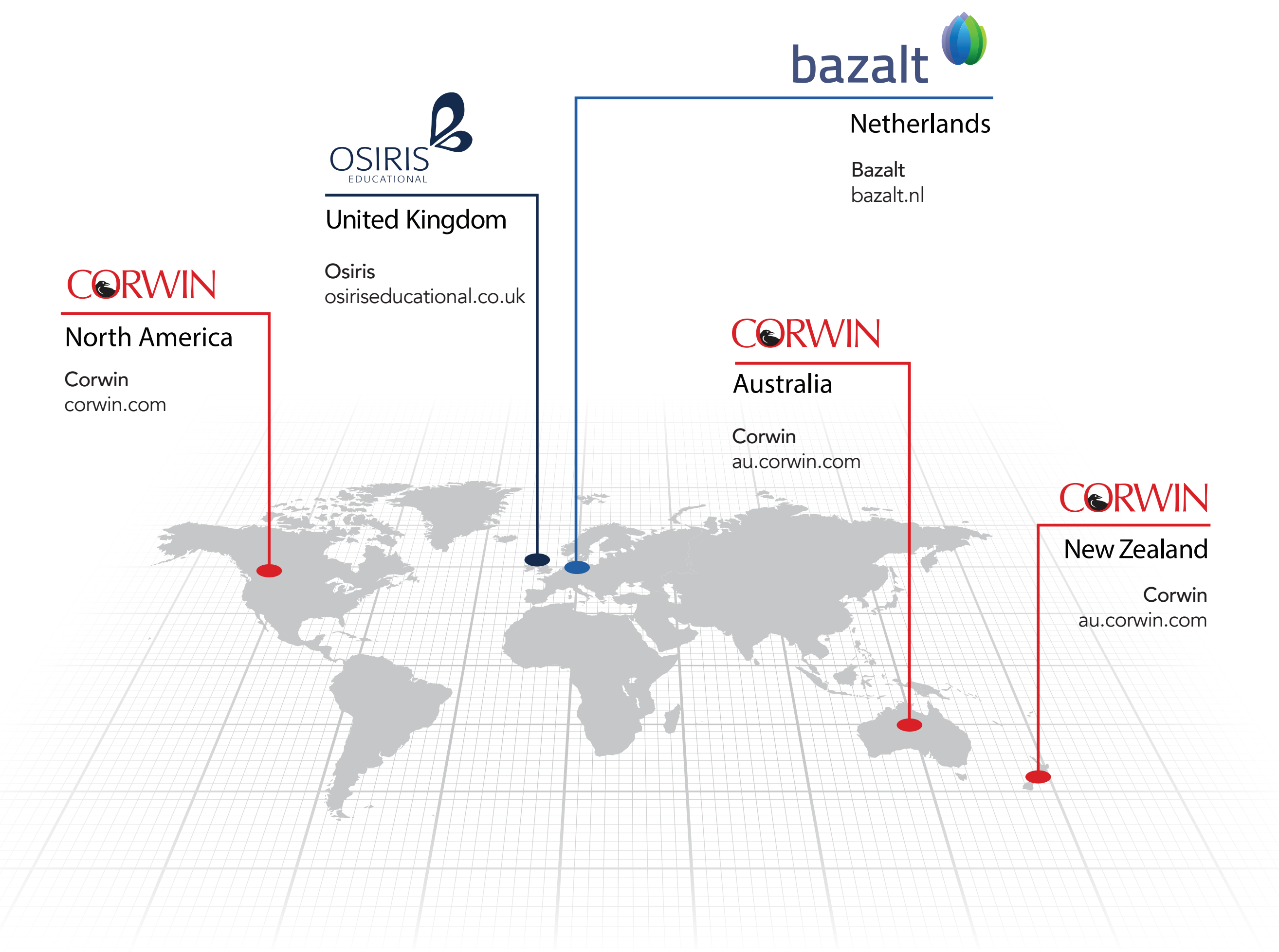

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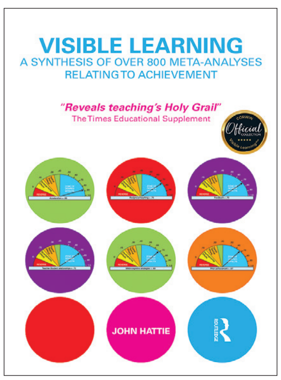

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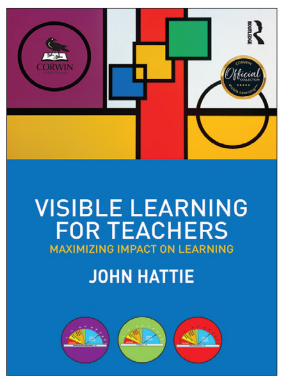

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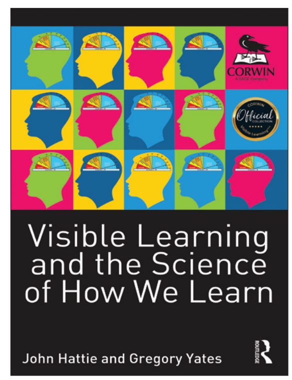
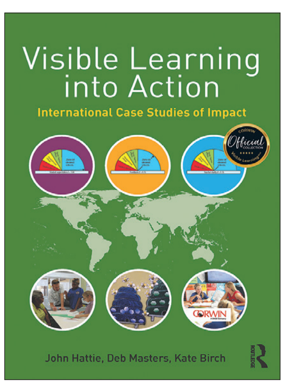


VISIBLE LEARNING AND THE SCIENCE OF HOW WE LEARN



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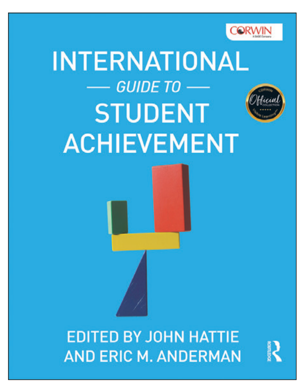

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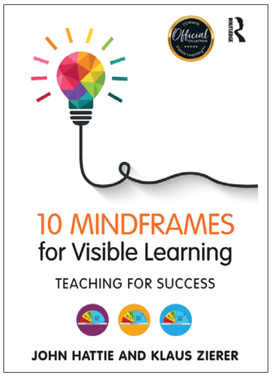
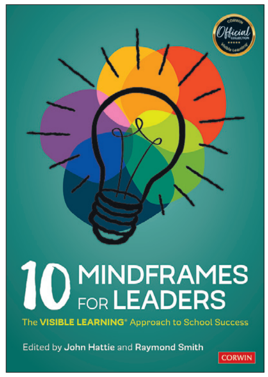
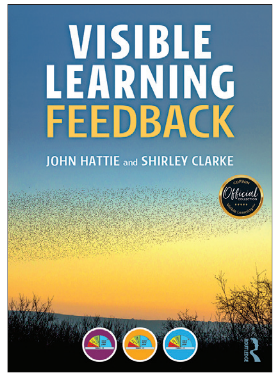


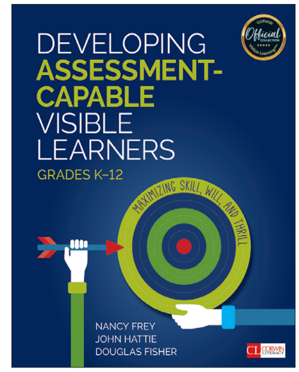
10 MINDFRAMES FOR VISIBLE LEARNING



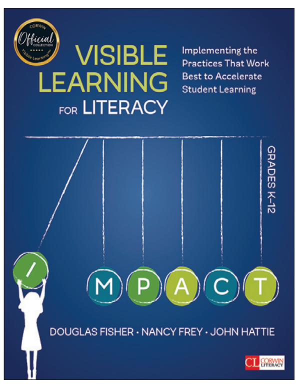
10 MINDFRAMES FOR LEADERS



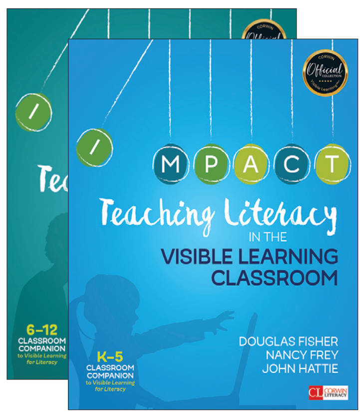
VISIBLE LEARNING FEEDBACK



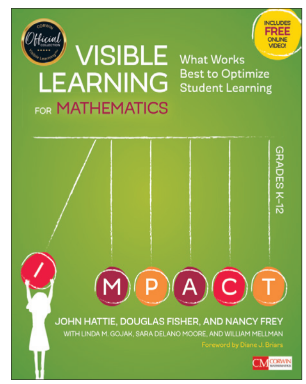
DEVELOPING ASSESSMENT-CAPABLE VISIBLE LEARNERS, Grades K–12



VISIBLE LEARNING FOR LITERACY, Grades K–12

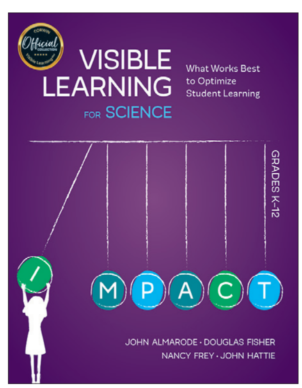


TEACHING LITERACY IN THE VISIBLE LEARNING CLASSROOM, Grades K–5, 6–12

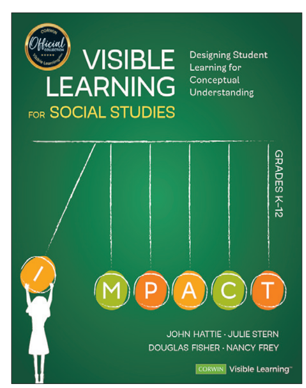


VISIBLE LEARNING FOR MATHEMATICS, Grades K–12

TEACHING MATHEMATICS IN THE VISIBLE LEARNING CLASSROOM, Grades K–2, 3–5, 6–8, & High School



VISIBLE LEARNING FOR SCIENCE, Grades K–12



VISIBLE LEARNING FOR SOCIAL STUDIES, Grades K–12