The Analogue Revolution – Rethinking the Future of AI Education

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It was a lightbulb moment. My 14-year-old niece, British-born but long a resident (now citizen) of the United States, came to visit one glorious summer in Wales. She is a cookie-cutter model of what US technologist Marc Prensky, back in 2001, dubbed the 'digital native'.[1] She was born and bred in the internet-connected era, her growing brain wired in step with an exponentially digitising world, buzzing with gigabytes of data eager for her attention. She is intuitively smartphone savvy. Her thumb blurs over the screen like the dot-matrix printer that died out before she was born.

She is also an *educational* digital native. She moved to Texas in the early years of her life and has attended well-funded, technology-enhanced schools all the way since. Each of the 4,000 children at her high school received an iPad, the device a nexus for almost every part of her educational journey – diary, learning, planning, assignments, assessment, teacher interaction, data gathering, research.

I, by contrast, am Prensky's flip-side – the 'digital immigrant'. I grew up in a time when the screen meant, for the most part, scheduled and limited TV. Much of its content was achingly unsuited to youth, so the largest portion of my childhood was lived beyond the screen, eyes focused in yards rather than inches. My time was spent negotiating a world of objects, people and events. I remember periods of profound boredom – yes, *boredom* (remember that?) – my mental engine idling while it attempted to find a gear, any gear. In school, 'technology' meant the tools of 'design and technology' – lathes, band saws, buffers, hammers, workbenches.

Of course, computerisation was just around the corner. (For those attempting to place my age, I was born in 1970.) My early forays into digital technology were desultory gaming with a Spectrum ZX81. At university, however, I found a Damascene digital conversion. Computing took hold. I became conversant, then proficient, then dependent. The keyboard and monitor became the scaffolding of my working day – they still are. Soon the smartphone arrived and won its place as my permanent left-pocket accessory, a portable on-off switch between the analogue and the digital. But I still, and will always, carry a ghost-like memory of the pre-digital age. Like a true immigrant, I live in a country I was not really born into.

Back to the summer visit. My niece and I set out by car to explore the Gower Peninsula of South Wales. At one point in the journey, I needed to check my route. I reached around the driver's seat and pulled out a book of road maps. My niece's reaction was arresting. 'What is *that*?' she exclaimed. Note, not 'What are you doing?' or 'Where are we?' but 'What is *that*?' I replied uncertainly. 'It's, er, a book of maps.' She looked reflective and honest: 'I've never seen one of those before. We usually use Google Maps or the car's sat nav.'

Apparently, the map book was a revelation. Such was her interest that she actually climbed from the back of the car into the front to explore the pages. There

was much to take in – the breadth of the territory covered by the large format; the very literal sense of spatial and directional orientation through the medium of scale; the symbols and road classifications; the distance between places; the mental demand required to locate yourself and your destination and to plot a route between them; the way the map showed her where she was in relation to other places, her body in place and time. In small-screen navigation she was a blip on a path hidden from her. On the map, she understood where she was in the world. She was *here*.

To me, the digital immigrant, the analogue map was familiar, quotidian, reliable and functional, albeit a little retro. For my niece, it was unfamiliar, demanding, even fresh. And that, with my educational hat on, got me thinking.

The fourth educational revolution

Anyone in education who questions the future of education technology (EdTech) is almost duty-bound to demonstrate that they are not a sour-faced old Luddite. I'm going to stick with the script. The fact is, my life is soaked in digital technology. In the near-total absence of meaningful manual skills, I have built a working life around the scaffolding of screens, keyboards and software. I might be a digital immigrant, but I've done well out of my hyper-productive, digitally enhanced adopted country.

I fully embrace and recognise the benefits of EdTech. It even excites me. Today's child roams digital shelves in virtual libraries that are greater than the world's most august physical repositories. EdTech delivers immersive 'gameified' learning, turning all the cogs of a child's brain. It can delivery modern pedagogy with exceptional precision and engagement. To a large extent, it is the future. So, in no way am I hostile to well-developed, judiciously deployed EdTech.

But change is blowing in from the horizon. It's called artificial intelligence education (AIEd). It's going to be big.

AIEd augurs a genuine transformation in teaching and learning. Through adaptive machine intelligence, ever improving itself, AIEd offers the possibility of delivering personalized, responsive and powerful learning journeys to each and every student, freeing teachers to concentrate on pupil development rather than time-draining chores. To be fair, AIEd is already hard at work in some classrooms and has been for some time, so we are not coming at this topic entirely blind. But we are just at the beginning of the AIEd journey. The launch of OpenAI's ChatGPT on 30 November 2022 showed the world the formidable potential of large language model (LLM) AI, when the global audience was allowed to play with it. With quantum computing on the horizon, even if we don't hit peak-AI in the form of artificial general intelligence (AGI), the capabilities of AI in the next five years alone are likely to be astonishing, not least in education.

As AIEd flowers to full growth, we might indeed see what British education expert Sir Anthony Sheldon has called, in the book of the same name, the 'fourth education revolution'.[2] The first revolution, he argues, came at the dawn of humanity, when information and skills were first informally but fluidly shared between individuals, families and tribes. The second arrived with the birth of civilisation (thank you, agricultural revolution) and trade, accompanied by the emergence of writing. Settled, increasingly literate, populations led to intellectual specialisation and the foundation

of organised learning, beginning about 2500 BCE and leading to the first schools and universities by the medieval age.

Then came books, and everything changed. The third educational revolution that followed the invention of the Gutenberg printing press in 1436 was a long-running and complex affair that continues to this day. Education was progressively transformed as the centuries marched on, especially when the Industrial Revolution married deep social changes with universal education and the introduction of STEM subjects alongside classical liberal arts. The third education revolution also settled onto the tracks of a particular, some might say peculiar, mode of teaching – a teacher at the front of a classroom, commanding the minds of 20–30 obliging children sat in serried ranks. This was a world of textbooks and lectures, of set-pace whole-class learning. Each child within this eyes-forward system was in a personal and variable relationship to the overall progress of the class.

Sheldon argues that we are still, to a large extent, stuck in a half-millennium old educational tradition, one that is now ill-suited to modern learning challenges. Despite the technological progress from the late 20th century to the present day, particularly in the realm of computing, teaching strategies at the beginning of the 21st century are not a million miles from where they were several hundred years ago. Teacher at the front. Do this. Learn that. Keep up.

There's a discussion to be had here, not least whether the third era of education was changed by pedagogical and organisational shifts in education since the 1960s. But parking that, Sheldon's impending fourth revolution is on the horizon. This is the age of AIEd. Summarising broadly, gone will be the days of one-size-fits-all teaching and learning. Instead, students will interact with a personalised AIEd system, one in which they are incrementally and intelligently guided on a personalised learning journey. The AI responsively tailors content and assessment to the individual needs, tracks wellbeing and progress, identifies aptitudes and fosters skillsets. Gone are the days of attempting to print out a student to a universal template.

This is genuinely exciting stuff – the use of the word 'revolution' is warranted. According to its proponents, optimised AIEd could potentially lay a lifelong learning path for each individual, its guiding digital hand supporting the formative experiences of schooling, college, finding employment, starting and raising a family, creating a business, managing finances, and much more. In education, teachers will have their time liberated from clock-draining administrative and marking burdens. Theoretically, that will give them more time to focus on the specific needs of individual children, the AI's reporting functions giving them the most detailed information about student student progress and when interventions are required. In the most advanced AIEd, cameras linked to facial and behavioural recognition software could monitor student participation in the classroom, looking out for disengagement, confusion or isolation. (Don't write this off as sci-fi – AI behavioural monitoring software is already in use in some schools in China and India.) AIEd could also foster social interactions, making meaningful pairings between students and educators based on shared needs or stimulating contrasts. Fully realised, AIEd signals the end of traditional classrooms. A revolution indeed.

There is a chorus of support for the fourth educational revolution, albeit one

modulated with varying degrees of caution. Amongst some of the world's leading educators, researchers and EdTech companies, the excitement is palpable, the ambition limitless. The fizz is neatly summed up in the Pearson Education report *Intelligence Unleashed: An argument for AI in Educatio*n, which declares:

> We look towards a future when extraordinary AIEd tools will support teachers in meeting the needs of all learners. Drawing on the power of both human and artificial intelligence, we will lessen achievement gaps, address teacher retention and development, and equip parents to better support their children's (and their own) learning. Importantly, doing this will require much more than borrowing the language of AI – we need to go deep, harnessing the power of genuine AIEd, and then working to apply it in real-life contexts at scale.[3]

I am not going to disagree with the idea that the revolution is arriving. Nor am I going to say that this revolution is to be resisted – it cannot and, in part, should not. But there is a risk within all revolutions, namely that it might destroy as much, potentially more, than it creates. Most proponents for AIEd acknowledge the dangers. But I've often struck how marginalised those acknowledgements can be, confined to an isolated box feature or a short chapter, a sober and brief discussion outside the house before heading back inside for the party. But there are serious discussions to be had. I want to focus on what I see as crucial to both the success of AIEd and to the wellbeing of future generations of students – how we manage the educational relationship between the digital and the analogue worlds. It might seem almost quaint that I persist in making the distinction between those two realms. I concede that this could well be symptomatic of my age. But I start my argument from an undeniable truth. However dualistic we might think we are, we are ultimately just bodies.

Technology, meet Biology

We are physical beings. There is an appeal in avoiding this truth. The idea that we are somehow disembodied, liberated spirits just taking a ride in a biological taxi has been a defining idea of great philosophy and global religion. Dualistic thinking gives existential hope, namely that somehow we can transcend the depredations of body over time. But when it comes to EdTEch, and our interactions with it, we need to put our embodied, biological reality centre stage if we are to make judicious decisions about the future of AIEd.

I start my argument with a sad truth. The balance of research now seems to indicate that the mental health of young people has undergone a measurable and wincing decline since about 2006–07, the years in which smartphones were introduced and high-speed internet took off. This position has been laid out most prominently by the American social psychologist Jonathan Haidt and journalist/activist Greg Lukianoff, initially in a 2015 *Atlantic* article 'The coddling of the American mind', then in a book of the same title in 2018.[4] Haidt has also worked with Professor of Psychology Jean Twenge to detail the recent evolution of adolescent mood disorders.[5] In these and other works, Haidt et al. have tracked the unprecedented (truly) leap in serious psychological issues amongst young people, especially females, from 2010. The researchers stripped out factors such as

increases in self-reporting and benchmarked the arguments against grim measurables – serious depressive episodes requiring treatment; self-harm requiring hospitalisation; attempted, or successful, suicide. Pulling the data from official sources, they demonstrate how the rates of serious mental outcomes have leapt between 50 per cent and 150 per cent since 2010, the results depending on the specific demographic. There was also an equivalent jump in self-reported loneliness, from about 17 per cent in 2000 to nearly 40 per cent in 2018.

Haidt and others have pegged the youth mental health crisis, at least in part, to social media on smartphones, which hit saturation levels in 2010–11. Here we are entering an arena of hot debate, a statistical battleground raging over causation and correlation. But forgetting the content being viewed, the connections between sheer time spent looking at a screen and the declining quality of a young person's mental health seem secure. A US 9th or 10th grader using an electronic device for more than five hours per day is twice as likely as a light user to suffer serious depressive symptoms and to have a suicidal episode.[6]

In fact, 5+ hours of screen time per day in young people is not merely realistic, but in many cases is actually conservative. In 2021, the Common Sense organisation published its latest findings regarding the use of social media and digital entertainment by US tweens and teens. There were some unsettling headline findings. Between 2015 and 2019, it found that media use by tweens grew by 3 per cent and for teens 11 per cent. For tweens, this meant an average increase of eight minutes per day total screen time compared to the previous two years, but 49 minutes per day for the teens. Then came Covid-19. For young people the pandemic was disastrous on so many levels, and we see a flight into digital media use as part of the psychological and social response. From 2019 to 2021, media use grew by 17 per cent for both tweens and teens. This translated into an 8–12-year old using digital media for an average of 5:33 hours every day, while teens were screen-surfing for a dizzying 8:39 hours per day. Notably, one of the great drivers of the increase was not social media (i.e. interaction with others), but entertainment media (YouTube, TikTok etc.) – watching videos. This habit was heightened in teens from low-income families. Reading, it was found, did not increase in usage.[7]

Given the generational disruption of the pandemic years, we must be cautious about using them as a benchmark. So where are we now in 2023? Is the tide receding? Not really. According to a cluster of research, in 2023 the average US teen spends 7 hours 22 minutes looking at screens, an increase of nearly two hours since 2015. At least three hours of that time is watching TV or online videos. Such patterns are borne out internationally. UK data published on Statista for 2018, notably pre-pandemic, indicated that every week a British 12–15-year-old consumed 13.3 hours of TV, 20.5 hours of internet, 13.8 hours of gaming and 16.8 hours of other mobile phone use. The grand total is 64.4 hours per week, far more than the hours consumed in the average full-time job. 2023 data found that the average British teenager spent 114 minutes every day just looking at TikTok.[8]

So what has this to do with EdTech? If we look at these figures from the perspective of biology and psychology, quite a lot as it turns out. Take basic biology first. As human beings, we have evolved to move. That means running, jumping,

standing, walking, lifting, swimming, bending, squatting. These core physical acts, repeated frequently and occasionally vigorously, are critical for our physical development. They are what ensure we have healthy cardiovascular systems, physical strength, durable bones, flexible joints, smooth circulation, quick reflexes, good sleep. That's on the plus side. A lack of physical movement or exercise whacks us on many levels – cardiovascular disease, obesity, back pain, hypertension, cancer. In fact, excessive sitting is connected to 35 serious health issues.

Trouble is, we are all doing an awful lot of sitting and awfully little movement. This is not a new thing. The rise of office culture condemned many people to seats even before the internet age. The difference was that in the pre-digital age people largely sat at work only. Outside those hours, the more manual nature of existence kicked in. People were obliged to do stuff that required the full spectrum of physical movements, even if they were not consciously pursuing 'exercise' as we know it.

Today, an average person in the West spends 10–13 hours per day sitting. That's not good for us. It's particularly not good for young people, who thanks to digital media are now finding epic amounts of inertia. In 2016, the Public Health Agency of Canada released its *Canadian 24 Hour Movement Guidelines for Children and Youth*, a series of age-stratified recommendations for the balance between physical activity, sleep and sedentary behaviour across a 24-hour period. For young people aged between 5 and 17 years, the following was regarded as optimal:

- An accumulation of 60 minutes of vigorous physical activity every day, focused primarily on aerobic exercise. Muscle and bone strengthening activities should be incorporated at least three times a week.
- Each day should also include 'Several hours of a variety of structured and unstructured light physical activities'.
- 9–11 hours of 'uninterrupted' sleep for children aged 5–13 years and 8–10 hours per night for those aged 14–17 years, 'with consistent bed and wake-up times'.
- No more than two hours per day of recreational screen time, with 'limited sitting for extended periods'.[9]

Even at an instinctive level, most of us will recognise that a large proportion of today's youth is falling short of these ideals. Research published in 2013 in the *British Journal of Sports Medicine*, based on a sample of 5,000 children tracked since the 1990s, found that average daily exercise was just 29 minutes for boys and 18 minutes for girls.[10] Not only do most teens fall well short of the recommended 60 minutes of formal exercise each day, but there has been a general drop of the activities that define the analogue childhood – playing physical games, being outdoors, sport at school, walking or cycling long distances, doing physical chores. The consequences of this precipitous drop in exercise, compounded by poor diets, are profound in the long term. The right dose of exercise each day is a true medicine against some of humanity's most serious mental and physical afflictions. The World Health Organization (WHO) states that physical activity, amongst other things:

- helps protect us against cardiovascular diseases, cancer and diabetes

- reduces symptoms of depression and anxiety
- enhances thinking, learning and judgement skills
- ensures health growth and development in young people.[11]

Note the penultimate point here about the *mental* effects of physical activity. Analogue fitness is a matter of *academic* importance. The aforementioned 2013 study, conducted by the universities of Strathclyde, Dundee and Bristol, discovered an increase in academic performance for every 17 minutes of daily exercise for boys and 12 minutes for girls. The 5,000-strong sample was assessed at ages 11, 13 and 15/16, corresponding with major exam or assessment benchmarks in the UK educational calendar. It found that 'Children who carried out regular exercise, not only performed better academically at 11 but also at the age of 13, and in their exams at 16'. There were some further surprises in the report. It found, for example, that girls could boost their performance in science through physical exercise. It even speculated, based on the results, that 'it was possible that children who carried out 60 minutes of exercise each day could improve their academic performance by a full grade'. The study authors made an important conclusion: 'Physical activity is more than just important for your physical health. There are other benefits and that is something that should be especially important to parents, policy-makers and people involved in education… If moderate to vigorous physical activity does influence academic attainment, this has implications for public health and education policy by providing schools and parents with a potentially important stake in meaningful and sustained increases in physical activity.'[12]

So exercise is critical. And that's before we get to the matter of sleep. Today's teens, and many younger children, are often red-eyed and sleep starved. An estimated two out of every three children regularly sleep less that the recommend amount. Things get really out of hand if they are allowed to take a smartphone into their bedrooms at night. A 2017 study at the University of Utah concluded that 41 per cent of children aged 6–19 didn't get enough sleep if they had a mobile device in their bedrooms (this represents a 10 per cent increase over those who did not have the device in the bedroom). Fifty-two per cent of the children also reported poor sleep quality if they used their device before bedtime. (Compare this to 34 per cent of children without access to a device prior to sleep.)[13] Research published in 2019 found the situation even worse – 57 per cent of teens who used technology in the bedroom suffered from sleep problems.[14]

As we now know, the short-wavelength blue light emitted by digital devices suppresses the production of melatonin, which helps us to sleep. Scientists now believe that children and adolescents are actually more sensitive to blue-light effects than adults. And this is before we add the stimulating nature of the content they are watching. A couple of hours of John Wick shoot-outs or bullies getting owned just before going to sleep is not, on any level, going to help the body or mind float down into slumber. The result for young people is both sleep deprivation and deficient sleep. The observed effects include significant mental health issues (depression, anxiety, inattention, volatile moods) and a host of physical problems (long-term increased exposure to heart disease, high blood pressure, diabetes, stroke, obesity).

Before we drop back onto the tracks of our thinking about education, we all need to put sleep and exercise back centre stage. Just watch what happens if we don't.

Tapping the dopamine

Let's squirrel down a little deeper into our insight about the relationship between screen time and mental health. One of the most revelatory areas of psychological exploration over the last decade has been into the brain chemical dopamine and its effects.

In the crudest of nutshells, dopamine is a neurotransmitter that acts as a messenger between cells in your brain and between your brain and your body. Psychologically, it does a whole package of stuff. It acts as a neurological reward centre, with a critical relationship to brain functions such as memory, attention, mood and motivation. We need dopamine to function as human beings. The modern problem is that we are now getting too much of it.

Professor Anna Lembke, in her bestselling work *Dopamine Nation,* has explained with engaging clarity how overworking the dopamine system through constant stimulus and chasing feel-good experiences can lead to catastrophic physiological and psychological effects.[15] If we push the dopamine reward system hard and often, it effectively establishes an addictive circuit. That circuit can lead to hard-wired depression, anxiety, boredom, compulsive behaviours and loss of attention. Lembke likens our dopamine systems to a seesaw. When we do something that gives us a cognitive and biological kick – eat our favourite biscuit or watch a YouTube clip we really like – the dopamine system presses down on the 'pleasure' side of the seesaw. But as with many of our bodily processes, the brain then attempts to reset the balance and achieve homeostasis. Pleasure and reward might feel good to us, but to the brain too much pleasure is actually a problem that needs to be corrected. It does so by pressing down on the 'pain' end of the seesaw. But to get things back on an even keel, dopamine levels are dropped to *below* the baseline of where they started out and slow bounce back. This explains why moments of psychological high are frequently followed by sensations of ennui or gloominess. It's just your brain trying to sort things out. But if we press down too insistently on the pleasure side of the seesaw, eventually the dopamine system responds by plonking down permanently on the pain side. That's when a whole flock of mental health issues come home to roost.

Crucially, the dopamine surge is linked to the *expectation* of a reward, not the reward itself. When we get the actual reward, that's when the dopamine seesaw begins its downward journey on the pain side. Sensing the pain of this withdrawal, we therefore start to hunt for the next reward sensation to make us feel better. This is the basis of how any addiction reinforces itself, from eating a few too many Pringles to serious drug abuse.

The real issue highlighted by Lembke and others is that we live in an age in which our dopamine systems are in constant overuse. The source of our dopamine hits does not need to be digital media. Indeed, it can be anything – drink, sex, food, or even healthy pursuits such as exercise. The problem is excess, and here the digital domain is triumphant. The ubiquitous smartphone is supercharged with apps

that are purposely designed to be as addictive as possible. An overarching design principle of many apps, and especially social media, is *infinite scrolling*. The designers don't want you to leave, and so ensure that the process never ends – every bit of information has the next bit presented in your eyeline, just a tap away. And much of it is proper dopamine-inducing stuff, triggering a surge with each tap or just the expectation of the tap. This is why we can scroll through YouTube videos for unconscious long minutes, vaguely aware that nothing is feeling fulfilling, but still hunting for the resolution.

Lembke explains that the psychological impact of the smartphone inn particular is 'staggering', explaining that 'The smartphone is the modern-day hypodermic needle, delivering digital dopamine 24/7 for a wire generation. If you haven't met your drug of choice yet, it's coming soon to a website near you.' Most of us know a little what she is talking about. Try this experiment. Put your phone on the table in front of you. Now pick up a book and read it, determined not to look at the phone once over the next hour. For you, this might be a moment of sublime stillness and peace. But for many of us, the mute phone will start grinding away at our attention without really doing anything. Your brain starts to chatter. I just need to check this fact. What's happening on the news? Has that important email come in? God forbid it should buzz or ping to tell you that a message has arrived. If it does, don't answer it. Instead just observe the strange internal twisting sensation, the surge of immediate attentional command. That's your dopamine system firing with Pavlovian predictability.

This is all important for the future of EdTEch. AIEd in particular is presented as *stimulus*, the inherently responsive nature of the machine-learning packaged in software that breaks through the tedium and boredom of the past. Anthony Sheldon, for example, explains that 'The real power and flexibility stems from digital text separation of content and its "display." Unlike printed text, where content and display are static, digital content can be put over in countless ways and in multiple modalities'.[16]

AIEd will perfect the delivery of 'multiple modalities'. Educational digital content will be designed to stimulate from the ground up, energised by gamification, 3D visualisations, personalised real-time chat, auditory and sensory feedback, instant creativity, plus an unimaginable expense of global knowledge, a keyboard click away. None of these things are bad in themselves. On the contrary, linking educational content to dopamine stimulus is actually a key ingredient behind the motivation to learn and the retention of information. Just to reiterate, at no point am I arguing against EdTEch and AIEd per se. But given the amount of stimulus already in children's lives, and its detriment in many areas of bodily or mental wellbeing, adding more stimulus during the school hours needs to be seriously considered in terms of its time volume and its nature.

We have already noted that the average non-educational screen time use for children in the Western world varies between about five to eight hours a day. Now add a possible 1–4 hours of in-school EdTech use. The upshot is that a child might be staring at a screen for somewhere between six and 12 hours per day. Someone getting a decent eight hours sleep a night (which many children are not) has about

16 waking hours to play with. This means that a child with heavy non-educational *and* educational screen time could be spending roughly 40 to 80 per cent of their conscious day looking at a digital interface.

Now factor the dopamine effect back into this equation, it is easy to see how a young person might be fighting a losing battle with their own psychological self-regulation. The problem, with an opportunity buried in it, is that we are only just beginning to understand the effects of long-term and heavy immersion in screen time. In 2020, a group of seven educational specialists published an editorial in the journal *Computers and Education*. In it, they sounded a cautionary note based on gathering research into the relationship between screen time and learning. Their lead conclusion was blunt: 'A growing body of research shows that the use of interactive screens in childhood and adolescence is associated with decreased academic performance, as well as greater social and emotional problems.'[17] The authors collected a litany of issues connected with constant digital preoccupation, including child obesity, sleep problems, adolescent depression, aggressive behaviour, increased symptoms of ADHD, poorer performance at schools, suicidal thoughts, adverse changes in 'brain chemical, gray and white matter, and brain connectivity' and problematic dopamine and cortisol (the stress chemical) release. They also pointed to research showing how the brain itself is fundamentally remodelled by prolonged and persistent screen interactions: 'there is substantial research showing that indiscriminate use of interactive screens is associated with changes in brain architecture. In fact, such changes may resemble those observed in substance-dependent subjects.'

The opportunity I hinted at above is this. As we enter the age of AIEd, we are in a position to seek the optimal blend of analogue and digital, adopting the right educational future to balance *both* biology and education. But first, a brief reflection on time.

Time on your side

There is a wider existential question about digital use in society. It's about how we spend our lives. We can test this out using a simple thought experiment. First, take a moment to think about all your *intentions* for your life. This is usually the beefy, important stuff – family, career, contentment, home life, travel, etc. Your intentions are the goals that, hopefully, propel you forward into a meaningful future.

Now think about where the bulk of your *attention* goes. Attention is where the bulk of your cognitive and practical effort is invested. This is where things can get dark. As philosopher William James pointed out in his recommended read *Stand Out of Our Light* (2018), your *intentions* are where you want to go, your *attention* dictates where you will actually go. For sure, getting the two in alignment is a perennial problem of being human. But today, intentions and attention have never been so divergent. In what James calls the 'attention economy', powerful cognitive-commercial industries work brilliantly to guide your attention to a place of its choosing. The most important, finite resource in our possession – time – is increasingly captured by digital means.

This reality applies to adults every bit as much as children. But today's youth is

particularly vulnerable, given what we have already seen about screen time. A 2004 Gallup Youth Survey asked a large body of American teenagers aged 13–17 to state their top goals in life. The results were as follows:

- Finish school/attend school/college – 71%
- Good job/career/want to do a specific job – 53%
- Get married/have a family/be in love – 44 %
- Be successful/famous – 13%
- Be financially secure/rich – 12%
- Be happy/enjoy life/have fun – 10%
- Be a good Christian – 9%
- Play sports – 7%
- Be a good person – 5%
- Buy a car or motorcycle – 5%
- Make a different/help people – 5%

All worthy goals. Note what is *not* here: 'Spend up to 80 per cent of my waking life looking at screens.' Based on current trends in youth consumption, this is what they might actually do with their lives. As older people know all too well, every activity has an opportunity cost, valuable hours easily turning into sand that runs through our fingers while we are distracted. This opportunity cost for young people could be maximised in a way we find hard to predict. And the vast majority of what they are looking at is not, frankly, high-grade content. In 2009, researcher Neil Selwyn published his article 'The digital native – myth and reality'. He stated: 'The findings show that young people's engagements with digital technologies are varied and often unspectacular – in stark contrast to popular portrayals of the digital native. As such, the paper highlights a misplaced technological and biological determinism that underpins current portrayals of children, young people and digital technology.'[18]

Varied and often unspectacular. How young people voluntarily spend their digital attention is important for how we develop future AIEd. What we might see as arresting EdTech might be less compelling for a young person whose sense of digital content has benchmarks for stimulation and interest set higher than many of us might understand.

Reframing AIEd

By now, it might seem that I am simply building up a grumpy and alarmist case against EdTech in general. This is *not* my position. Instead my argument is the following. When we come to develop the AIEd of the future, we need to foreground one fundamental truth: we cannot neglect biological and psychological realities. Building on top of this, I would also argue that we need to construct the future of analogue learning with as much deliberation and intention as digital learning. Only this way will we do right by the bodies and minds of our youth, plus we might actually *improve* their chances of finding employment and satisfaction in adult life. Furthermore, there is the possibility, as with my niece, that for those who spend their lives immersed in digital stimulation, analogue experiences could be the most

challenging sources of educational stimulation. Again, personal experience offers some completely untested evidence in this regard. My local council (which will remain nameless) recently built a spectacular, multi-million pound museum to celebrate the life and history of our city. I did a straw poll amongst my daughters and their teenage friends about whether they liked the museum or not. They gave it an emphatic thumbs-down. Why? Because it was a heavily digitised museum, with much of the content presented through impressive interactive screens. The teenagers, apparently, had had enough of screens. They really wanted stuffed animals and weird things in jars. They craved analogue.

I will now turn to outline some perspectives on building the future analogue and digital mix. I admit that there is much uncertainty about the future of AIEd. I cannot predict the shape, volume or outcomes of future EdTech, so I offer my suggestions as discussion points, not hardened rules.

1) Think about total student screen time

We need to plan AIEd taking into account the total volume of screen time the pupils are absorbing every day. Learning design should aim to keep in-school screen time at sensible levels. This will take some planning, especially at high school/secondary school levels, not least because it requires coordination across all subjects the student is taking. When designing curricula or teaching plans, we need to consider the *cumulative* screen time across the pupil's day, week, months and semesters. Here, ironically, is where AI can step in to help us out with aplomb. If there is one thing AI is superb at, it's scheduling and modelling.

The specific amount of time allocated to digital learning in the classroom is going to be contentious and complicated. Questions abound. For example, is it right to limit the exposure to quality content in the classroom just because children might be absorbing large volumes of poor-quality content outside the school gates? ('No' would seem to be the answer.) Current research suggests that children aged 5–18 should be spending no more than two hours per day on devices. In an educational context, that is impossible to enforce – children are getting more than double that exposure just at home. Other research acknowledges that *what* the students are looking at is as important as how much they are viewing. Spending three hours completing a well-constructed digital learning course is, of course, way more profitable than watching three hours of TikTokkers doing rollerblade tricks.

Further research is evidently needed as AIEd rollout takes place. However, in the absence of this research I would suggest a maximum EdTech exposure of 2–3 hours per day. If greater awareness could push down average extra-school digital consumption to about 5 hours per day, this means a total daily screen time of 7–8 hours, which is up to 50 per cent of waking hours. This is still a big chunk of change, but it leaves the *majority* of the school day, potentially, digitally free (assuming, perhaps, a no-smartphone policy in the school). Note that there is nothing to stop the analogue part of the day being devoted to thinking about the digital activities. It's now well known that many of the world's leading software entrepreneurs have regular periods offline with books in remote places, using the isolation to make undistracted, productive leaps in their thinking. Properly constructed, analogue time can have a

stimulating interaction with the digital time.

2) Consider wellbeing effects

Whatever AIEd systems and software are on offer, they need evaluating in terms of their impact on bodies and minds, not just on educational outcomes (although the two are in reality coterminous). Observant teachers are acutely sensitive to behavioural changes in individual students or indeed in the mood of the classroom. Schools will need honest and diligent means of collecting behavioural impact insights relating to the use of AIEd and filtering those insights up to decision-makers within schools or regional governance, or indeed at national levels. We need an honest and independent framework for evaluating AIEd in the future, so we can sort the wheat from the chaff.

One of the advantages of AIEd is that it can, or should, be responsive to new input parameters, tweaking the systems to allow for improved wellbeing outcomes (for example, by modifying total screen time or changing the nature of the learning delivery). The critical point is to monitor health outcomes, rather than simply assume that all is well or assume that such outcomes are beyond all control.

3) Plan analogue futures as intensively as digital futures

Many readers who are teachers might well roll their eyes at parts of this article, in a 'chance would be a fine thing' way. There are many schools in the developed world, and the majority of schools in the developing world, where computerisation of the classroom is either limited or absent. This being said, AIEd has such revolutionary potential that in the future it might become ever more critical to *plan* analogue experiences, rather than assume that they will naturally occur.

Future technological investments in education will always be driven in part by factors beyond pedagogy and teaching practice, such as economic imperatives. It is conceivable that successive governments might see AIEd as a tool for streamlining budgets, at a cost to analogue experiences. In some countries, there is already something of a prolonged insurgency against key strands of analogue learning. In the UK, for example, between 2010 and 2019 there was a 16 per cent reduction in the hours devoted to physical education in secondary schools.[19] A systematic review and meta analysis of declining physical activity in global schools over the Covid-19 pandemic found a subsequent 20 per cent drop in physical activity, not straightforwardly bouncing back now the pandemic has largely run its course.[20] Back in the UK, 68 per cent of primary school teachers and 39 per cent of secondary school teachers reported a significant reduction in music teaching and services during the Covid period.[21] Given the nature of the pandemic, this is understandable to a degree, but it comes atop a profound long-term decline in music instruction, especially for Years 7–9. We can cap this picture with the fact that student entries for GCSE Design and Technology (D&T) have halved in the decade up to 2022; 44 per cent of students took D&T GCSE in 2009, but this fell to just 22 per cent in 2020.[22]

These are significant losses or reductions. PE, D&T and music together offer some of the purest forms of multi-dimensional analogue thinking, bolting together creativity, logic, analysis and mind-body coordination. But even outside subject-

specific framings, we should consider how analogue education can be reinvested and reinvigorated in the digital future. And by analogue, I mean in its fullest range of expression – physical activity, movement, construction, music, exploration, art, discussion, writing/note-taking by hand, observing, organising. These are already in our classrooms, but amidst the excitement of AIEd we must make sure we don't lose sight of them. That might seem unthinkable and alarmist. I'm not so sure. If someone had said to me in the 1980s that by the 2020s children would spend more than half their lives looking at a hand-held phone, that would have seemed unfathomable.

A good future approach will be to build both analogue and digital into a strong project culture, with the pupils switching *consciously* between the two modes to achieve a practical outcome. This is important on another level. There is a real chance, given the pace at which EdTech is adopted, that the developments in the 'AI' part of the equation outpace the 'Ed' part of the equation, resulting in a user base of young people adopting technologies outside school that are more advanced than those inside the classroom. We witness an early sign of this developing arms race in students use ChatGPT for homework, essays and other assessments.

Using analogue alongside the digital is also critical to skills development. We need to remember that despite more than a decade of EdTech in classrooms, many employers still report serious deficiencies in young people's transferable skills. In May 2023, for example, the UK think-tank Demos published a report entitled *The Employability Badge: Skills for life, work and a stronger society*. One of its key conclusions acts as balance to the idea that our main priority should be to infuse our children with IT skills: ''We found that 60% of employers struggle to hire young people with sufficient technical skills, while 50% say they struggle to hire young people with sufficient transferable skills like leadership, teamwork and emotional resilience. However, while technical skills are important, we found that transferable skills are particularly valuable for young people's employability. 57% of employers told us they value transferable skills over technical skills, compared to just 10% who say they value technical skills more.'[23] The report cautions against the automatic assumption that technical skills are king in the future jobs marketplace. Indeed, the very strengths of AI mean that we cannot fully see the extent to which it will downgrade technical skills in the long term. This does not mean that pessimism forces us to underinvest in technical training, but rather that we should at no point regard analogue skills training as secondary.

4) Look at what's left over off-screen

Pure old-school knowledge – i.e. the retention of facts – has something of a stodgy image, given its musty connotations of dust-dry passive learning. But people who know stuff can usually do stuff. I've worked in former Soviet countries with people brought up under some of the least-inspiring educational systems ever devised. But they are as bright and as innovative as anyone I've ever met, partly, I believe, through their constant exposure to problem-solving with limited resources. But they also tend to *know* a lot. Having a body of internalised information you can handle fluently, without a recourse to external resources, can be handy. It is portable, permanent (with work), and periodically useful. Trouble is, it's hard gained.

Things have changed now. The world's knowledge is just behind the digital screen. The debate about the relationship between young minds and all this information is a hot one, and resolution is unlikely until greater data are gathered and studied. On the one side, there is some emerging research that the use of digital media helps to cement retention of factual information. EdTech has the advantage of guiding active-learning and memorisation strategies, rather than leaving it to self-discipline and personal method to achieve. The more interaction with a subject, the more retention – 'Memory is the residue of thought', as cognitive psychologist Daniel Willingham states.

Other research is more cautious, reflecting concerns that using digital devices to acquire factual information is actually an outsourcing of personal understanding to a device, producing a deep 'illusion of competence'. Another potential issue is that rather aiding the acquisition of knowledge, some EdTech could teach them more about gaming the system to the accepted outcome – process knowledge rather than worldly knowledge. A higher-education study recently published in the *Journal of Educational Psychology*, for example, studied 2,433 students over an 11-year-period. It found that 'the percent of students who did not benefit from correctly answering homework questions increased from 14% in 2008 to 55% in 2017'.[24] Basically, it's saying that those students who scored highest on homework assignments consistently performed worse on exam questions, and vice versa. The implication is that the exams revealed what they did know, while the homework revealed how they processed the assignment with digital assistance.

Does this even matter? We might be in the process of becoming *homo sapiens digitalis*, and using AI as an external super-brain might be the next stage in our evolution. I recently spoke to a highly educated, well-informed individual who said that he was not going to teach his primary-age child how to do mental arithmetic – what was the point, as technology would do it faster and more accurately? My response is that we cannot take technology's unwavering presence for granted on a situational basis. Even in today's tech-centric world, my work regularly takes me into situations where screens are out for an hour or two and I have to rely on traditional skills. (Teaching in countries with power outages taught me that.) Furthermore, disruption to digital infrastructure can and does happen. The nature of our world's security threats means at some level everyone must be able to switch into the analogue mode convincingly, if only temporarily. (This is why officer recruits in the world's navies are still taught age-old compass and sextant navigation in an age of GPS.)

My point is that by building the analogue into education as consciously as the digital, we ensure that knowledge is both tested and consolidated in multiple domains. Good AIEd will frequently push the student away from the screen to test and prove their knowledge in the analogue world.

5) Don't let AIEd do all the work – the importance of failure

How should AIEd guide the student to the learning outcomes? Tucked away in this question are core issues at the heart of AIEd. Some of them are peripheral to this essay, but are worth a passing mention. Take privacy and security, for example. A

top-end AIEd system, following a child over at least 11 years of schooling, will acquire an intimacy and insight into that child that will likely rival or surpass that possessed by the parents. Someone will own this information and will put that data to work. Given the worrying dual-use potential of any personal data, which we have now witnessed with painful clarity, the idea that data will be always responsibly handled in education should not be taken as axiomatic.

Leaving that discussion for another time, we might look at future AIEd as something akin a particularly attentive and unusually available personal tutor. The system, powerfully aware of the student's strengths and weaknesses, will script the learning journey on the fly, guiding around obstacles and incomprehension until the learning outcomes are reached to the satisfaction of all parties. A phrase I have seen repeatedly in AIEd literature is that the new digital learning environment will provide 'a safe space to fail'. The student can therefore free-climb the rockface following a personalised route, but in the complete assurance that they won't *really* fall. Instead they will experiment with all alternative routes until they reach the top.

We need to think about this model of learning carefully. First, we have to be cautious about assuming the AIEd will guide to the best outputs for the *student*, rather than the best outputs for the institution operating the software. I'm not suggesting Machiavellian intent here, but rather that schools and educational boards will likely be the buyers of the software, not the students, and that might potentially skew the priorities. Also, advanced AIEd might ultimately work like the barriers that hesitant or inexperienced bowlers can erect either side of a bowling alley. They never allow the ball to roll dispiritingly into the gutter, and you always knock down some pins. The key point is that if you keep those barriers up over time, you are unlikely to gain a genuine sense of your ability, or lack of it. Furthermore, if you leave the barriers up permanently you will learn how to *use* them to get the result you want; the guidance becomes integral to your strategy for success. Take the barriers down, however, and you'll see what you can *really* do, without external aid.

AIEd, if not well-designed, could potentially work in this way, providing nicely padded walls the student can bounce off, secure in the knowledge that the system will take them to the right destination. But, again, the work of Jonathan Haidt and others suggests that 'a safe space to fail' could, long term, be problematic for young people, resulting not in stronger young adults but individuals more prone to being easily deflated, discouraged and disconnected. Hitting the wall of full-face, undeniable failure can be brutally instructive and critically formative. It can tell you what you are good at, where you should invest your energies, where you need to work on your character, and many other insights. I speak with some personal experience here – getting my PhD in later life was, I believe, a solid by-product of my utter failure at school when I was 16. I was forced in the most confrontational way to start life anew, with more realism and focus.

To be clear, a good educational system should do its level best to ensure all students reaches their fullest potential. Nor should repeated, system-wide failure be in any way tolerated. My argument is rather that when we come to design AIEd we should at least avoid the possibility that the student will reach the learning outcomes *no matter what*. There must be a distant, conscious possibility of failure, but framed

with lots of off-ramps to avoid that fate. Only that will teach long-term personal responsibility for learning, rather than learned dependency on a software scaffolding, disorientating when it is removed.

6) Think about analogue when it comes to skills

I cannot predict the future job market, but I am confident that AI will have an enormous impact on it. In fact, I believe that it will hit us harder than we think. I see it happening in my own industry, publishing. I'm starting to hear of actual editors being partly replaced by AI-driven copy-editing software, the human editor brought as a lower-paid proofreaders to check the AI's work. It's also heartbreaking to see how many rattled illustrators have contacted me for work over the last few months, anxious that their hard-won skills will be trumped by an AI engine. What makes this particular sad is that I'm already part of the problem. I have a forthcoming project that needs heavy illustration. Hard economics means that I'm already checking out AI as a solution, rather than giving a human being a month's work.

AIEd proponents often suggest that we need to train young people to use AI at the highest levels, while retaining the things that human beings do best, especially decision-making. AI might be able to crunch the data and produce a portfolio of options, but then a human should step forward and take the informed decision from their rounded perspective. I have a few issues with this position. One is that we might over-egg humans when it comes to decision-making. We certainly do make decisions in our work. Some of those decisions are of high value and import. But many of them are the repetition of experience, rather than brainstorming a blue-sky innovation. And AI is marching strongly into this territory. There is the very strong possibility that AI will ultimately outperform humans in many areas of decision-making, particularly in day-to-day decision-making based on experience. We have some high-profile examples of AI's capabilities in this regard. In 2015, Google Deep Mind's AlphaGo AI famously beat the world's best player of Go, an ancient Chinese game that is *all* about making decisions. It achieved its 4–1 series win by literally playing millions of virtual days in a compressed time period, acquiring all the experience it needed at warp speed. Similarly, in 2020 an AI aircraft fighter simulator beat a top US fighter pilot in five straight dogfights. This led many senior military officials to predict that AI-flown aircraft will become the norm in the near future, because humans will simply not be able to compete with the AI. Others countered that if the dogfight had been *real*, rather than digitally staged, the outcome would have been different. This is a good example of a phenomenon we hear frequently, when people say 'AI can do this, but it can't do *this*.' Well, in December 2022 a modified F-16 fight jet, piloted completely autonomously by AI, performed 17 hours of manoeuvres without any human intervention. There is already confidence at the Defense Advanced Research Projects Agency (DARPA) that their Air Combat Evolution (ACE) programme will produce AI pilots superior to human pilots very shortly. In some ways they are playing catch-up – Chinese AI aircraft have been defeating human pilots in mock dogfights since June 2021. US Defense Secretary Mark Esper has said that 'We see AI as a tool to free up resources, time and manpower so our people can focus on higher-priority tasks and arrive at the decision

point, whether in a lab or on the battlefield, faster and more precise than the competition.' Sound familiar? The words say one thing, but the logic of the evolution says another.

It is commonly said that AI finds easy the things that humans find difficult, and difficult the things that we find easy. The greatest challenge to AI is basic but complex analogue activities. Untangling a bag of wet laundry into associated piles and hanging in on a washing line with even distribution is something most humans can handle by their early teens. For AI, that task would be a herculean challenge, demanding millions of lines of code. And this has relevance for education.

In terms of future skills, it might well be that we should not attempt to train humans to compete on the same ground as AI, but rather look at a fusion of technical and analogue skill sets that optimise the human advantages. In March 2023, OpenAI, Open Research and the University of Pennsylvania published a report exploring the 'Labor Market Impact Potential of Large Language Models'. It listed 34 professions 'Without any exposed tasks', which basically meant that these professions are largely impervious to being performed by LLM technology. The list essentially reads like a career guide to skilled and semi-skilled *manual* labour. It's worth scanning the list in its entirety:

1. Agricultural Equipment Operators
2. Athletes and Sports Competitors
3. Automotive Glass Installers and Repairers
4. Bus and Truck Mechanics and Diesel Engine Specialists
5. Cement Masons and Concrete Finishers
6. Cooks, Short Order
7. Cutters and Trimmers Hand
8. Derrick Operators Oil and Gas
9. Dining Room and Cafeteria Attendants and Bartender Helpers
10. Dishwashers
11. Dredge Operators
12. Electrical Power-Line Installers and Repairers
13. Excavating and Loading Machine and Dragline Operators, Surface Mining
14. Floor Layers, Except Carpet, Wood, and Hard Tiles
15. Foundry Mold and Coremakers
16. Helpers–Brickmasons, Blockmasons, Stonemasons, and Tile and Marble Setters
17. Helpers–Carpenters
18. Helpers–Painters, Paperhangers, Plasterers, and Stucco Masons
19. Helpers–Pipelayers, Plumbers, Pipefitters, and Steamfitters
20. Helpers–Roofers
21. Meat, Poultry, and Fish Cutters and Trimmers
22. Motorcycle Mechanics
23. Paving, Surfacing, and Tamping Equipment Operators
24. Pile Driver Operators
25. Pourers and Casters, Metal

26. Rail-Track Laying and Maintenance Equipment Operators
27. Refractory Materials Repairers, Except Brickmasons
28. Roof Bolters, Mining
29. Roustabouts, Oil and Gas
30. Slaughterers and Meat Packers
31. Stonemasons
32. Tapers
33. Tire Repairers and Changers
34. Wellhead Pumpers[25]

Each of these careers involves a heavy, in some cases total, analogue component. Many of them are mentally demanding (I've been a dishwasher, so I speak from experience), but require the translation of decisions and experience into physical effects. Many also require an interface with technology, but translate the digital input into analogue output. We then turn to the list of 'Occupations with highest exposure'. These are the jobs AI has in its gunsights. For a white-collar worker like me, the list is vertiginous, but here are some of the most vulnerable:

- Interpreters and translators
- Survey researchers
- Writers and authors
- Public relations specialists
- Mathematicians
- Web and digital interface designers
- Blockchain engineers
- Accountants and auditors
- News analysts, reporters and journalists
- Legal secretaries and administrative assistants

And these are jobs with the 'highest exposure'. The model identified dozens more occupations that are exposed to a significant degree to impact from LLMs.

My point from all this is not to scare ourselves, although it might well achieve that. Rather, the skills that we develop through AIEd should not be based on a cognitive presumption that many areas of human activity are intrinsically preserved from AI, when they are not. Making an intelligent fusion between digital education and the full diversity of analogue education seems to offer a promising strategy for our future workforces. Training for skilled manual work, for example, is not something tackled well, if at all, in modern education. But in a future world where some of the most desirable skills might well be highly analogue, we should ask ourselves why this is the case? May the old days of 'home economics' and 'design and technology' might need revisiting, assisted by AI but with a definite hands-on praxis.

7) Encourage an on/off relationship with technology

We live in a world that now elides the digital and the physical. Young people in particular flow effortlessly between screen and world. They may well our evolution

into ‘augmented reality’. But there is a cost.

We now know that multitasking as a productive skill is largely a myth. Try to do multiple things at once almost invariably results in a negative cost to both time and quality. Hopping constantly between smartphone is multitasking taken to its extreme. The average American, for example, touches their phone 2,617 times a day, rising to 5,000 times a day for heavy users. The average owner will check their phone every 10–12 minutes – that’s 96 times a day, although 66 per cent of Americans will check their phones 160 times a day. The opportunity cost of this activity has yet to be fathomed.[26]

Another of my recommendations, therefore, is that we should build metacognitive training about digital use into our education at every level. The goal is to give young people a sense of *conscious* control over their digital life, rather than allow the app developers, pushed notifications and overloaded dopamine systems dictate the pace. A modern curriculum needs to teach mental mode-shifting between the digital and the analogue if we are to get the best out of both.

As an experiment to demonstrate, try this for one day. Whenever you reach for your phone or sit down in front of a computer, say the following: ‘I am now accessing [state device or software]. My intention is to [state intention]. I aim to be on this technology for [state time you intend to use it]. While using the technology I will resist the following distractions [state distractions].’

How does that feel? Making a statement of intent before reaching for the technology actually primes the mind to align intentions and attention. You are expressing your control of the technology, not simply succumbing to its rhythms and distractions. You can do something similar for analogue activities. Whether digital or analogue is not the point. By immersing yourself in what you are doing, without distraction, is a key to clarity, purpose and calm.

Training young people to do this mode switching is paramount. By switching between analogue and digital domains purposefully in the classroom, young people can create that quality most eroded by digital living – control. It could also help transform their experience of *time*, reducing the attritional opportunity cost of constant phone use and hopefully surprising them with leaps in productivity. But I would argue it has to be taught formally as part of an education programme. The power of digital media is too great to allow it to happen naturally.

This is all relevant to the future development of AIEd. The software of the future should have stop/go timing built into its core processes. Furthermore, the systems should not be so all-dictating that it becomes difficult for judicious teachers to implement involuntary breaks, if they feel they are warranted. The teacher, not the software, should be the ultimate arbiter of control.

A way forward

When it comes to AIEd, the tenor of this article is definitely cautious. I believe that the immersive plunge young people have taken into digital living has not always been to their aggregate benefit, certainly when it comes to mental wellbeing and physical health. If AIEd expands its reach, it may be that unwittingly we add more screen time to young people already at maximum load.

Perhaps my concern arise in part from my parallel career in writing about military history and defence. In this tragic domain, if someone can think it then someone will usually do it, regardless of how terrible the consequences. When it comes to AIEd, we simply can't see the future. We do not know how powerful it will become. For example, many AIEd proponents say that AIEd will support the teacher, not replace the teacher nor act as a tool to evaluate the teachers themselves. Are we sure we can say that? On what logic? Why wouldn't the AI, which is purposed to figure out the optimal solution for the student, conclude that at some level teacher performance might be part of the problem? Wouldn't that information be extremely useful to the school management? What if the system recognises that the more time the class spends with a particular teacher, the worse the assessment outcomes?

I write this article at the very beginning of the AIEd revolution. And frankly, we can't see where it will go. There is the very real possibility that the technology will accelerate faster than educators can keep up with it. There is also the chance that the sheer excitement about emerging products obscures discussion about the *best* way to deliver the learning objectives, with all options on the table. There are further seminal metacognitive questions about how young people will respond to more pervasive and personalised AIEd. The Center for Democracy and Technology recently highlighted the 'chilling effect' on children when they know that they are being heavily tracked and monitored by technology. According to the research, six in ten students said that 'they did not feel comfortable expressing their true thoughts and feelings online if they knew that their activity was being monitored'.[27] This effect was particularly pronounced on students from marginalised communities. As reality-TV producers know, the camera does not capture the natural behaviour of the subjects, but rather the behaviour of the subjects conscious that a camera is trained upon them.

We need to take this on board as we go deeper into AIEd. The situation we need to avoid is that in which students self-consciously riff with the AIEd, not aspiring to the knowledge or skill in itself, but rather to gaming the system in the way that digital natives quickly comprehend and at which they excel.

It might be well-hidden, but in some areas I'm a wide-eyed believer about the potential of AIEd. As a means to provide education to millions of disadvantaged children living in areas with a scarcity of schools and of teachers, AIEd could be life-changing. In the developed world, AIEd could provide targeted training environments for a whole range of skills that might be beyond the typical expertise of available teachers or the facilities of a regular school. AIEd could, by this reasoning, provide an invaluable tool for training in the very analogue skills I have been recommending.

As we go into the AIEd future, we need to keep the discussion of analogue centre stage for both teachers and learners. We need to recognise that young people are bodies as well as minds, completely integrated. We should also rethink analogue for the digital age. How do we produce young people who can transfer digital insight into analogue action, if required, and vice versa? To do that we must *teach* analogue skills fully, across their full spectrum of sensory tasks. It may well be that the distinct fifth educational revolution is an analogue one.

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Dr Chris McNab
Dr Chris McNab is the director of the publishing and educational consultancy Colourblue Ltd and has 23 years of experience as an author, publishing consultant, project manager and educator. He is the author of more than 100 non-fiction titles, his international readers ranging from children to academics, and he is an equally

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