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Technology and Education

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This paper is about technology and its association with education. More specifically the paper provides an insight into contemporary views about technology and education and raises a couple of issues about learning and teaching that seem important to education , especially in a context on disparate innovative forces which are occurring globally in society and the economy. The paper seeks to propose a way forward with technology and teaching.

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"Would you tell me, please, which way I ought to go from here?"
"That depends a great deal on where you want to get to," said the Cat.
Alice's *Adventures in Wonderland*

In this paper, I want to do these things. First, I'll review some contemporary views about technology and its impact on just about everything. Second, I'll do a reality check on technology's "new" pedagogies and teaching. Third, I'll raise a couple of issues about learning and teaching that seem very important to me as education is buffeted by disparate innovative forces. Finally, I'll propose a way forward with technology and teaching.

Let me state at the outset that I am not a technology sceptic, replete as I am with a computer, iPhone, iWatch and numerous other devices. Nor am I a cheerleader for particular technologies in education, apart for a fondness for Apple products. However, I am optimistic about the use of technological know-how to disrupt how we do education and convinced that technology will have profound changes on what we call teaching. Policy makers will need to be keenly aware of technological solutions to educational problems while maintaining research-based evidence that teaching is key to the policy process.

Part I: Technology

Technologies represent new ways of doing things and once mastered, create lasting change. They disrupt and replace older ways of doing things and make older skills and organisational procedures irrelevant.

There is a clear message in the world today. The nature of work is changing. It is leaner, more productive, more technologically advanced, with high-level technical skills. Education and especially teaching at all levels are not islands that can resist these global changes. As the economist Joseph Schumpeter taught us many decades ago, the most significant advances are achieved by a process of "creative destruction" that replaces the way people, industries, and countries do things[1].

Education shares with "technology" a great liking for fads. There is always the "next big thing" that will transform life as we know it. Think of classroom TV, teaching machines, Open classrooms, New Maths, constructivism, and dare I say it, "outcomes"… the list goes on and on. Like technology, it is difficult for teachers and policy makers alike to recognise what fads will have the greatest impact.

The McKinsey Institute argues that when looking for 'impact', we should use four criteria to identify "general-purpose" technologies: (i) high rate of technological change; (ii) broad potential scope of impact; (iii) potentially large economic value impact and (iv) significant disruptive impact. Many technologies have these characteristics, but some appear to be capable of doing it more effectively, very soon, if not today or next week, then by 2025. I want to dwell on the first four on the list.

[1] Schumpeter, J. (1975) *Capitalism, Socialism and Democracy.* New York: Harper, [orig. pub. 1942], pp. 82-85.

Table: Potentially Disruptive Technologies[2]

Mobile Internet	Increasingly inexpensive and capable mobile computing devices and internet connectivity. More than 1.1 billion people use smartphones and tablets. 2-3 billion more by 2025.
Automation of Knowledge Work	Intelligent software systems that perform knowledge work tasks. 110-140 million FTE by 2025. Education: more 1 on 1, scheduling, mastery Vs semesters …
Internet of Things	Networks of low cost sensors and actuators for data collection, monitoring and decision-making built into devices, architecture …
Cloud Technology	Dominant paradigm for computer hardware and software resources delivered over a network or the Internet as a service. Enables mobile devices, automation of knowledge work, Internet of things. Replacement of software and infrastructure
Advanced Robotics	Robots with enhanced intelligence and senses that augment human activity
Autonomous Vehicles	Navigation without, or with minimal, human intervention
Next Generation Genomics	Fast, low cost gene sequencing using advanced big data and synthetic biology
Energy Storage	Superior electricity storage techniques
3-D Printing	Techniques to create objects by printing layers of material based on digital models
Advanced Materials	Materials with superior strength, weight, conductivity, utility
Advanced Oil and Gas Recovery	Extraction by using lower level pollution
Renewable Energy	Electricity generation with fewer polluting elements

General-purpose technologies are particularly important. Because they are so pervasive, they are highly disruptive. General-purpose technologies also generate new technologies. For example, the

[2] I have based the following discussion on Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., Marrs, A. (2013) *Disruptive Technologies: advances that will transform life, business and the global economy*. McKinsey Global Institute, p. 27. http://www.mckinsey.com/insights/business_technology/disruptive_technologies

printing press in the West accelerated learning, scientific discovery and political upheavals and change. The discovery of paper making in China led to developments in the arts and calligraphy, organisational procedures and design, and was a major driver of Chinese civilisation. The arrival of the ATM --- "hole in the wall" banking changed that sector forever and in doing so transformed even technologically illiterate people into password, swipe card, and phone bank users.

Of course, we should remember that technological changes are not the only way that societies change. Demographics such as the entry of women into the workforce in the West and China and the migration from rural to urban in China have enormous impacts. These shifts tend to combine with general-purpose technological changes to have long lasting effects. Indeed, commentators say that the high penetration of mobile devices, and the wide popularity and use of social media are all advantages on which China will build it next stage of development[3].

Furthermore, general-purpose technologies with significant effects are taken up unevenly. The old lag behind the young, and many developing countries outstrip the developed countries as they adopt early and leapfrog existing technologies. There are also downsides to many of these technologies as some people become de-skilled or replaced by smart machines and processes. Nevertheless, the pace and direction of "technological progress increasingly determines who gets hired, how our children are educated, how we find information and entertainment, and how we interact with the physical world"[4].

Cloud technology is a game changer. It gives power to mobile devices, the automation of knowledge work, the Internet of things. It replaces software and infrastructure demands on organisations and individuals. It provides self-service anywhere, anytime, anything. It enables users to expand or shrink their services as the need arises. There are 2.5 billion Internet users today and this is predicted to rise to more than 5 billion by 2025. They will rely on connected devices, software, including HD video streaming and storage[5]. Shared resources on cloud systems can only deliver that kind of scale.

Futures

Imagine what that means for schooling. Most schools and school systems cannot afford the infrastructure for effective IT systems. They suffer from obsolescence and the cloud frees them from infrastructure investment, management and future planning. It also provides access to Internet only software such as Microsoft Office 365, Google and Apple Apps. Renting a cloud server today is about one third the cost of buying and maintaining similar equipment. Schools and school systems are highly sensitive to such economics.

By 2025, it is too late for schools and school systems, for "Education", to plan responses to such technological change. For example, who can afford to be the last cassette user in a DVD world? It is time to look ahead to find those technologies that could and will affect schooling and

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[3] China's next chapter: Tech, manufacturing, and innovation. **http://www.mckinsey.com/Insights/AsiaPacific/Chinas_next_chapter_Tech_manufacturing_and_innovation?cid=china-eml-alt-mip-mck-oth-1306**

[4] Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., Marrs, A. (2013) *Disruptive Technologies: advances that will transform life, business and the global economy*. McKinsey Global Institute, p. 27. http://www.mckinsey.com/insights/business_technology/disruptive_technologies

[5] Mell, P., Grace, T. (2011) The NIST definition of Cloud computing. National Institute of Standards and Technology, *NIST Special Publication*, 800-145.

education seriously, and to determine how to shape policy so that technologies serve their interests and those of their clients. The question is how?

1. Education in the next decade or so will be involved in rapid innovation. Products, services, business processes, market strategies, teaching and teachers will be under pressure to change. Institutions will have to generate new ways of developing and procuring products, organising themselves, reaching their students, clients and customers, and being prepared to move quickly when other technologies challenge them.
2. All educators, especially educational administrators, must understand what technology can do for their institutions and indeed the profession of teaching. They must be prepared to separate hype from reality, something schools have not been all that good at doing.
3. Teachers and Education administrators need to be appraised of Bower and Christensen's *seminal article*[6] on disruptive innovation: successful organisations that focus too heavily on their main established business can miss technological innovations that blind-side them and change the rules of the game. There are many examples such as Canon and Rank Xerox, Alibaba, TenCent, Uber, Big 10 and G08 universities and Udacity and Kaplan. Failure to reinvent can lead to extinction, especially at the lower end of the market.
4. Technologies have the potential to radically alter the composition of the workforce. What may seem out of the question today for teachers may in 2025 look like good sense. But, and here is the up-side, where jobs are replaced by technology, new and higher value adding jobs with different skill sets are created. The early message is that the bar for required skills will go higher. School curricula, teacher education and teacher professional development are especially sensitive to these pressures if they repeat the messages of the past and are subject to restraining influences such as unionism. Just think about the impact PISA results have had on education systems irrespective of the cries of anguish from detractors. In addition, mobile Internet and automated knowledge work open up vast means for delivering education services more effectively and responsively to more students. Poverty, indigenous issues, health and a myriad of other areas could benefit greatly by applying these technologies.

In summary, (i) teachers may be replaced or directed elsewhere in the education chain of services as automated knowledge work and distributed Internet devices take hold. Moreover, such survivors will certainly have a different profile compared to schoolteachers today.
(ii) Teaching work itself may well be changed. Teachers are more likely to be "learning managers"[7] who design and construct individualised learning programs for students who may be located anywhere in a city, country or the globe. Their skill set will be based around clinical models, technology-based delivery systems and research-based cognitive-neuroscience approaches to learning. Their work requirements will be to achieve desired achievement outcomes in *all* of their students, regardless of age, race, class, gender, location, language or history. Their salaries will be far higher than today, based on a demonstrated capacity to deliver these outcomes. In this respect, they will be 'professionals', 'knowledge workers' in the full sense.
(iii) Of the schools that survive, their organisation and governance will probably be different --- running as partnership networks locally and internationally. They will probably look more like

[6] Bower, J. L., and C. M. Christensen. (1995). Disruptive Technologies: catching the wave. *Harvard Business Review,* 73: 1, pp. 43–53.

[7] See Smith, R., Lynch, D. (2006) *The Rise of the Learning Manager*: *changing teacher education.* Frenchs Forest: Pearson Education Australia for an explanation of "Learning Manager".

syndicated TV or mobile phone networked arrangements than today's schools so that teaching is a team effort amongst 'teachers', interpreters, social and health workers, universities and commercial partners.

Part II: Reality Check

Let's pause a moment. In 2013, there were approximately 9,468 schools in Australia[8] for 23,052,877 people[9], and 650,000 schools in China for a population of 1,354,040,000[10]. There are 47 universities in Australia with a host of other higher education providers. China has 3,271 universities and colleges.

In 2011, there were 290,854 teaching staff in Australian schools and 11.41 million in China. Schools as we know them are still here. Teachers as we know them are definitely here!

Many teachers make extensive use of technology now[11]. The Internet opens a vast treasure of knowledge in addition to natural social skills, language abilities, and cultural awareness. Marzano suggests a student who has a good knowledge of facts, generalisations and principles ("crystallised" or learned intelligence") is more likely to be successful at school than students who do not have this knowledge[12]. In fact, this kind of knowledge is more important than innate intelligence for school success. Using computers and having access to the Internet potentially might make students more successful at school, if they know more as a result of using computers. There is some evidence that students today do know more than in previous generations, but not all of it is relevant for schooling. For example, Street Kids know an enormous amount about such things as survival. That knowledge may not be all that appropriate for getting the VCE or into graduate school… Again, maybe it could be!

Having said that, there is evidence that having computers in classrooms is associated with an increase in student achievement (effect level of .31 in Hattie's scheme[13]). However, using devices is no guarantee that students will learn the content that schools, systems and nations value or that is really useful for them. Moreover, and this is really important, having students use devices is not the same as 'pedagogy'. Let's explore this last point a little more.

Pedagogy

In the most general, omnibus sense, "pedagogy" can mean *the theory* and *practice* of *teaching, learning,*

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[8] http://www.abs.gov.au/AUSSTATS/abs@.nsf/Previousproducts/4221.0Main%20Features32010?opendocument&tabname=Summary&prodno=4221.0&issue=2010&num=&view=

[9] http://www.abs.gov.au/ausstats/abs@.nsf/0/1647509ef7e25faaca2568a900154b63?OpenDocument

[10] http://worldpopulationreview.com/population-of-china/

[11] e.g. Hastie, M., Chen, N-S., Smith, R., Kinshuk, I., Hung, C. (2010) A Blended Synchronous Learning Model for Educational International Collaborations. *Innovations in Education and Teaching International*, 47: 1, pp. 9-24; and Hastie's LinkedIn pages at http://au.linkedin.com/pub/megan-hastie/38/aa2/593

[12] Marzano, R. J. (2004) *Building Background Knowledge For Academic Achievement*. Alexandria, VA.: Association for Supervision and Curriculum Development, p. 13.

[13] See Hattie, J. (1999) *Influences on Student Learning*. http://www.education.auckland.ac.nz/webdav/site/education/shared/hattie/docs/influences-on-student-learning.pdf

and assessment[14]. Also, it can mean "an action *learning approach*"[15] or any number of other "approaches". Furthermore, it can mean a rather more sustained focus on the legitimate means for *transmitting socially valued knowledge*, what some people would call "methods" of instruction or teaching. It includes those direct and indirect activities, orchestrated by the teacher, to expose students to new knowledge, to reinforce knowledge, or to apply knowledge[16]. In this last sense, pedagogy is a *link* between "curriculum" (*socially valued knowledge)* and "assessment" (evidence that students have grasped *socially valued knowledge)*. Bernstein[17] referred to this trilogy as a 'relay'.

Experience shows that educators and policy makers tend to focus on curriculum and assessment, while "pedagogy" is taken for granted as something anyone and everyone can do or that happens naturally. "Pedagogy" is what my colleague David Lynch and I have referred to as a "void" in Education talk in Australia. The notion of a void is not just an issue in the Antipodes.[18]

As an aside, but important for contemporary education debates, notice the italicised terms above. The omnibus definition of pedagogy appears fine until one realises that it collapses just about everything known in Education into a curriculum-teaching-assessment category of enormous complexity that confuses the "what" and the "how" of teaching. It perplexes rather than explains, especially for beginning teachers. In contrast, Bernstein's work showed that "teaching", "curriculum" and "assessment" are different *analytic* domains and one cannot substitute one for the other, even if at the moment of teaching, they come together. In addition, it makes little sense to talk about "learners" rather than "students" (are aircraft passengers 'fliers' or pedestrians 'walkers'?). "Learners" can only be identified after the event as it were!

Furthermore, the teaching profession seems relaxed about curriculum having structure and coherence as knowledge and skills[19], and assessment exhibiting familiar processes and procedures. But it resists the idea that pedagogy, the 'how' of teaching, might have generalizable principles to it beyond those espoused in personal experience and the passed on teacher folklore that every beginning teacher meets in schools.

Making such distinctions is important when technology enters the mix. The existence of information technology, software, data, digital resources, the Internet, social media, animations,

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[14] Sharples, M. McAndrew, P., Weller, M., Ferguson, R., FitzGerald, E., Hirst, T., Mor, Y., Gaved, M., Whitelock, M. (2012) *Innovating Pedagogy 2012*. Milton Keynes: The Open University. http://www.open.ac.uk/personalpages/mike.sharples/Reports/Innovating_Pedagogy_report_July_2012.pdf

[15] Herrington, J., Mantei, J., Herrington, A., Olney, I., and Ferry, B. (2008) New technologies, new pedagogies: Mobile technologies and new ways of teaching and learning. http://www.ascilite.org.au/conferences/melbourne08/procs/herrington-j.pdf

[16] See Marzano, R. J. (2000) *New Era of School Reform: Going Where the Research Takes Us*. Mid-continent Research for Education and Learning. Aurora, Colorado, p. 66. http://isaacnewtonsixthform.co.uk/newsite/index_htm_files/A%20New%20Era%20of%20School%20Reform.pdf

[17] Bernstein, B. (1971) *Class, Codes and Control, Vol. 3: Towards a Theory of Educational Transmissions* (Primary Socialization, Language and Education). London: Routledge; Bernstein, B. (1996) *Pedagogy, Symbolic Control and Identity: theory, research, critique*. London: Taylor and Francis.

[18] E.g. see Alexander, R. (2004) Still no pedagogy? Principle, pragmatism and compliance in primary education. *Cambridge Journal of Education*, 34: 1, pp. 7-33.

[19] See the discussion of declarative and procedural knowledge in Marzano, R. J., Pickering, D. J., Arredondo, D. E., Blackburn, G. J., Brandt, R. S., Moffett. C. A., Paynter, D. E., Pollock, J. E., Whisler, J. S. (1997) *Dimensions of Learning: Teacher's Manual*. 2nd Edition. Alexandria, VA.: Association for Supervision and Curriculum Development/McRel Mid-Continent Regional Educational Laboratory, p. 43 ff.

simulations, virtual worlds, YouTube videos, mobile phones, tablets and video cameras, encourages many commentators to claim that they represent "new *pedagogies*"[20]. Moreover, commentators claim that because students using digital devices can choose and process whatever the Internet offers, the idea of a set "curriculum" becomes less relevant and meaningful to the individual, and that leadership for worthwhile knowledge passes from educators to students. Some, inexplicably in my view, argue passionately that teachers should surrender a pedagogical role to become facilitators and guides[21].

All of the current technological innovations are opportunities to do a multitude of things educationally. Nevertheless, one cannot grasp the potential for effective teaching by just having tablets or the potential of the cloud. The fact that students like to follow their "individual interests" is important but by itself offers little teaching assistance to the millions of teachers and parents worldwide who want their students and children to succeed. That step requires additional information and professional skill that goes beyond such weasel words as "facilitator" or "student interests". Incidentally, making decisions about "teaching" and enacting them successfully, is actually what teachers *get paid to do*!

Interestingly, critics of the "old" classroom teaching tend to describe the "new" technology-based teaching in language that is really quite familiar. For example, in one recent publication the following are proposed as the "new" desired outcomes from technology-based teaching: (i) how to *find, analyze, evaluate*, and *apply* knowledge as it constantly shifts and grows (ii) skills such as *critical thinking, independent learning* (iii) knowing *how to use relevant information* within a field of discipline (iv) *entrepreneurialism* (v) *applying knowledge to meet the demands of 21st century society* (vi) opportunities to *develop, apply and practice skills* (vii) students learning to *manage their own learning throughout life* (viii) essential *information and technology literacy skills*, (ix) *mastering the technology fluency* necessary in specific *subject domains* (x) students *using technology to* help them *learn and develop*[22].

In addition, the use of technology in education is claimed to offer teachers more opportunities for effective teaching. Hybrid learning, the 'flipped' classroom, combines different modes of teaching such as classroom-based, digital resourced, and fully online. Web-based collaborative approaches enable students to construct and test knowledge through questioning, discussion, using resources from multiple sources, and teacher feedback. Social media encourage the sharing of experiences, and learning from each other.

It is not difficult to see why advocates of technology-based teaching are so enthusiastic. Mobile internet, the cloud, the Internet of Things together with thousands of examples of multimedia, stand-alone, open educational resources that can be downloaded free for educational use are a feast of goodies. Using this enormous pool of stuff, teachers can create modules that students can

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[20] See for example Distributed Learning, Enhanced Mobile Technology, Collaborative Intelligent Filtering, 3D Visualization and Interaction in *New Pedagogies for the Digital Age*. http://www.edudemic.com/2012/05/new-pedagogies-for-the-digital-age/

[21] E.g. Ken Robinson says schools kill creativity.
http://www.ted.com/talks/ken_robinson_says_schools_kill_creativity.html

[22] *A New Pedagogy is Emerging...And Online Learning is a Key Contributing Factor*. http://www.contactnorth.ca/trends-directions/evolving-pedagogy-0/new-pedagogy-emergingand-online-learning-key-contributing

study any time, anywhere, to package content and to integrate mobile devices into course delivery and assessment. Finally, technology provides teachers and students with enormous resources for self-directed and non-formal online learning experiences that either complement the school curriculum or allow for serendipitous exploration and development. My proposition though is that teachers have a responsibility to retain the roles of designing such experiences and assessing the learning outcomes.

In my view, few educators would have difficulties with any of this, apart from adding and subtracting items in the shopping list[23]. Indeed, as Sharples et al state:

> …to debate the relative influence of technology and pedagogy is to miss the point. Education is now *inextricably tied to technology*, whether through teaching with electronic whiteboards in class or sharing ideas with friends over social networks.[24]

Nevertheless, the core pedagogical question for teachers remains: "How"? It is really important that as teachers adopt the amazing potential of technology that they *do not just import the fallacies of face-to-face teaching* into the "new" world. In order to deal with this question, I now want to touch on teaching before concluding.

Part III: Learning and Teaching

Learning research

First, I draw on Kirchner et al's paper[25] to provide the barest description of a key 'learning' position based on solid empirical research over the past 50 years. This research provides "overwhelming and unambiguous evidence" that minimal guidance during instruction is "significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning". The conclusion is based on the distinction between long and short-term memory.

(i) long-term memory is now viewed as the central, dominant structure of human cognition. Everything we see, hear, and think about is critically dependent on and influenced by our long-term memory.

(ii) expert problem solvers derive their skill by drawing on the extensive experience stored in their long-term memory and then quickly select and apply the best procedures for solving problems. The fact that these differences can be used to fully explain problem-solving skill emphasizes the importance of long-term memory to cognition. We are skillful in an area because our long-term memory contains huge amounts of information concerning the area, hence the importance of background knowledge.

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[23] See for example the extensive discussion of such matters in Marzano, R. J., Pickering, D. J., Arredondo, D. E., Blackburn, G. J., Brandt, R. S., Moffett. C. A., Paynter, D. E., Pollock, J. E., Whisler, J. S. (1997) *Dimensions of Learning: Teacher's Manual*. 2nd Edition. Alexandria, VA.: Association for Supervision and Curriculum Development/McRel Mid-Continent Regional Educational Laboratory.

[24] Sharples, M., McAndrew, P., Weller, M., Ferguson, R., FitzGerald, E., Hirst, T., Mor, Y., Gaved, M., Whitelock, M. (2012) *Innovating Pedagogy 2012*. Milton Keynes: The Open University, p. 6, emphasis added.

[25] Kirschner, P. A., Sweller, J., Clark, R. E. (2006) Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41(2), 75–86, pp. 83-84.

(iii) the instructional consequences of long-term memory are that the aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned.

(iv) any instructional recommendation that does not or cannot specify what has been changed in long-term memory, or that does not increase the efficiency with which relevant information is stored in or retrieved from long-term memory, is likely to be ineffective.

(v) working memory is where conscious processing occurs. It is limited in duration and capacity

(vi) almost all information stored in working memory and not rehearsed is lost within 30 seconds and is limited to a small number of elements.

Notice how this research counters the ideas that in school contexts, teachers should be "facilitators" and that students who follow their own interests learn better. Today, many educators, educational researchers, instructional designers, learning materials developers and I must say technology-driven teaching advocates, appear to believe that minimally guided instruction is *the* "new" and are keen to implement it. On the surface it seems that a more vigorous emphasis on the practical application of inquiry and problem-solving skills seems positive compared to instruction based on the facts, laws, principles and theories that make up a discipline's content. Nevertheless, as Hattie points out, "These kinds of statements are almost *directly opposite* to the successful recipe for teaching and learning …"[26]. "[l]earning is not always pleasurable and easy…"[27]

Controlled experiments almost uniformly indicate that when dealing with novel information, learners should be explicitly shown what to do and how to do it.

> In so far as there is any evidence from controlled studies, it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners. Even for students with considerable prior knowledge, strong guidance while learning is most often found to be equally effective as unguided approaches. Not only is unguided instruction normally less effective; there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge.[28]

Teachers Matter

Teachers are amongst the "the most powerful influences in learning"[29]

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[26] Hattie, J. (2012) *Visible Learning For Teachers: maximizing Impact On Learning*. London and New York: Routledge, p. 26, emphasis added.
[27] Hattie, J. (2012) *Visible Learning For Teachers: maximizing Impact On Learning*. London and New York: Routledge, p. 17.
[28] Kirschner, P. A., Sweller, J., Clark, R. E. (2006) Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, 41(2), pp. 83-84.
[29] John C. Hattie, (2009), *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London & New York: Routledge, Taylor& Francis, p. 238.

> "…an individual teacher can have a powerful effect on her students *even if the school doesn't.*"[30]
>
> '…teacher and classroom variables account for more of the variance in pupil achievement than school variables…"[31]
>
> "…the most important factor affecting student learning is the teacher…"[32]
>
> "The act of teaching requires deliberate interventions to ensure that there is cognitive change in the student…"[33]

Work by Marzano and associates and others has shown that effective teachers generate learning gains in students no matter whether a school is effective or ineffective. Similarly, ineffective teachers fail to advantage students irrespective of what kinds of schools they are in. In short, teachers matter.

Moreover, Marzano, Hattie and others have shown particular kinds of teaching strategies are potentially more effective than others, irrespective of age group, curriculum areas, teachers, broad and narrow outcomes.

Finally, while these remarks focus on teachers and teaching, the key criterion outcome is "learning". The aim of "teaching" is definite student achievement outcomes. "Teaching" puts greater focus on assessing student learning outcomes rather than describing or assessing teachers.[34]

Teaching must have an effect on student learning

A point I want to stress is that while the teaching profession seems to believe that teaching prowess is a unique characteristic of individual teachers and that every teacher has their own pedagogical approaches, contemporary research indicates that there are pedagogical strategies that work better than others in school settings. Hattie's research is perhaps the best known although Marzano's research and writings are equally influential.

Hattie and Marzano have popularised the idea that a teaching approach must have *effects* on student achievement if it is claimed to be effective. Hattie in particular uses research evidence to build and defend a model of teaching and learning. This makes innovations accountable, not to the personal whims of policy makers, teacher's unions, teachers or principals, but to students and their communities.

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[30] Marzano, R. J., Pickering, D. J., and Pollock, J. E. (2001) *Classroom Instruction That Works*. Alexandria, VA.: Association for Supervision and Curriculum Development, p. 2, emphasis in the original.

[31] Scheerens, J. (1993) Basic school effectiveness research: items for a research agenda. *School Effectiveness and School Improvement*, 4: 1, p. 20.

[32] Wright, S. P., Horn, S. P., Sanders, W. L. (1997) Teacher and classroom context effects on student achievement: implications for teacher evaluation. *Journal of Personnel Evaluation in Education*. 11, p. 63.

[33] Hattie, J. (2012) *Visible Learning For Teachers: maximizing Impact On Learning*. London and New York: Routledge, p. 16.

[34] See Jensen, B. (2012) *Catching Up: Learning From The Best School Systems in East Asia*. http://grattan.edu.au/static/files/assets/00d8aaf4/130_report_learning_from_the_best_detail.pdf

Hattie's work identifies 138 different influences on student achievement and places the major results from thousands of research studies along a continuum of "effect" sizes.

[Technical note: An effect size of d = 1.0 indicates an increase of one standard deviation on student achievement. A one standard deviation increase is typically associated with advancing a student's achievement by *two to three years* or *improving the rate of learning by 50%*. When implementing a new program, an effect size of 1.0 would mean that, on average, students receiving that treatment would exceed 84% of those students not receiving that treatment. Hattie proposes that anything with an effect size of over 0.4 is likely to have a visible, positive effect on student achievement. To put it another way, an effect size of 0.2 or less is low, 0.4 is medium and 0.6 or more is high.][35]

These "effects" are then criteria for teachers to use when assessing their own teach**ing** effectiveness: the discussion about teach**ing** is more critical than the discussion about teach**ers** and their personal and professional attributes. At the policy and school level, the quality of the *effects of teachers on learning* is the key issue, where teachers have a responsibility to retain the roles of designing and delivering such experiences and assessing the learning that is consequence of their actions.

Here are some of Hattie's findings.

INFLUENCE	EFFECT	SOURCE OF INFLUENCE
Feedback	**1.13**	**Teacher**
Students' prior cognitive ability	**1.04**	**Student**
Instructional quality	**1.00**	**Teacher**
Direct instruction	**.82**	**Teacher**
Remediation/feedback	**.65**	**Teacher**
Students' disposition to learn	**.61**	**Student**
Class environment	**.56**	**Teacher**
Challenge of Goals	**.52**	**Teacher**
Peer tutoring	**.50**	**Teacher**
Mastery learning	**.50**	**Teacher**
Parent involvement	**.46**	**Home**
Homework	**.43**	**Teacher**
Teacher Style	**.42**	**Teacher**
Questioning	.41	Teacher
Peer effects	.38	**Peers**
Advance organisers	.37	**Teacher**
Simulation & games	.34	**Teacher**

[35]See https://www.google.com/url?sa=f&rct=j&url=http://growthmindseteaz.org/files/Hattie_Dweck_2012.doc&q=&esrc=s&ei=F3TGUfHqDYmWiQfXqoDYDg&usg=AFQjCNGfAVjLgS8clltLhjd4g3GyQQPaAQ; Marzano, R. J. http://www.marzanoresearch.com/documents/AppendixB_DTLGO.pdf; Haystead, M. W., Marzano, R. J. (2009) Meta-Analytic Synthesis of Studies Conducted at Marzano Research Laboratory on Instructional Strategies. http://www.marzanoresearch.com/documents/Instructional_Strategies_Report_9_2_09.pdf

Computer-assisted instruction	***.31***	***Teacher***
Testing	.30	**Teacher**
Instructional media	.30	**Teacher**
Aims & policy of the school	.24	**School**
Affective attributes of students	.24	**Student**
Physical attributes of students	.21	**Student**
Programmed instruction	.18	**Teacher**
Ability grouping	.18	**School**
Audio-visual aids	.16	**Teacher**
Individualisation	.14	**Teacher**
Finances/money	.12	**School**
Behavioural objectives	.12	**Teacher**
Team teaching	.06	**Teacher**
Physical attributes (e.g., class size)	-.05	**School**
Television	-.12	**Home**
Retention	-.15	**School**

The computers-in-schools innovation is interesting. For example, it is possible to locate 31 meta-analyses, 17,952 studies, and 352 effect-sizes studies that investigated the effects of introducing computers on student's achievement (see Hattie, 1986). These effects can be statistically synthesized to determine an overall effect as well as assessing the influence of such things as males versus females, different uses of computers, subject areas, and so on. The average effect-size across these 557 studies was .31.

This means that compared to classes without computers, the use of computers was associated with advancing a student's achievement by approximately three months, improving the rate of learning by 15%. About 65% of the effects showed improved achievement, and 35% of the effects were zero or negative. The average student achievement level after using computers exceeded 62% of the achievement levels of the students *not* using computers. Importantly, the effect-size of .31 would not be perceptible to the naked observational eye. It would be approximately equivalent to the difference between the height of a 5'11" and a 6'0" person[36].

In short, when we say "teachers are important", we mean effective teach**ing** is important. Enhancing teacher quality in this sense means re-assessing teaching so that it becomes evidence-based, is planned collaboratively and is clearly focussed on each teacher having a minimum effect of .40 in each teach**ing** session.

Part IV: Technology and Teaching

My last point is that these ideas can be brought together in a myriad of ways as long as they retain the essential ingredients noted earlier. The implication of Hattie's work and that of others is professional development on educational technology should focus, with precision, on what *students*

[36] See https://www.google.com/url?sa=f&rct=j&url=http://growthmindseteaz.org/files/Hattie_Dweck_2012.doc&q=&esrc=s&ei=F3TGUfHqDYmWiQfXqoDYDg&usg=AFQjCNGfAVjLgS8clltLhjd4g3GyQQPaAQ;

need to learn, rather than on how to use a specific device[37]. While sometimes teachers do just have to sit and learn how to use a device such as an iPad, that should not be the starting place. The starting place should be what *students need to learn*, such as learning how to be better at mathematics, or learning how to write more analytically, or to hold critical discussions by comparing historical conditions and events.

This is not as easy to do as it might sound because the new technologies available to teachers and students offer great scope for defining achievement outcomes. It is helpful then to combine what is known about effective teaching strategies and a category scheme for available technologies. The following tables do this.

Instructional Strategies[38]	**Definition**
CATEGORY	
Setting Objectives and Providing Feedback	Setting direction for learning and feedback to students on how they are performing on each goal
Reinforcing Effort and Providing Recognition	Enhancing student understanding of the relationship between effort and achievement and rewards and praise for attaining a goal
Cooperative Learning	Opportunities for students to interact in ways that increase their learning
Cues, Questions and Advance Organisers	Enhance student ability to retrieve, use, and organise what they know
Non-linguistic Representations	Enhance student ability to represent and elaborate knowledge using mental images
Summarising and Note-taking	Enhance student ability to synthesize information and organise it in ways that capture the main ideas and supporting detail
Assigning Homework and Providing Practice	Extend opportunities for students to practice, review and apply knowledge and to reach an expected level of proficiency for a skill or process
Identifying Similarities and Differences	Enhance student ability to understand and use knowledge by engaging them in finding ways things are alike and different

[37] Pitler, H., Hubbell, E. R., Kuhn, M. (2012) *Using Technology with Classroom Instruction That Works*. 2nd Edition. Alexandria, VA.: Association for Supervision and Curriculum Development/McRel.

[38] See Marzano, R. J., Pickering, D. J., Arredondo, D. E., Blackburn, G. J., Brandt, R. S., Moffett. C. A., Paynter, D. E., Pollock, J. E., Whisler, J. S. (1997) *Dimensions of Learning: Teacher's Manual*. 2nd Edition. Alexandria, VA.: Association for Supervision and Curriculum Development/McRel Mid-Continent Regional Educational Laboratory.

Generating and Testing Hypotheses	Engaging students in making and testing hypotheses as a means for enhancing their understanding and use of knowledge

Pitler, Hubbell, and Kuhn have devised 9 categories of technology that can be used to form a matrix of instructional strategies and technologies[39]. This is a useful planning tool rather than a "model" to be followed slavishly. The categories appear in the following table, but as we can predict, the entries in the right hand column are bound to be hopelessly outmoded.

CATEGORIES OF TECHNOLOGY		
Category	**Definition**	**Examples**
Word Processing Applications	Create documents in which the text can be displayed in linear or visual modes	Google Docs, Microsoft Word, Apple Pages, Wordle
Organising and Brainstorming Software	Helps user to organise and thinking, connect and categorise ideas, and show processes	Webspiration, Inspiration, Smart Tools,
Data Collection and Analysis Tools	Allow users to gather and analyse data	SurveyMonkey, Excel. eClicker, Poll Everywhere,
Communication and Collaboration Software	Replaces or enhances traditional forms of communications with video, audio, text, or any combination of these, share and discuss ideas, pictures, web links, and links geographically separated parties	Skype, FaceTime, TypeWith.me, Diigo, FaceBook, Twitter, qq, Weibo,
Instructional Media	Facilitate the creation of videos and recordings intended for use in teaching and learning	BrainPop, Discovery Education Streaming, Khan Academy
Multimedia Creation	Combine audio, video, music, pictures, drawings, in any combination	PowerPoint, Keynote, Photoshop, iPhoto, Globster, VoiceThread, iMovie
Instructional Interactives	Manipulated by the student in enhance a skill or concept, including games, manipulatives, and softyware that assesses the student	MathBoard, Intro to Math, Star Chart

[39] Pitler, H., Hubbell, E. R., Kuhn, M. (2012) *Using Technology with Classroom Instruction That Works*. 2nd Edition. Alexandria, VA.: Association for Supervision and Curriculum Development/McRel, p. 10.

Database and Reference sources	Information and data	RubiStar, Visual Thesaurus, Wikipedia, WolframAlpha, GapMinder
Kinesthetic Technology	Technologies that interact with the student's geographic or physical location	Nintendo Wii, Xbox Kinect, GPS devices

So what are the main messages about technology and teaching?

1. Technology offers enormous scope for fantastically *effective student learning*. Get with it.
2. Teaching is now *inextricably tied to technology* and not an add-on. It is now a fundamental part of a teacher's repertoire for selecting *good instructional practice*. Best do some serious PD.
3. The evidence from controlled studies uniformly support *direct, strong instructional teacher guidance* rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners. Teachers matter: celebrate it.
4. There are definite *pedagogical strategies* that work better than others. If this means you have to change your mind, then do it.
5. Stay current with the principles of computing and distributed learning so your *professional capability* is enhanced. Don't get blind-sided.