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Models for successful schools in a digital age

A research study and literature review

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leadership consultancy in digital education

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Abstract

"Education is a tension between passing down fixed stores of knowledge and drawing out possibilities in the learner" Peadar Kirby

This white paper was commissioned by HP in a quest to uncover and understand the factors that make some schools more successful than others in improving learning outcomes when digital technology is widely implemented across the K-12 sector. The intention is to identify the interdependencies and find the key proof points that can make a significant difference to technology enhanced teaching and learning environments in three market segments: (1) Western Europe and the Nordics (2) Balkan States, Hungary and Poland and (3) Middle East and Turkey.

HP are aware of many individual schools around the world that are successfully implementing digital technologies. This white paper identifies and details some clear success factors that help schools flourish, aid governments to successfully implement large scale education technology initiatives and also to better comprehend and demonstrate common causes of failure or disappointing results and key learnings from both large-scale national and local school-based investments.

As we move towards the second half of the 21st Century, digital literacy and a clear understanding of how technology is influencing and will increasingly continue to influence their lives, is imperative for our students to become active citizens in the modern globalised world. It is also clear from the research and case studies that well-applied technology significantly enhances the learning and teaching experience once the right conditions, leadership and support are in place.

Dr Michelle Selinger and Peter Hamilton, EdTech Ventures

Executive Summary

The aim of this white paper is to better understand the economic, social and educational drivers and the factors that contribute to success and common causes of failure to help leaders and policy-makers plan for successful technology-enhanced learning implementations through research analysis and case studies (see Figure 1).

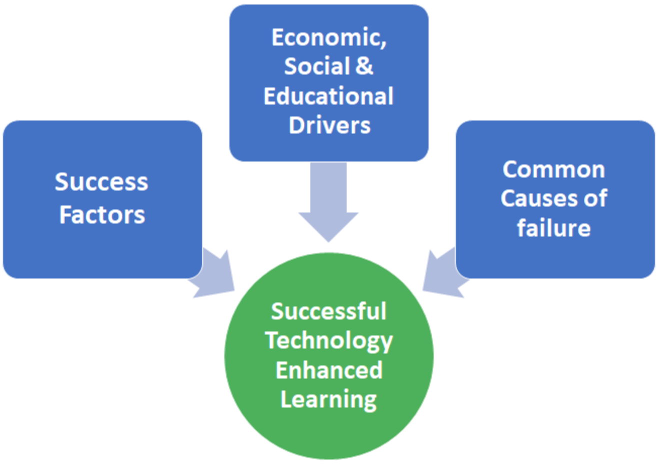


Figure 1 Drivers, success factors and common causes of failure

Impact of digital technology on schools

The massive change in access to information provided by digital technology has already transformed many education processes where the technology and usage models are well applied. Research and case studies consistently show that the 21st century approach to knowledge is about processing and applying information rather than storing up the facts of past, more static knowledge, which is now ubiquitous and easily accessible. This drives a new view on priorities for educators and curriculum design, and the pedagogies required for what Araya and McGowan have called the 'streaming of knowledge'. Yet the debate remains about *whether*, rather than *how*, students should use digital technology in schools to support their learning. The white paper will show that it is essential for all education systems to grasp the opportunities that these new and highly accessible technology capabilities provide and to seek to reimagine the processes of education to prepare our young people for the challenges of the second half of the 21st century.

This white paper demonstrates from research evidence, recent case studies and broad international experience in both large-scale and localised implementations of technology in education, that there are common success factors and approaches that lead to positive results and common risk factors that consistently tend to produce sub-optimal results. By understanding the combination of factors that bring success, HP can work more intelligently with clients to ensure that future implementations will be significantly more positive for all parties.

Historical view of digital technology in schools

Evidence shows that well planned and managed implementations of digital technology can have a significant impact in the K-12 sector when well-coordinated with the other key factors that lead to better learning outcomes. The investment in technology has been and continues to be significant with a report from EdTechX Global and IBIS Capital[i] estimating that by 2020 some USD252 billion will have been invested in education technology. However, much of the publicity surrounding impact studies over the past ten to fifteen years is mixed, conflicting and, at worst, shows negative or marginal impact.

Some of this research and experience is now becoming a little dated as much of the research took place in the first decade of the 21st century. Over the intervening time there have been significant advances in Internet bandwidth, device cost and accessibility, as well as an increase in the quality and availability of education software and Cloud services. Due to the central position of technology in our societies and economies it ought to now be considered as integral to both teaching and learning, to school management and to administration of 21st Century institutions.

The challenge then is to identify the reasons for the lack of clearly reported improvement; to determine whether this is mostly a macro view; and to discover the key success factors, at a more micro level. We have searched out good schools where technology has been built on a robust infrastructure, with future proofed usage models, tools and devices. Starting with strong and clear leadership from the top, these schools have made technology an integral factor in improvements to learning outcomes and pedagogical approaches, and to increased efficiencies and effectiveness of management and administration. The next and most crucial step is to develop strategies that can support the scaling of effective practices in ways that are acceptable from both an economic and a cultural perspective. These strategies can then be tailored to large scale, government led interventions, or to individual schools working in either a regional cluster or alone.

Summary of research to date

Media reports of research on the implementation of digital technologies in the K-12 sector tend to gloss over any positive findings and only report the negative - often with attention grabbing headlines. This creates confusing or conflicting results, frequently with a brief aside to some incremental improvement. These reports invariably question the significant financial investment made by individual schools and jurisdictions.

A comprehensive review of research shows that it is *how* technology is integrated, not the technology *per se*. We are constantly adding 21st-century technologies to 20th-century teaching practices. The evidence suggests that until views change about the purpose of education and how society prepares young people for work and life over the next few decades, digital technologies will always be bolt-on rather than integral to learning and teaching and will only be used to help teachers teach the way they always taught. We are now almost 20 years into the 21st century yet the movement to large scale technology-enabled learning process reform is sadly lacking. We return to this debate later but first we consider the impact of large scale device implementations around the world.

Large scale implementations

Despite popular belief, there are several positive examples of the success of large scale technology implementations in schools especially when time is factored into the equation. The World Economic Forum recently commissioned an extensive report from the Boston Consulting Group (BCG)[ii] to explore the potential for technology in education. Their research suggests that there is no "one size fits all" solution and that in addition to the well documented evidence that pedagogical changes are required to ensure technology makes a difference, technology solutions need to be tailored to the individual economic and social situation of a jurisdiction. Local support and a complete understanding of the circumstances under which the digital transformation is to take place will ensure there is more chance of a successful implementation. Not all implementations are about technology use in the classroom - the addition of a robust MIS system can also bring about significant school improvements

However, many reviews of large scale implementations have shown little or negative impact from the technology. The research and the authors' own experience of large scale deployments indicate that common reasons for the failure or disappointing results (notwithstanding the commentary above) are due to the approach taken to the technology and infrastructure design, planning and implementation. By addressing the reasons why programmes are less successful, future implementations can be made successful. In later sections of the paper we address some of these historical challenges and examine new and improved solutions for an increasingly and better-connected world in which multiple types of devices are available.

The most common reasons for implementations not achieving their full potential appear to be:

- Big bang and 'technology first' implementations are often very politically driven with too much technology put into the system too quickly
- Usage models are not well considered in a 'technology first' approach
- Effectiveness and timing of leadership and teacher professional development and implementation of the technology. Lack of coordination results in overly lengthy time lags or lack of logical progression between training and the deployment of the technology
- Software and services are not sustainable. Locally and poorly supported software and services are deployed and modern Cloud solutions are not well understood or factored into the planning
- Content is often culturally unsuitable and/or highly expensive and is not adapted for context
- Devices are incorrectly specified and are underpowered
- The total capital cost is too high resulting in pilot deployments not being scalable or sustainable across the full education system. Device replacement cycles put further strain on sustainability and budgets and TCO is not well considered
- Network and Internet connections are not reliable or lacking in the bandwidth required to support many synchronous users leading to disruption in continuity of teaching and learning.
- Too much focus is placed on content and big VLE or learning platform solutions rather than more organic approaches focused on school needs and the development of appropriate usage models
- Cybersafety is inadequately considered in the planning process

- Poor or no baseline studies, insufficient funding for monitoring and evaluation and lack of agreement on metrics make it difficult to assess true impact.

Individual school success stories

Several schools around the region were interviewed for case studies which identify the significant factors that make for successful technology rich schools. Each of these case studies looked specifically at whole school improvement and identified the other contributory factors that led to their individual success and help to understand the unique success factors and proof points.

The analysis of the case studies provides clear evidence that it is an integrated approach to the technology that makes a difference. Successful schools are committed to:

- Building students 21st century skills
- Providing students with a broad vision and understanding of the world in which they live and will work
- Understanding the needs and aspirations of the community in which the school is located
- Maintaining close links and engagement with families
- Constantly searching for ways to innovate and to reinvent the learning environment
- Recognising each student as an individual
- Curriculum and assessment innovation
- Encouraging teacher and student creativity
- An authentic learning environment
- Inquiry and project based learning
- Building partnerships with industry, academic researchers and with other schools.

Pedagogical success when digital technology is employed across the school appears to be dependent on:

- Strong leadership from the top
- Support for teachers to integrate technology that is school based and classroom focused and is particularly successful when expertise is brought in to support teacher development, which may be from a peer support network or through the establishment of centres of excellence to provide this support
- A clear rationale for the use and distribution of technology resources
- Learning spaces designed for independent and group learning that are not always teacher centric
- Students taking responsibility for their learning and setting and evaluating their own goals, leading to strong motivation and engagement
- A productive and supportive interaction between teachers, between students and between teachers and students
- A variety of teaching models from exposition to individual, pairs and group learning and including blended and flipped learning
- Multimodal learning opportunities

Pedagogical success is also predicated on a sound technology infrastructure and modern devices with sufficient capability to support student activity.

The factors impacting school improvement

The factors that impact on school improvement are complex and technology is not the panacea but a significant contributory element. The evidence from research and the school case studies makes it clear time and time again that unless digital technologies are integrated into schools and their use is accompanied by a change in pedagogical approaches, there can be few significant improvements in learning outcomes. However, this is still not enough as there are many factors that affect learning outcomes. The reimagining and the reengineering of schools will need to take all these factors into consideration:

- Curriculum and assessment reform
- Leaders and teachers first with strong stakeholder engagement
- Pedagogical changes accompanied by strong professional development for education officials, principals and teachers
- Plans for the development of students' mid-21st century skills, preparing them for life in the 2nd half of the 21st Century
- Economically viable solutions
- Future proofing implementations with long term planning.

What happens in schools is of course crucial to learning, but how students perform will also depend on many other factors such as the political, economic and social landscape and on parental/guardian attitude and support. The contribution of digital technologies to this landscape will only have an impact if the access to devices and other tools is backed up by a suitable infrastructure and a methodology that adds value rather than replicates what already exists, albeit through an alternative medium. Figure 2 is a simple model that identifies all the factors that impinge on learning outcomes.

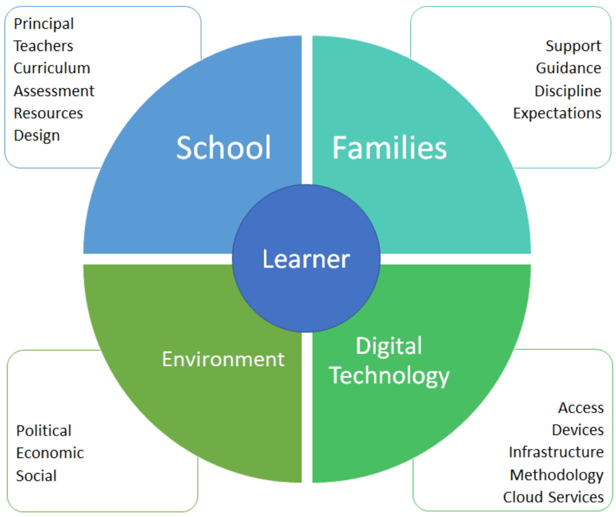


Figure 2 Dependencies for learner outcomes

Digital technology for the future

It is clear from the evidence that today's digital technology solutions *can* have a real impact on teaching and learning as well as on the management and administration of the schools. However, for the technology investment to make a significant impact and to realise the full potential, these solutions must be accompanied by a thorough reconsideration of the nature and purpose of schooling and the need to reimagine and reengineer the K-12 system for the rapidly changing workplace and societal environment of the second half of the 21st century. Significant research has demonstrated how inadequately prepared our workforces are today and the lack of awareness of the profound changes that will continue throughout the 21st century.

The problem is that we are still evaluating and designing education systems and testing our students based on 19th Century paradigms. A more skills-based, collaborative and creative education process supported by the digital technology that is the major toolset of the 21st Century knowledge economy will better prepare students for life and work as we move towards the middle of the 21st Century. The technology can aid the improvement of authentic formative and summative assessment as well as learner self-assessment, and will ensure transparency in the teaching and learning process as demonstrated in Figure 3 below. We are at an inflection point where memorising, although important, is less vital with easy access to ubiquitous information through connectivity. Instead, students need to apply critical thinking and creativity, understand how to find information and recognise the importance of questioning the reliability of the source and the validity of the information they find.

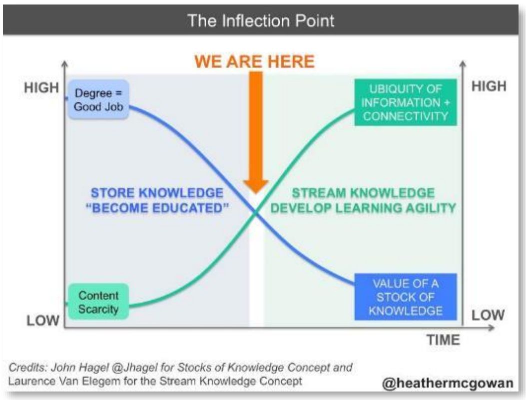


Figure 3 From stores of knowledge to streaming knowledge

Recommendations, proof points and conclusion

Based on the research in the white paper there are a number of recommendations that will help to build successful implementations of digital technology either at scale or for individual or small groups of schools.

Country and region wide initiatives

There are many things that can go wrong with highly visible and politically charged large scale deployments. Learning from one's own mistakes is expensive and damaging at many levels, so both learning from others and adapting to context are crucial to ensure that any investment in digital technology is going to have a beneficial and long-term impact on learning outcomes and preparing students for their future. The recommendations here are based on exemplars of good practice as well as learnings derived from those mistakes others have made and are divided into four areas (Figure 4).

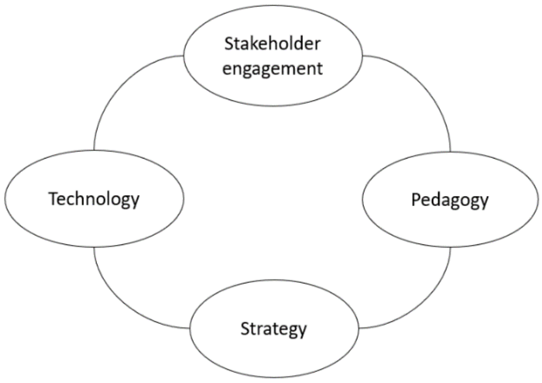


Figure 4 Large scale implementation recommendation categories

Based on the case studies presented in this white paper and on research evidence from the literature, it is clear that strong leadership, with a focus on developing robust 21st century pedagogical practices, should lead any digital transformation strategy - whether it be within a school or across a group of schools in a municipality, or part of a large-scale implementation plan. The comments made above about large scale implementations are also valid. With these in mind the recommendations for school wide implementations are divided into these four sections (Figure 5).

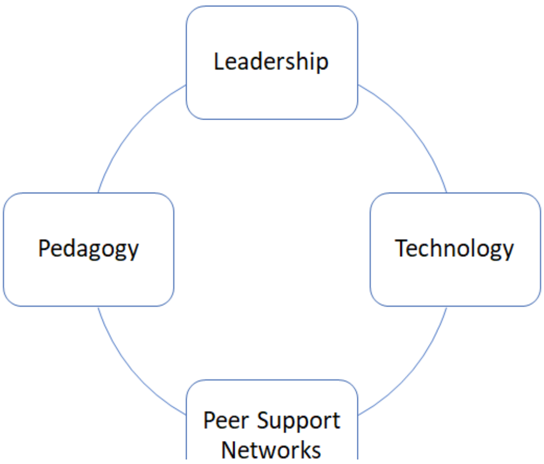


Figure 5: Implementation framework for schools

Conclusion

There is an imperative for immediate action in our education systems to address skills, workforce and societal needs for the second half of the 21st Century and digital technology is integral to that process**.** A defined organisational change strategy is needed whether it be for large scale implementations or at the individual school level, with strong governance processes where a framework, the roadmap and priorities are all outlined.

Well-defined sustainable and replicable business models can help pilot initiatives to be successfully scaled. Replicability, sustainability and scalability have proved to be the most difficult achievements for most development projects in education. Countries around the world have piloted many education technology projects and used the findings to inform policy. They have discovered that in implementing an effective country-wide deployment of technology infrastructure, content and teacher training, the use of digital technology, although improving, is not yet becoming embedded in the curriculum universally however high the level of funding e.g. Becta, 2006[iii].

Support is required from ministerial agencies with national and local businesses and sponsorship all working together to identify innovative ways of acquiring and deploying digital tools and resources in schools and finding ways of sharing and spreading exemplary practice effectively.

This white paper demonstrates the positive impact of technology in schools if all the other key factors required for success are in place and developed alongside the deployment. These factors include strong leadership, curriculum realignment and assessment for 21st Century learning, adequate resources and pedagogical shifts. Baseline studies and clear and meaningful evaluation criteria are also crucial if the improvements in learning outcomes and student preparedness for their future are to be effectively measured.

1. Introduction

There are many individual schools around the world that are successfully implementing digital technologies. This white paper identifies and details some clear success factors that help schools flourish, aid governments to successfully implement large scale education technology initiatives and better comprehend and demonstrate the common causes of failure or disappointing results from such investments.

If our students are to become active citizens in the modern globalised world, then digital literacy and a clear understanding of how technology is influencing, and will increasingly continue to influence their lives is imperative. A recent OECD[iv] report concurs with this statement and recognises the challenges that educators face:

> *"… from information overload to plagiarism, from protecting children from online risks such as fraud, violations of privacy or online bullying to setting an adequate and appropriate media diet. We expect schools to educate our children to become critical consumers of Internet services and electronic media, helping them to make informed choices and avoid harmful behaviours. And we expect schools to raise awareness about the risks that children face on line and how to avoid them." (p3)*

The massive change in access to information provided by digital technology has already transformed many education processes where the technology and usage models are well applied. Research, particularly case studies, consistently show that the 21st century approach to knowledge is about processing and applying information rather than storing up the facts of past, more static knowledge which is now ubiquitous and easily accessible. Yet, the debate remains about *whether*, rather than *how*, students should use digital technology in schools to support their learning. This white paper will show that it is essential for all education systems to grasp the opportunities that these new and highly accessible technology capabilities provide and to seek to reimagine the processes of education to prepare our young people for the challenges of the second half of the 21st century. This theme is further explored in a recent Microsoft sponsored report *Redesigning Education: Meeting the Challenges of the 21st Century*[v].

This white paper also aims to demonstrate from research evidence, recent case studies and broad international experience in both large-scale and localised implementations of technology in education, that there are common success factors and approaches that lead to positive results and common risk factors that consistently lead to sub-optimal results. By understanding the combination of factors that bring success, private sector organisations like HP can work more intelligently with clients to ensure that future implementations will be more profitable for all parties.

2. Historical view of digital technology in schools

The evidence suggests that well planned and managed implementations of digital technology can have a significant impact in the K-12 sector when well-coordinated with the host of other factors that lead to better learning outcomes. The investment in technology has been and continues to be significant with a report from EdTechX Global and IBIS Capital[vi] estimating that by 2020 some USD252 billion will have been invested in education technology. However much of the publicity surrounding impact studies over the past ten to fifteen years is mixed, conflicting, and at worst, shows impact as mostly negative. In all other sectors of society and enterprise the introduction of technology is rarely questioned. Technology is perceived as an essential element in improving effectiveness and efficiency, and has become an indispensable part of the infrastructure in these sectors. However, the investment in digital technology in education is constantly being challenged, and many leading thinkers and writers have commented on the lack of clear measurable impact. For example, John Hattie spent 15 years studying and ranking the factors that affect standards. He found that 'computer aided instruction' ranked 71st out of 183, and stated there was *"no evidence that technology has yet had any above-average impact."* [vii]

Some of this research is now becoming a little dated with much of the research having taken place in the first decade of the 21st century. The last major meta impact study appears to have been in 2012[viii] and the only significant study since then was conducted in 200 schools worldwide by OECD in 2015[ix]. Over this time there have been significant advances in Internet bandwidth, device cost and accessibility as well as an increase in the quality and availability of education software and Cloud services.

The OECD 2015 report suggests that technology ought to now be considered as integral to both teaching and learning, and to school management and administration. This is being borne out in country education plans. For example, the Irish Government Department of Education and Skills has recently developed a Digital Learning Framework for Schools[x] calling for the embedding of technology broadly throughout all teaching and learning practice. This view was also prevalent in a BBC report in which interviewees were certain that technology should be used in schools, but better ways of using it needed to be found.[xi]

The challenge then is to identify the reasons for the reported lack of improvement; to determine whether this is mostly a macro view; and to discover the factors at a micro level that single out those successful schools where technology has been built on a robust infrastructure, with future proofed usage models, tools and devices. Additionally, these schools will have made technology an integral factor in improvements to learning outcomes and pedagogical approaches, and to increased efficiencies and effectiveness of management and administration. The next and most crucial step is to develop strategies that can scale effective practices in ways that are acceptable from both an economic and a cultural perspective. These strategies can then be tailored to large scale, government led interventions, or to schools working in either a regional cluster or alone.

2.1 Summary of research to date

Media reports of research on the implementation of digital technologies in the K-12 sector tend to gloss over any positive findings and only report the negative - often with attention grabbing headlines. This creates confusing or conflicting results, frequently with a brief aside to some incremental improvement. These reports invariably question the significant financial investment made by individual schools and jurisdictions.

In a comprehensive review of research including many meta-studies, Higgins *et al* [xii] concluded that there *are* improvements to learning when the technology is used well but often less "*when compared with other researched interventions and approaches (such as peer tutoring or those which provide effect feedback to learners)*". Their research outlines some key and important points:

> *The range of impact identified in these studies suggests that it is* ***not whether technology is used (or not)*** *which makes the difference,* ***but how well the technology is used to support teaching and learning****. […] It is therefore the pedagogy of the application of technology in the classroom which is important: the how rather than the what. This is the crucial lesson emerging from the research." (p3)*

This thesis is backed up by many of the studies reviewed for this white paper. It is *how* technology is integrated not the technology *per se*. There is no "holy grail" as Hattie explains, "*rather, technologies used to enable and accelerate specific processes can dramatically improve learning, but its impact depends on how it is used*." [xiii] (p2). The 2015 OECD study referred to earlier also suggests that the reasons for technology not supporting any significant improvement in learning is because "*we have not yet become good enough at the kind of pedagogies that make the most of technology; that adding 21st-century technologies to 20th-century teaching practices will just dilute the effectiveness of teaching*." (p3). Both OECD and Toyoma also observed that the way technology is currently used does not 'level the playing field' of learning, as students who are behind "*need high-quality adult guidance more than anything else*" [xiv], thus stressing the importance of pedagogy yet again but with a focus on using technology to support differentiation.

The crux is in the challenge of "*adding 21st Century technologies to 20th Century teaching practices".* The evidence suggests that until views change about the purpose of education and how society prepares young people for work and life over the next few decades, digital technologies will always be bolt-on rather than integral to learning and teaching and will only be used to help teachers teach the way they always taught. We are now 18 years into the 21st Century yet the movement to large scale technology-enabled reform is sadly lacking. We return to this debate later but first we consider the impact of large scale device implementations around the world.

2.2 Large scale implementations

Despite popular belief, there are several positive examples of success of large scale technology implementations in schools especially when time is factored into the equation. The World Economic Forum recently commissioned an extensive report from the Boston Consulting Group (BCG)[xv] to explore the potential for technology in education. Their research suggests that there is no "one size fits all" solution and that in addition to the well documented evidence that pedagogical changes are required to ensure technology makes a difference, technology solutions need to be tailored to the individual economic and social situation of a jurisdiction. BCG found that "*education technology can yield the best results if it is tailored to a country's unique educational challenges, such as those* *related to inadequately trained teachers or insufficient financial resources, among others*". Yet consultants from rich developed nations often make recommendations to the Ministry of Education of an emerging or developing country that are unaffordable and unworkable and rarely engage sufficiently with local knowledge and expertise.

Local support and a complete understanding of the circumstances under which the digital transformation is to take place will ensure there is more chance of a successful implementation. For example, the intervention of the Kenya Institute for Curriculum Development (KICD) which intercepted early in the Kenyan government's pledges for devices for all in a countywide initiative. KICD successfully lobbied for higher specification devices with keyboards and Microsoft Windows to better support education objectives for project-based learning, research work and knowledge creation activities.

Not all implementations are about technology use in the classroom - the addition of a robust MIS system can bring about significant school improvements. One of the most successful was in the Indian state of Haryana which is known for its high enrolment rate. 99 per cent of the 4.5 million students are enrolled in state or private schools. Despite the existence of more than 40 pilot projects aimed at raising standards, the state was unable to make any headway and many children were still unable to read by their fifth year of schooling. Boston Consulting Group designed a new roadmap in 2013 and by 2014 improvements were beginning to show[xvi]. The key reasons for improvement were:

- The development of a top-down, state wide and systemic roadmap
- Recognition that any successful intervention had to be designed to scale across thousands of schools and had to be flexible and achievable with an online, centrally managed monitoring system
- New accountability systems and data and assessment systems, upgraded capacity and a renewed focus on quality improvement through a range of in-school and systemic initiatives.

This effort resulted in:

- 1.8 million students assessed monthly in all subjects with results available within 10 days
- A new performance appraisal system for 100,000 employees
- Information on more than two million students, uncovering half a million fake students which resulted in a 15 per cent cost saving
- 3 per cent to 6 per cent increases in numeracy and literacy rates in two years and outperforming increases in several other regions.

However, many reviews of large scale implementations have shown little or negative impact from the technology. The research (e.g. Trucano, 2010[xvii]; World Economic Forum, 2011[xviii]), and the authors' own experience of large scale deployments indicate that the main reasons for the failure or disappointing results (notwithstanding the commentary above) are due to the approach taken to the technology and infrastructure design, planning and implementation. By addressing the reasons why programmes are less successful, future implementations can be assured of success. In later sections of the paper we address some of these historical challenges and examine new and improved solutions for an increasingly and better-connected world in which multiple types of devices are available.

The most common reasons for implementations not achieving their full potential appear to be:

- Big bang and 'technology first' implementations are often very politically driven, with too much technology put into the system quickly
- Usage models are not well considered in a 'technology first' approach
- Timing of leadership and teacher professional development and implementation of the technology lack coordination resulting in overly lengthy time lags or lack of logical progression between training and the deployment of the technology
- Software and services are not sustainable. Locally and poorly supported software and services are deployed, and modern Cloud solutions are not well understood or factored into the planning
- Content is often culturally unsuitable and/or highly expensive and is not adapted for context
- Devices are incorrectly specified and are underpowered.
- The total capital cost is too high resulting in pilot deployments not being scalable or sustainable across the full education system. Device replacement cycles put further strain on sustainability and budgets and TCO is not well considered.
- Network and Internet connections are not reliable or lacking in bandwidth required to support many synchronous users leading to disruption in continuity of teaching and learning.
- Too much focus is placed on content and big VLE solutions rather than more organic approaches focused on school needs and development of appropriate usage models.
- Cybersafety is inadequately considered in the planning process
- Poor or no baseline studies, insufficient funding for monitoring and evaluation and lack of agreement on metrics make it difficult to assess true impact.

2.3 Big-bang and 'technology first' implementations

These implementations often push too much technology into the system without proper consideration of the supporting infrastructure and capabilities required. Planning focuses on the technology but does not adequately plan for a whole school improvement strategy, resources, teacher and leadership development, stakeholder engagement, change management, integration into school and classroom activities, and usage model development. Commonly this leads to disappointment, lack of clear results, rapid obsolescence of the technology and often abandonment. Populist political motives are common drivers for 'technology first' large-scale initiatives with many examples of election pledges made to provide computers. These motives often lead the planners to set the wrong objectives and priorities to meet narrow political purposes.

Many deployments have not sufficiently understood or considered the usage models that can be employed in a modern and rich multimodal teaching and learning environment. The full set of learning and teaching usage models are not researched, understood or planned for. Often very one-dimensional usage models are considered in high level planning, and software solutions, 'interactive content' and learning platforms have been oversold as panacea solutions by the technology industry based on a mechanistic view of the education process.

Many deployments installed low-cost and low capability devices and expected too much from them, while fast and large-scale deployments suffered from built in obsolescence as the specifications of new devices advance rapidly. Little engagement by education leaders and very little planning for teacher development, usage models or infrastructure preparation led to many of the common causes of failure of a rapid roll-out of lowest possible cost technology.

2.4 Enterprise Grade Internet Infrastructure

Many of the referenced studies which identify Internet bandwidth as a constraint in school technology programmes are now 10-15 years old when commonly available connection speeds were generally 5 per cent or less of today's connection speeds. This led to challenges in providing a seamless learning experience. Additionally, wireless broadband was either not yet widely available in the countries in later projects. A school is a small to medium sized enterprise with high levels of synchronous usage when many students across multiple classes access the network at peak times during the school day. Unless a commercial grade network design is implemented with adequate local area network (LAN) capacity within the school and Internet bandwidth into the school to support this high level of usage and peak usage patterns, the network will be unreliable when teachers and students need to depend on it most. Today most advanced schools will have an Internet bandwidth of several hundred megabits per second (Mbps) with state of the art schools moving to connections of 2 Gbps and higher.

2.5 Examples of large scale implementations

Below are just a few examples drawn from numerous country and regional major and rapid implementations that demonstrated many of the common flaws outlined above but some also show elements of success.

Magellan initiative in Portugal

The widely publicised Magellan initiative in Portugal [xix] was intended to provide a major jump-start to reformation and modernisation of the classroom while also making a significant contribution to economic development through the growth of local manufacturing and an export industry for Portugal. The roll-out of computers to schools began in September 2008 and was suspended by the Ministry of Education in 2011. While the OECD 2015 report[xx] did show that Portugal had the largest jump in computer usage in schools between 2009 and 2012, and there were some measurable economic benefits, the 'technology first' nature of this major initiative exposed many of the common flaws in a 'big-bang' style deployment.

The initiative set out with a very worthy objective of mass distribution of Magellan laptops to democratise access to technology and their everyday use in classrooms to prepare children for the future. However, a study by the University Portucalense reported in the Algarve Daily News[xxi] found that that the portable Magellans served more as a simple support and not as a central feature for innovation in teaching. The study noted that the electronics kept failing, pointing out a "*lack of leadership, involvement and encouragement from directors, a lack of rooms equipped with power outlets and Internet access, a lack of technical assistance for the laptops which broke down* *frequently and lack of planning to include the Magellan in class activities and curricula*." Even though many of the reports on the Magellan project were quite negative, individual case studies revealed that in some schools there were significant gains made.

Thailand 'One Tablet per Child' Project

2.1 million tablets were distributed between 2012 and 2014 with the aim of giving one tablet to every grade 11 student. However, in May 2014 the project was cancelled because, as the Bangkok Post noted**,** "*Technology experts have thrown their weight behind authorities' plans to drop the Pheu Thai Party-initiated One Tablet per Child policy, saying the project was failing to meet its objectives*". In a paper describing the challenges, Viraypong and Harfield (2013)[xxii] suggest that there were many unexplored issues in designing and implementing tablet activities for such a large and varied group of students and so far, there was a lack of evaluation on the effectiveness of these tablet activities.

The authors proposed four challenges that need to be met to improve Thailand's one Laptop per Child project that are all included in the list of causes of failure above:

- Developing contextualised content
- Ensuring usability
- Providing teacher support
- Assessing learning outcomes

LA Unified School District (LAUSD) iPad initiative

An iPad project in the LA school district in the US in 2013[xxiii] also proved highly controversial as the implementation was not integrated into a school improvement programme. In fact funds were *diverted* from improving the decaying fabric of schools to buying iPads without due consideration of their suitability for all students and a robust cost-benefit analysis. Before the project launched there were warnings about the total cost of ownership being significantly higher than planned, with a figure of two to three times the published cost of providing the hardware and the software preloaded onto the iPads. The extra costs included the "*hire of school technical assistants, providing the wireless infrastructure, loss of tablets, and repair of broken tablets, insurance, professional development for teachers, costs for replacement devices when three-year warranties expire, etc*".[xxiv]

Australian Digital Education Revolution

A commitment was made in 2007 to provide a computer on the desk of every upper secondary school student with associated upgrades to the broadband infrastructure in schools. This initiative also met with serious concerns as insufficient resources were provided for essential professional development and funding for suitable educational software which would ensure a better chance of a successful rollout. This omission was later rectified. Five years after implementation of the so called "Digital Education Revolution", Australian schools now enjoy comprehensive access to high-quality equipment and support services. However, like other country initiative reviews, it is reported that the general belief is "*the real benefits of information and communications technologies in schools will not be realised if the provision of ICT is seen as a supplementary activity, and not a core element of school operation*".[xxv]

A Middle Eastern country-wide plan

In an unpublished review for a Middle Eastern country undertaken by one of the authors of this white paper, technology used as supplementary to classroom activity was evident. There was a significant under-utilisation of technology in schools across all areas, although there were also some pockets of good practice to draw evidence and hope. Reasons for under-utilisation were poor Internet access; access (or lack thereof) to computer labs; poorly maintained equipment; no updating of the virtual learning environment; little repair and refurbishment of computer equipment in schools; and a lack of ongoing professional development. There was also a lack of true commitment to integrate technology in education across the country, little accountability, and a very weak institutional interest in education technology. However, as in other initiatives, pockets of good practice emerged in individual classrooms and schools. For example, there was an increase in PISA scores for many schools that were part of the initial roll out of digital technology.

U.S. Project RED

In 2009 a seven-year study in the U.S. entitled Project RED[xxvi] aimed to find the key to raising student achievement and cost effectiveness when integrating technology in American schools. The team studied 997 schools across 49 states and in the District of Columbia. The research compared findings by student-computer ratios (1:1, 2:1, 3:1, etc.)

The findings from the initial Project RED study provided ground breaking evidence about student - computer ratios:

> *The data revealed that schools employing a 1:1 student-computer ratio along with Key Implementation Factors (KIFs) outperformed other schools. The data also revealed significant opportunities for improving education return on investment (ROI) by transforming teaching and learning. Dispelling a widely accepted myth, the data showed that student-computer ratios did matter. Schools with a 1:1 ratio outperformed schools with a 2:1 ratio on all 11 measures. Furthermore, schools with a 2:1 ratio outperformed schools with a 3:1 ratio and so forth down the line.*

However, it was found that less than 1 per cent of schools with 1:1 programmes demonstrated the use of all nine KIFs and 67 per cent were using fewer than half of them. Recognising the need for more support to make technology integration more successful, the Project RED Team created resources for Phase II. These included a peer-support network featuring a web-based hub and regional summits where educators could learn from the experiences of others and collaborate with districts undertaking similar work. In Phase III much of the learning from so called “Signature Districts” were analysed along with the reasons for expensive and unnecessary failure of high profile 1:1 programmes

The KIFs identified are described below in Figure 6.

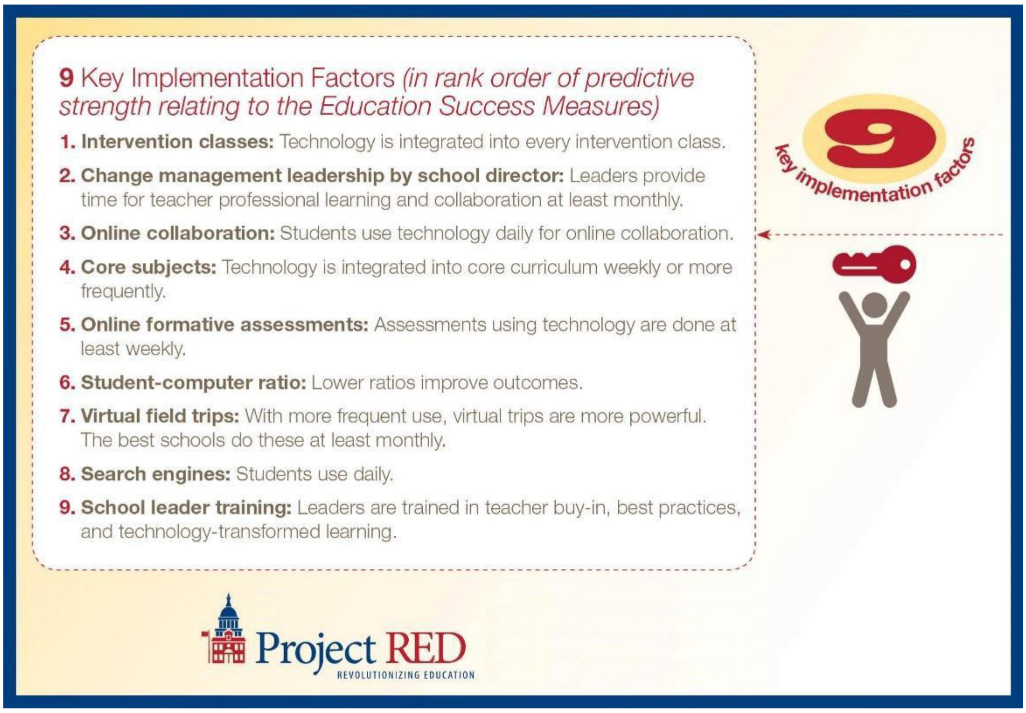


Figure 5 Key Implementation Factors in Project RED I

It was discovered that there was a breakdown in understanding of key areas in many of Project RED's findings and recommendations. As a result, Project RED, published briefs around these challenge areas to support schools:

- Leadership
- Communication
- Instruction, Pedagogy and Data
- Professional Learning
- Finance

The learnings from the research informed these briefs and include these key factors in each category that need to be addressed for a successful implementation:

Leadership

- Change management leadership by the principal
- Providing time for teacher professional learning and collaboration on a regular and ongoing basis
- Principal training in the components of change leadership such as ensuring teacher buy-in, a shift to technology transformed learning and other best practices.

Communication

- Effective communication is essential to the success of any endeavour involving more than one person
- Poor communication leads to challenges in implementation.

Instruction, Pedagogy and Data

- Although the benefits of personalised learning are well recognised, there was little evidence of it and most practices were instead teacher developed and directed. More professional developed is required
- The idea of each student co-creating their goals, curriculum path and mode of operation seems ideal, but poses challenges to traditional beliefs about learning and the structures in place in most school environments
- Matching the appropriate pedagogy to the desired learning appears to yield better outcomes
- The most important factor in improving student outcomes appears to be the effective use of ongoing formative assessment data. When students have a digital system that automatically collects data throughout their learning process and provides actionable information to each student and the teacher in real time, it is possible that improvements in student outcomes could be exponential
- The ability of a district to collect and turn ongoing formative data into actionable information needs to be addressed.

Professional Learning

- A major shift from a traditional approach to professional development (episodic training for teachers), to more ongoing professional learning experiences including communities of practice and other job-embedded approaches lead to positive changes in student outcomes.

Financial Brief

- Understanding the total cost of implementation and how to maximize a district's current situation
- Capturing savings through digital efficiency that can be redeployed to offset technology expenses
- Identifying the long-term financial benefits of improved student outcomes by lowering costs associated with factors such as course repetition, disciplinary actions, dropout rates, etc.
- Maintaining the status quo e.g. paper-centric practices such as printing assignments, copying content, quizzes and paper and pencil tests, adds to the cost of implementing 1:1 technology and needs to be addressed.

2.6 Is it all about devices?

Much of the research is about the impact of students having ready access to devices and particularly one to one initiatives, although there is extensive research on the use of interactive whiteboards (IWBs) (e.g. Hennessey and London[xxvii]) which demonstrates that often they become replacements for the conventional whiteboard and allow teachers to show pre-prepared documents and presentations but do not make sufficient use of connectivity or interactivity. Teachers also preferred to use conventional boards.

Like most forms of technology, training on the use of IWBs and their effective use in the classroom takes time. Hennessey and London noted that previous studies showed pedagogical change only comes with significant investment in professional development and is generally only observed after at least one year of full-time use by teachers. Teachers mediated the use of the IWB so their impact on students' learning indicated no robust, clear cut positive effects. It is the context and the nature of use of IWBs that are important. Where there is no change in views of the purpose of education as stated earlier, old practices will persist, and teachers will appropriate the technology to do what they always did[xxviii]. Nevertheless, effects on learner achievement attributed to IWBs are generally more positive than for all other forms of technology.

Research on the use of video conferencing and collaboration and social media tools exists yet it is less extensive. There is also research on devices for teachers, but at the end of the day, the general view yet again, is that without a change in pedagogy and a review of the purpose of schooling, then digital technology will not make a significant impact on learning in schools.

Learning space design is another significant factor. In research conducted in U.S. schools and colleges, Steelcase showed the value and importance of redesigning classrooms to become places where digital tools and physical resources could co-exist and have equal value.

> *During the past decade, colleges and universities have increasingly recognized the value of "in-between places" — i.e. informal areas outside classrooms where interaction tied to learning can occur. Now that concept has even more relevance. Flexible spaces have become more important than ever. Classrooms with mobile tables and chairs, wider hallways to support more activities, cafés with whiteboards, lounges with informal seating and power connections, moveable walls so space can be easily divided and recombined — these are among the fast-emerging design imperatives for effective educational environments.*[xxix]

Figure 6 A modern learning space at St Monica's Primary, North Parramatta, New South Wales, Australia. *[Source: Hamilton Lund]*

3. Individual school success stories

As there are a multitude of studies on individual subject areas but few on whole school improvement, several schools around the region were interviewed for case studies which identify the significant factors that make for successful technology rich schools. Each of these case studies looked specifically at whole school improvement and identified other contributory factors that led to their individual success and help to understand the unique success factors and proof points.

The analysis of the case studies provides clear evidence that it is an integrated approach to the technology that makes a difference. The research evidence for success discussed earlier is evident in the case study schools. Successful schools are committed to:

- Building students 21st century skills
- Providing students with a broad vision and understanding of the world in which they live and will work
- Understanding the needs and aspirations of the community in which the school is located
- Maintaining close links and engagement with families
- Constantly searching for ways to innovate and to reinvent the learning environment
- Recognising each student as an individual
- Curriculum and assessment innovation
- Encouraging teacher and student creativity
- An authentic learning environment
- Inquiry and project based learning
- Building partnerships with industry, academic researchers and with other schools.

In many jurisdictions the schools were often restricted in their innovation potential by the political environment and dictates of the government, although some had a stronger mandate than others. However, the evidence shows that if a school is willing to innovate they may be given special dispensations by the government to test new regimes particularly in assessing students' learning.

Pedagogical success when digital technology is employed across the school appears to be dependent on:

- Strong leadership from the top
- Support for teachers to integrate technology that is school based and classroom focused, and is particularly successful when expertise is brought it to support teacher development
- Clear rationale for the use and distribution of technology resources
- Learning spaces designed for independent and group learning that are not always teacher centric
- Students taking responsibility for their learning, setting and evaluating their own goals leading to strong motivation and engagement
- A productive and supportive interaction between teachers, between students and between teachers and students
- A variety of teaching models from exposition to individual, pairs and group learning and including blended and flipped learning
- Multimodal learning opportunities.

Pedagogical success was also predicated on a sound technology infrastructure and modern devices with sufficient capability to support student activity. Some of the key factors are:

- Sufficient and reliable bandwidth to cater for all the demands of the school
- Sufficient Wi-Fi access points for all students to be online when required
- Technology underpins the way the school operates
- A clear device policy including the use of smartphones
- Good technical support
- A preference for laptops over tablets as the keyboards made for easier use as input devices
- 1-1 over any other ratio only if accompanied by other structural changes in pedagogy and learning design
- Local support and funding for digital transformation or for special technology focused initiatives.

3.1. The factors impacting school improvement

The factors that impact on school improvement are complex; technology is not the panacea but a contributory element. The evidence from research and the school case studies makes it clear time and time again that unless digital technologies are integrated into schools and their use is accompanied by a change in pedagogical approaches, there can be few significant improvements in learning outcomes. However, this is still not enough, there are many factors that affect learning outcomes. Successfully reimagining and reengineering schools will take into account:

- Curriculum and assessment reform
- Leaders and teachers first with strong stakeholder engagement
- Pedagogical changes accompanied by strong professional development for education officials, principals and teachers
- Plans for the development of students' mid-21st century skills
- Economically viable solutions
- Future proofing implementations with long term planning

However, this is not the whole picture as schools do not work in a vacuum. They are subject to many external factors which can support or limit their educational outcomes. What happens in schools is of course crucial to learning, but how students perform will also depend on many other factors such as the political, economic and social landscape and on parental/guardian attitude and support. The contribution of digital technologies into this landscape will only have an impact if the access to devices and other tools is backed up by a suitable infrastructure and a methodology that adds value rather than replicates what already exists, albeit through an alternative medium. Figure 8 is a simple model that identifies the factors that impinge on learning outcomes.

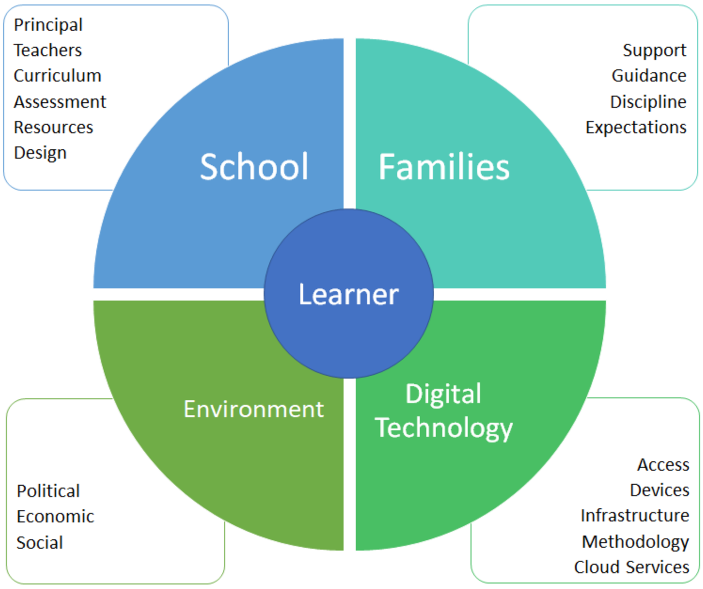


Figure 7 Dependencies for learner outcomes

The World Band Development Group[xxx] have also been working along similar lines, albeit without mention of digital technologies, and have produced this diagram (Figure 9). The figure also shows how complex learning is and how it is driven by some many changeable factors.

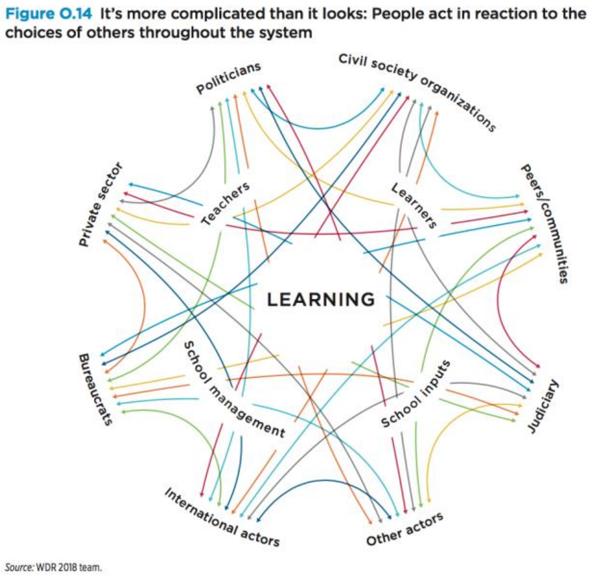


Figure 8 Factors that impact on learning [*Source: World Bank Development Group*]

The Environment: political, economic and social

For education reform to be effective, there needs to be the political will with clearly articulated visions, goals and directions for education that are matched to the needs of society and to the aspirations for and direction of economic growth. Technology will be an integral part of that reform agenda, not bolted on, and with sufficient funding identified and earmarked so that current initiatives and new programmes can be built on or integrated into existing developments.

Education has always been political. Charles Handy once said that education was prone to a fifty-year time lag as those who make decisions about the type of education students will receive were educated two generations earlier. These decision makers fail to recognise that the world is very different from the world they were being prepared for, let alone the fact that in 20 years' time the world will be very different again[xxxi].

As we head for the middle of the 21st Century we are experiencing the most rapid rate of change in society, the economy and workplace that humanity has ever experienced. Reform is overdue and imperative if we are to keep pace with a rapidly transforming society and workplace. Technology such as AI, robotics and automation will fundamentally change most jobs as well as our experiences of interacting with society and government. In some instances it will change their nature, whilst in others it will eliminate jobs, activities and inter-relations. This is not a new phenomenon, but it is one that is now taking place at an unprecedented rate. Education systems must adapt to both new and different challenges.

The notion of 21st century skills has been much discussed and quantified since the 1990s (see above), yet coming to the end of the 2nd decade of the 21st century, many commentators are still challenging education systems around the world to recognise the need to reform and reinvent education to prepare students for an uncertain future. Instead, we have a tinkering at the edges of a system that is more resistant to change than any other sector. While outdated education models persist, digital technologies can have little impact as educators grapple with how to make use of the tools and services to teach and assess students in a traditional didactical model rather than use of the technology to develop the other important skills students will need to succeed.

Many assessments of the application of technology to K-12 education are compared against 19th century education paradigms and processes. A more fundamental reimagining is required with the opportunities presented by the Internet, computing technology and the Cloud now available and much as industry benefited from the 'business process re-engineering' phase in the 1990s.[xxxii]

Expenditure on education and how teachers are positioned in society has a real impact too. In a country analysis of the target regions, the data showed that spending on the K-12 sector was approximately half of the total of education spending in the two European regions, whereas in the Middle East it was about one third (except for Turkey) although the data from the United Arab Emirates was 20 years old. In Western and Northern Europe, Switzerland spent 10.8 per cent on education overall, while France was the lowest spending just 6.2 per cent. In Eastern Europe and the Baltics both Croatia and Serbia spent 9.6 per cent while Poland spent 7.4 per cent and Hungary spent 4.9 per cent. The Middle East is very varied. Both Israel and Jordan spent just over 14 per cent of public spending on education while the United Arab Emirates spent just 5 per cent (1997 data).

On average across OECD countries, pre-primary teachers' actual salaries are 74 per cent of the earnings of a tertiary educated 25-64-year-old full-time, full year worker. Primary teachers are paid 81 per cent of these benchmark earnings, lower secondary teachers 85 per cent and upper secondary teachers 89 per cent. However, there are huge differences between teachers' salaries in the various regions. For example, teachers working in Luxembourg at upper secondary level are paid USD 153 per hour, and at the lower end of the scale, teachers in Hungary are paid USD 36. Generally, teachers in the Nordic region, whose education systems are highly rated, are paid more with an average of USD 110 per hour compared with the OECD average of USD 74. The actual salaries of teachers also compare favourably with other full-time workers in tertiary education. The highest paid teachers are in Luxembourg.

School reform

To ensure a stable society and economically sound global economy, reforms in curricula and what is assessed as well as how it is assessed, are long overdue. New creative and transversal themes need to be introduced and rich cross-curricular based tasks ought to become more mainstream. Within this setting, innovations in teaching and learning supporting the development of new thinking and additions to the current set of higher-order skills will be essential to prepare creative *'makers and shapers'* for the late 21st Century.

There is little research on why *'islands of good practice'* in the use of digital technology continue to exist. Such practice is seldom spread and embraced by others within a school or across schools given the availability of low cost and free collaboration and communications tools plus good practice resources (e.g. Promethean Planet, TES). When this research is conducted it is often within a specific subject area and rarely focuses on whole school improvement. The spread of innovative ideas tends to be within subject areas and does not spill across the whole school.

Principals and teachers

It is clear from the research and from the case studies that in the schools where improvements in learning are realised, there is strong leadership and there are teachers who understand the potential of technology and integrate it into their teaching. Although the research points to the fact that it is teachers who make the real difference in schools, teachers can only do this if they are supported by a principal who gives them time and space to grow with a degree of autonomy and who understands the impact potential of digital tools and solutions.

Pedagogy

There is considerable discussion about digital pedagogies i.e. pedagogies associated with technology. However, good pedagogy is good pedagogy and it can be supported, enriched and enabled by the 'digital' element. Husbands and Pearce in a review of research[xxxiii] have produced this list of nine effective pedagogies which are consistent with, and enhanced by, a technology-rich learning environment:

1. Effective pedagogies give serious consideration to pupil voice
2. Effective pedagogies depend on behaviour (what teachers do), knowledge and understanding (what teachers know) and beliefs (why teachers act as they do)
3. Effective pedagogies involve clear thinking about longer term learning outcomes as well as short-term goals
4. Effective pedagogies build on pupils' prior learning and experience
5. Effective pedagogies involve scaffolding pupil learning
6. Effective pedagogies involve a range of techniques, including whole-class and structured group work, guided learning and individual activity

7. Effective pedagogies focus on developing higher order thinking and metacognition, and make good use of dialogue and questioning in order to do so
8. Effective pedagogies embed assessment for learning
9. Effective pedagogies are inclusive and take the diverse needs of a range of learners, as well as matters of student equity, into account.

It is the best application of the usage models discussed below that make these effective pedagogies more effective through technology. What is needed to prosper in the modern global economy and society is a personalised, adaptive, learner centred approach that prepares students with strong content knowledge and understanding together with 21st Century transversal skills. The features of this usage model are outlined in Figure 10 below.

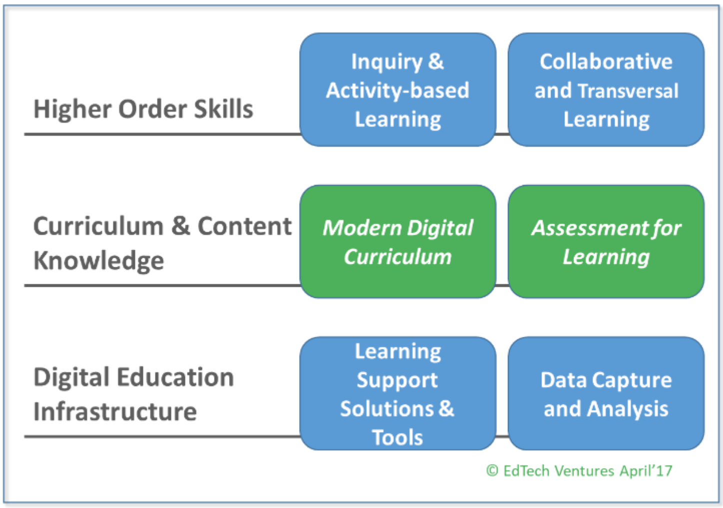


Figure 9 New approaches to learning

Professional development

Professional development is perceived in many countries as vital. However, it is the nature of the training teachers undertake that will help reshape the profession and prepare them for the new pedagogies relevant to both the future needs of their students and the integration of technology. In the country analysis undertaken for this white paper, it was noted that schools in the Nordic regions provided less professional development workshops for teachers within schools than most countries. Given that this region spends and invests a lot on education and feature high in most of the PISA results, this might seem surprising. The answer lies in the professionalisation of teaching. In Finland, for example, teachers are extremely well qualified (e.g. a five-year master's degree for primary school teachers) and professional development is regarded as a personal endeavour backed up by regular appraisal, so learning to find effective ways to use technology in the classroom, for example, is the personal responsibility of each teacher[xxxiv]. Technology integration also needs to be built into pre-service courses and teachers encouraged and supported to update their skills as the technology advances.

Curriculum

The development of creativity, collaboration and communication skills is integrated holistically with a curriculum structure which supports high levels of attainment in STEM, literacy, social and cultural education, the arts and modern ICT skills. Strong assessment for learning helps the student learn and helps the teacher guide and coach the students to achieve their potential. Seamus Hegarty, in a recent article, suggests that we need to revisit what 'well educated' means today and look to what schools are doing in the light of that:

> *"If schools do not know what lies down the road, maybe they should concentrate attention on developing each individual's capacity to the full and ensuring they live full lives as children and young people, and focus less on skill acquisition directed at an indeterminate future. Who after all is best placed to thrive in an uncertain world – people who are versed in the narrow set of skills currently prioritized, or fully rounded adults with a broad set of competencies?"*[xxxv]

There are steps to make the curriculum more cohesive and comprehensive, embedding the skills needed for students' future life as workers and citizens. Technology has an important role to play here. Moves for cross-curricular thematic teaching are in place in many schools with several classes coming together in large open plan, technology-rich learning spaces to be taught by four or five teachers with specialisms spanning curriculum areas. The technology enables students to work effectively in teams with input and support when needed from teachers and other adults.

As the demands of the workplace are changing, STEM education has become more prominent and so has the demand for the teaching of these subjects through cross-curricular themes as "*integrating all disciplines offers students the opportunity to make sense of the world in an authentic way*".[xxxvi] Industry involvement also helps support authenticity and has increased student engagement. Education needs to engage with business and industry to gain a better understanding of trends in the STEM skills needed now and in the future. International research also indicates that 75 per cent of the fastest growing occupations require STEM skills and knowledge[xxxvii], and employment in STEM occupations is projected to grow at almost twice the pace of other occupations.[xxxviii]

We discuss the computer science curriculum and the role of industry at a later stage, but what is clear is that the curriculum is evolving in line with the evolution of society but education authorities in many countries are not keeping pace with the rate of change.

Assessment

Globally there is a general move to think about reform of how student learning is assessed across all levels of education using a range of assessment modes. The concept of technology-supported assessment is a relatively new area of research and development, but it is becoming clear that it is already beginning to play a significant part in assessment reform. There is also global recognition that current assessment structures are not measuring some of the 21st century skills. For this reason, the 2012 international PISA study conducted by OECD included a technology based, interactive problem-solving assessment in recognition of the fact that problem-solving skills are particularly in demand in fast-growing, highly skilled managerial, professional and technical occupations[xxxix]. The justification for inclusion of this type of assessment made by the PISA team is clear:

> *"… the emphasis in education is shifting too, from equipping students with highly codified, routine skills to empowering them to confront and overcome complex, non-*

> *routine cognitive challenges. Indeed, the skills that are easiest to teach and test are also the skills that are easiest to digitise, automate and outsource. For students to be prepared for tomorrow's world, they need more than mastery of a repertoire of facts and procedures; students need to become lifelong learners who can handle unfamiliar situations where the effect of their interventions is not predictable. When asked to solve problems for which they have no ready-made strategy, they need to be able to think flexibly and creatively about how to overcome the barriers that stand in the way of a solution."*

Charles Handy also referred to this when he so articulately said that we should grade people on outputs not inputs, and that we should assess them on what they do with the knowledge, not how well remembered it is.[xl]

In most cases technology is used for accessing learning resources or submitting assigned homework, but technology has the potential to facilitate engagement in meaningful and authentic learning experiences, and there are methods of keeping track of student levels of achievement. There is considerable evidence of the use of computer-based testing tools for generating and administrating tests, as well as reporting results. There is the potential to generate tests of different difficulty levels as well as adapting the difficulty level of assigned test items depending on performance. Technology also allows flexibility in scheduling with learners being able to take tests anywhere at any time.

However, such testing constitutes only one of the available categories of assessment methods and its use for grading and ranking learners is only one of the many purposes of assessment. New formative assessment solutions are emerging from multiple providers that will help present students with curriculum aligned questions and formative assessments supporting learning objectives and outcomes. Adaptive capabilities are still maturing to provide students with personalised learning programmes, but assessment and guidance matched to students' capabilities and learning preferences are more advanced.

There are many other assessment tools currently in use and others in development for schools, two of which are described in the solutions below - *Learning by Questions* and *Bettermarks*. These tools make formative as well as summative assessment easier and enable schools to assess more than recall, and importantly, to include 21st century skills in the mix. This new form of assessment for learning is yet to become mainstream in national testing around the region and, as assessment drives curriculum reform, there is a need to make significant changes in investment strategies if we are to see real progress in our students' experiences of schooling.

Schools now have access to a range of technologies that can be used for formative as well as summative assessment which provide evidence of learning through non-textual means utilising multimedia tools like video, animation packages and graphics as well as simulations, digital games, virtual worlds and virtual and remote labs. Coupled with self-evaluation of learning through tools such as eportfolios, students are encouraged to make choices and to take more responsibility for their learning to emerge with the skills they need for life and the workplace.

Learning analytics tools are still in their infancy, but these tools are becoming more and more sophisticated and reliable; by using them to gather a wide range of information about students' learning, more personalised and effective learning experiences can be developed.

Resources

Resources are increasingly being digitised and schools are moving to digital books which can be easily annotated and updated and also have the added value of multimedia capability. The proliferation of educational apps covers every subject. These apps are usually dynamic, interactive and afford multimodal capabilities, making learning easier to access and supporting understanding/recall in formats that students can select to suit their learning preferences or levels of attainment. This makes learning more personalised. Students are no longer limited to books, TV and radio, but have access to a wealth of information presented in every media format from text to podcasts, from graphics to video, and from dynamic visualisations to virtual and augmented reality.

In the recent research report from NESTA in the UK, a meta-review of literature from around the world concluded that "*the increasing wealth of online resources offers great potential for both teachers and learners; but places great demands on both to evaluate and filter the information on offer.*" [xli] This report yet again stresses the role of teachers in helping students to interpret and validate the information they find and to convert it into knowledge, when students learn with and through technology.

Little use is made of online collaboration tools apart from software platforms such as Edmodo (described below) or LP+ from Learning Possibilities although many classes in schools do have Facebook pages. The NESTA report explored the evidence for using people as a resource through online communication and collaboration. They concluded that there were four positive dimensions to learning through social media:

- The collaborative dimension requires tools that help learners develop mutual understanding
- The networked dimension requires tools that help learners interact
- The participative dimension requires tools that help learners to develop a strong community of knowledge
- The performative dimension requires tools that allow the outcomes of collaborative learning to be shared with others.

Inquiry and problem based learning can also be strongly supported using digital software and spreadsheet technology for data collection and analysis. Together with other digital tools such as digital probes and digital microscopes to collect real-time data and images, as well as robotics and coding, students gain experience of real-world applications of technology. Practice is also a valuable component of learning and there are many apps that support practice across the curriculum that take the drudgery out of basic skills learning to make it more exciting and engaging and prepare students for learning higher order skills. Resources are constantly improving with new developments that include the use of rich multimodal environments to create challenging problems at a higher level and provide appropriate feedback.

Families

Young people develop their experience and knowledge of digital and mobile technologies primarily in out-of-school settings, and the way they use these devices is clearly different from how they use technologies in school.[xlii]

Other early research describes evidence of a disconnect between how young people use technology in formal and informal learning activities:

> *In school, technologies are used in a structured, supervised, directed and mostly individual way to perform curricular work in public spaces. In contrast, at home and in other informal settings, technologies are used by young people in messy, non-supervised ways, socially and collaboratively, to pursue personal interests in private spaces. In informal settings, young people have developed habits and expectations of how technologies should be used, and because schools do not endorse the ways these technologies are used, it has created what some commentators called 'digital dissonance'.*[xliii]

In the more recent OECD 2015 study, data collected from students participating in the PISA assessment show that by 2012 computers were present in almost every household across most OECD countries, and often in large numbers. On average across OECD countries, only 4 per cent of 15-year-old students lived in homes with no computers, while 43 per cent lived in homes with three or more computers. However, this country average masks large disparities particularly between the developed world and other less developed economies. Internet access varied significantly between these countries too affecting the nature of computer based activity. As in the earlier research described in the paper by Lai *et al* [xliv], a little more than three years later, the level of usage in schools had not significantly increased and students were still making more use of technology outside school.

Young people, particularly in the developed world, often have their own personal devices and are using the internet away from family desktops and potentially without parental supervision or security controls enabled. This means it is harder for adults to monitor usage and it is therefore, more likely that their children will be subjected to online bullying, inappropriate content and access to people who may have malicious intent. This may be changing though. In an annual survey commissioned by Internet Matters in 2016[xlv], it was found that parents are becoming more knowledgeable about what they can do to protect their children, including implementing antivirus software and parental controls to prevent children from accessing content that is deemed unsuitable for their age groups. Despite this trend, a report by the UK Safer Internet Centre found that 70 per cent of 1500 young people aged between 8 and 17 had seen inappropriate images and videos online, and a fifth had received an image or video that aimed to bully them.

Safety and security concerns are now taken more into account in schools with online safety courses being taught. Moves to involve families more in the e-safety of their children are key as is the need for businesses to monitor their services to minimise the risk when young people are online. This includes enforcing age limits to access certain services, ensuring services have the tools in place to report inappropriate content and having clear communication channels with authorities should there be a need to report activities that could put safety at risk.[xlvi]

Digital Technologies

Moore's Law[xlvii] has driven an unprecedented rate of increase in the processing power and capabilities of technology over the past quarter of a century. This rapid development has occurred at an even faster pace in the development of our telecommunications and Internet infrastructure. Cloud capacity and service costs are now so close to zero for the service providers that amazing capabilities are being provided free or at very low cost to end-users. Andy Grove's 1994 projection that Internet capacity would be as cheap and accessible as water is rapidly coming true - even in developing economies.[xlviii]

Practices, constraints and considerations that were important less than ten years ago, when many of the impact studies referred to in this paper were carried out, no longer apply. The continuing reduction in price, increase in mobility and ubiquity of Internet connection (even in emerging markets) provides a set of capabilities and opportunities that did not exist even recently. There is no sign of the pace of innovation in devices, Internet capacity and Cloud solutions and services slowing down. Educators and learners now have amazing capabilities from which to take advantage. It is imperative for the continued progress of our societies and economies that we embrace these capabilities, learn how to use them in a secure and responsible way, and advance our education practice to prepare our young people for the second half of the 21st Century.

This next section outlines the access and infrastructure now available in our schools and homes, the continuing rapid advance in device technology at continuously reducing price-points, the usage models and methodologies now available and the need to embrace and drive these to maturity, and the powerful cloud services now widely available providing schools with secure and highly sustainable solutions. The OECD 2015 report also describes this challenge:

> *"…..Users of ICT – as we all are today – often must adjust to a new device or software or to new functions of their existing devices and applications. As a result, ICT users must learn, and unlearn, at a rapid pace. Only those who can direct this process of learning themselves, solving unfamiliar problems as they arise, fully reap the benefits of a technology-rich world."*

Access and Infrastructure

The speed of Internet connections is growing rapidly at almost twice as fast as the rapid growth of computer processing speed we have experienced over the past two decades, famously described as Moore's law. Internet speed at a given price point is doubling approximately every nine months, demonstrated by massive increases in bandwidth available to homes and businesses. Speeds of 100Mbps are common for many high speed domestic services. A similar service level and experience will be the minimum expectation for students and schools.

Wireless Broadband – 4G and 5G technologies

The speed of wireless broadband is also accelerating rapidly with 4G connection bandwidth of 10-20 Mbps common and 5G targets of 40-50 Mbps, allowing many emerging market users to 'leapfrog' to these high wireless speeds, and avoiding the need for fixed fibre line infrastructure.[xlix] This can have a positive impact in those countries where broadband provision is a challenge and proved to prohibit effective deployment of technology in schools.

Continued Rapid Advances in Device Technology

Challenges with low-cost and low-functionality devices have led to the downfall of many large-scale initiatives. Increasing performance of devices and the availability of more affordable devices are changing and with continuously improving opportunities for sustainability, giving access to technology for all.

Mike Trucano from the World Bank cites these factors as some of the most acute and important related challenges to digitising schools [l]:

- Affordability
- Connectivity
- Usability
- Accessibility
- Electricity

Serviceability and support can be added to this list, and a clear understanding of the lifetime total cost of ownership of the technology applied.

The move to mobile computing has meant technology can be widely available and the era when expensive machines are kept in locked computer labs ought to now be completely behind us. The increase in access and availability of devices in multiple form-factors to learners and educators all around the globe, with device performance and price points is continuing to improve every year. Many of the world's students, particularly in more developed economies, live in a multiple device world at school and home. They alternate between using high performance notebooks, tablets, 2-in-1 devices and smartphones, and this rich mix of devices is now accepted and made available in many of the leading digital schools visited during this research. Cloud services provide support for documents, file-sharing, imaging and many sophisticated software and support services including school MIS, LMS and formative assessment solutions.

Device technologies like the examples outlined above, together with the rapid increase in Internet infrastructure and access, provide levels of performance, affordability, portability, usability and reliability, supporting highly sustainable modern, connected, mobile learning. The opportunity and challenge for educators is to develop the practices and usage-models and the experience, ability and capacity in our education systems to take advantage of the technologies available.

Infrastructure and Environment Maturity

It takes time to establish a high level of fluency in the use of technology supporting teaching and learning. Teacher proficiency development begins with teacher laptops, training and peer network support.

Below is a simple maturity matrix to help set priorities and plan progression based on experience in many school systems and the case studies included here.

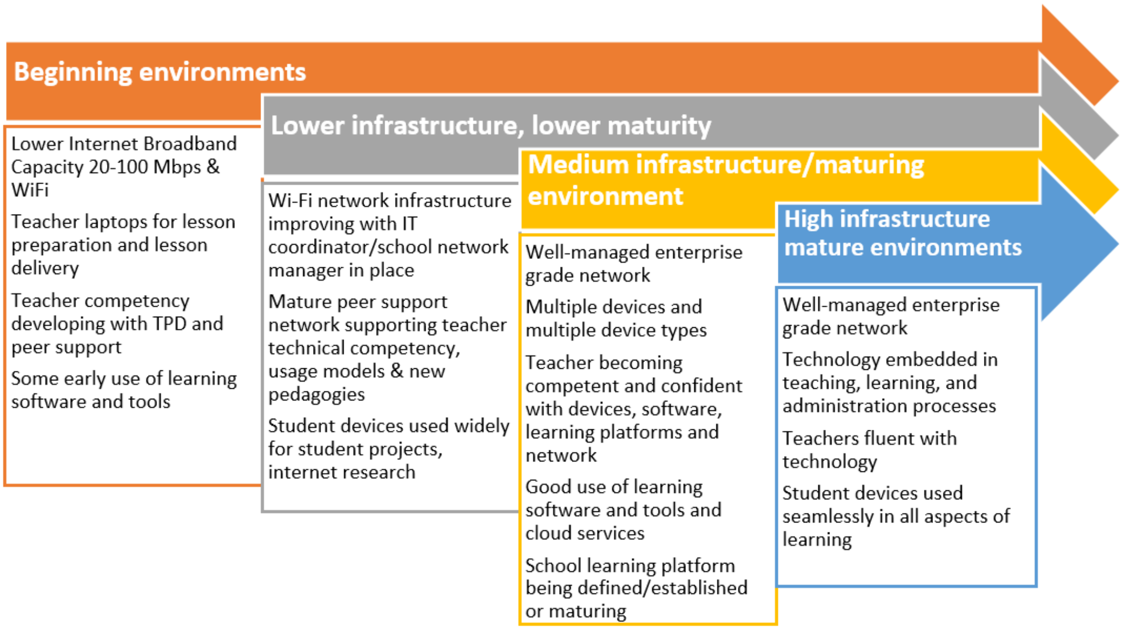


Figure 10 Infrastructure and Environment Maturity Model [Source: EdTtech Ventures]

A high-quality network connection and well-managed in-school network is a foundation for all successful initiatives to build upon, ideally with a full-time network manager. This is essential to developing teacher confidence to fully embed technology in the teaching and learning process.

In some developing countries the quality of Internet network available can be a constraint, and sometimes modern wireless 3G or ideally 4 or 5G technologies are a strong alternative. Funding is a key factor in all education systems; hence the need for a well-planned progression, through various maturity stages supported by strong leadership commitment from the top, to lead to the best results. The table below shows this maturity progression model in more detail and with more of the attributes that lead to this maturity outlined.

Infrastructure and Environment Maturity	Attributes
1. High infrastructure mature environments	• Well-managed enterprise grade network • Internet bandwidth up to 2gbps or more • Multiple devices in classroom, with multiple device-types supported • BYOD and/or school provided technology including mobile phone usage policy • Technology embedded in teaching, learning, and administration processes • Teachers fluent with technology • Student devices used seamlessly in all aspects of learning • Good use of learning software and tools, cloud services, including school learning platform, digital curriculum and assessment technologies • Privacy and data protection policies well embedded and understood
2. Medium infrastructure/maturing environment	• Well-managed enterprise grade network • Internet bandwidth up to 2Gbps • Multiple devices and multiple device types • Teacher technology skills growing, becoming competent and confident with devices, software, learning platforms and network • Good use of learning software and tools and cloud services • Student devices used for project based learning • School learning platform being defined/established or maturing • Beginning to use digital curriculum and assessment • Privacy and data protection policies well embedded and understood
3. Lower infrastructure, lower maturity	• Wi-Fi network infrastructure improving with IT coordinator/school network manager in place • Increasing Internet Broadband 100-200 Mbps • Teacher laptops for lesson preparation and lesson delivery • Mature peer support network supporting teacher technical competency, usage models & new pedagogies • Student devices at 5:1 and improving • Multiple mobile computer-on-wheels supporting classrooms • Student devices used widely for student projects, internet research • Increasing use of learning software and tools • Privacy and data protection policy in place • Initial Wi-Fi local area network capacity

4. Beginning environments	• Lower Internet Broadband Capacity 20-100 Mbps. Wireless 3, 4 or 5G technology may be used • Teacher laptops for lesson preparation and lesson delivery • Teacher competency developing with TPD and peer support • Student devices at 5:1 or 10:1 ratio • Mobile computer-on-wheels supporting classroom and reference usage • Student devices used primarily for student projects, internet research and skill building exercises such as games • Technology at home used to supplement PBL and research activities • Some early use of learning software and tools • Privacy and data protection policy defined

Table 1 Attributes for a range of markets at different stages of maturity

Methodology – Learning and teaching usage models enhanced by technology

As discussed earlier, many deployments have not fully understood or considered the rich and varied multi-modal teaching and learning processes regularly employed in innovative classrooms. Software solutions, 'interactive content' and learning platforms have often been over-sold as panacea solutions by the technology industry based on a simplistic or mechanistic view of the education process. Successful implementations commonly have taken a usage model first approach backed by good professional development in new pedagogies, approaches and supporting digital tools, and by strong peer support networks.

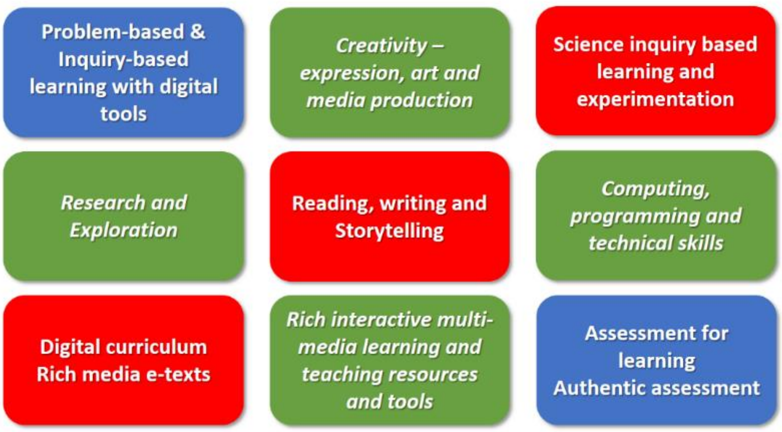


Figure 11 Learning and teaching is a rich multimodal process

In the imperative for reform presented earlier, it is necessary to prepare our students for the needs of the mid and late 21st Century. We need education to take advantage of the multiple opportunities technology presents. Learning and teaching needs to be a rich, engaging and relevant multimodal process with a focus on the development of transversal skills, collaborative learning and cross-curricular and thematic learning experiences to create an even richer environment and set of processes, many of which are outlined in Figure 11 above.

Project and activity-based learning has become an important and widely employed approach. Leading school systems in Northern and Western Europe have increasingly introduced student projects into the learning and teaching process - doing this almost exclusively with the support of technology for more than a decade[li]. In these experiences, technology is used for multiple tasks including research and references, data collection and analysis, media development, and presentation and report writing. These activities are now intertwined with the use of technology both individually and in collaborative learning modes. A rich thematic, cross curricular and collaborative project-based learning approach remains a goal for most education systems, and results from leading schools are demonstrating the value of this approach in the development of creative 21st Century learners and explorers.

Analysis tools and specialised software and modelling tools are frequently used in scientific education. Media tools are commonly used to bring several new dimensions to storytelling, adding creative imagery, video and audio recording, and even animation software such as the Plotagon Education solution. Mathematics education is particularly called out in this context by the OECD 2015 report:

> *"There is also a specific association between mathematics teachers' use of student-oriented practices, such as individualised instruction, group work and project-based learning, and their willingness and ability to integrate ICT into mathematics lessons."*

Teaching and learning with the Cloud

The Cloud is already providing many powerful tools and resources to schools worldwide. The Google Suite and Microsoft Office365 productivity tools, as well as some valuable open source solutions and tools, are widely used by teachers and students at all levels of education.

Learning platforms, school MIS solutions and LMS are now provided in the Cloud in a more manageable, affordable and sustainable way, removing the need for schools and education authorities to manage expensive local solutions. These solutions have good internet connections, high levels of reliability and uptime support technology integration. Security, privacy and data protection issues are managed by professional companies, although clear privacy and security planning and procedures are still essential.

Digital Curriculum solutions such as Vitalsource Bookshelf (www.vitalsource.com) are available on the Cloud anytime, anywhere, providing access to rich interactive digital curriculum and e-texts on all PC, tablet and smartphone devices. We need to challenge our publishers to move past conservative and very expensive print curriculum models and invest in innovative digital curriculum solutions.

Future proof

Full solution integration of LMS, MIS, digital curriculum and assessment is still at a relatively early stage, but all providers are working hard at this. A Cloud strategy future-proofs a school or education authority as the providers deliver more advanced and integrated solutions; these will seamlessly become part of their service offering.

Risk factors associated with digital technologies and approaches to address them

The case studies and large implementations show many risk factors which relate to the digital technology elements outlined in this section. Table 2 is a summary of some of these factors and approaches to address or mitigate the risk.

Solution Element	Key Risk Factors
Internet Infrastructure and Access	• Unreliable and inadequate broadband – inadequate broadband into school and unreliable school local area network (LAN)
Device Technology	• Rapid technology obsolescence of low spec devices or learning platforms • Total cost of ownership (TCO) not comprehended and budgeted • Support and Service inadequate • Poor device reliability and high DOA (dead on arrival) levels • Low power/low cost devices under-powered for expectations set • Poor logistics management in device distribution, management & support to schools
Methodology and Usage Models	• Technology first deployments with usage models not well considered or planned • Teachers not confident with technology, and not trained in usage models deployed
Learning Platforms & Cloud Services	• Privacy and security plan • Very low utilisation of learning platforms • Inadequate training or usage model development with learning platforms & cloud services

Table 2 Digital technology risk factors and how to mitigate them

Cloud Services

Cloud Services have become part of our everyday lives. Most of us have not begun to comprehend the full meaning of this as advanced Cloud capacity and service costs are now so close to zero for the service providers that amazing capabilities are being provided free of charge or at very low cost to end users.

There are social and political implications to this power. Our private lives are increasingly becoming public, so it is very important that privacy and data protection policies are well embedded and understood. The workplace and some social activities are being changed by this information revolution; some to a point we could not have imagined only a decade ago. It is imperative for educational, economic and social reasons that our schools adapt to and adopt these technologies to build an education system that prepares our population for the second half of the 21st Century. This technology has a much greater capacity for good as it reshapes the meaning, value and utility of information. Schools will be pivotal in making learners aware of these risks and ensuring their students are fully equipped to use the Internet safely and securely and to understand the potential dangers, while also taking advantage of these services to support and significantly enhance teaching and learning.

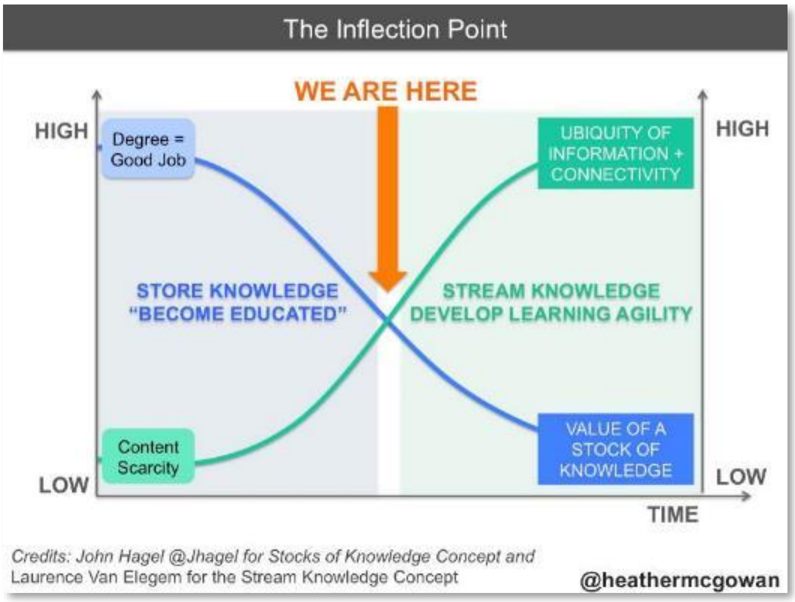
4. Digital technology – looking to the future

Much of the research on the impact of digital technology is now quite old with much done in the latter part of the 20th century and the early part of 21st century. The evidence is set in a time when the infrastructure was significantly less mature, devices were more expensive and much less powerful, and high power personal smartphones and tablets were not commonplace. Additionally, and as previously noted, the research tended to be overarching, focusing on the big picture and not considering details at the individual school level to examine the factors that lead to success or those that lead to little or no significant improvement. Other research examines either islands of good practice within individual schools, often led by an individual teacher, or large-scale implementations.

It is clear from the evidence that today's digital technology solutions *can* have a real impact on teaching and learning as well as on the management and administration of schools. However, for the technology investment to make a significant impact and to realise the full potential, these solutions must be accompanied by a thorough reconsideration of the nature and purpose of schooling and the need to reimagine and reengineer the K-12 system for the rapidly changing workplace and societal environment of the second half of the 21st century.

Significant research has demonstrated how inadequately prepared our workforces are today and the profound change that will continue throughout the 21st century such as the work of the European Commission[lii]. Other research from Heather McGowan and Daniel Araya[liii] outlines the need to move from 'storing up' fixed knowledge to developing the skills to 'stream' highly creative and flexible knowledge and ideas in this changing environment.

However, we are still evaluating and designing education systems and testing our students based on 19th Century paradigms. A more skills-based, collaborative and creative education process



supported by the digital technology that is the major toolset of the 21st Century knowledge economy, will better prepare students for life and work as we move towards the middle of the 21st Century. The technology, as noted earlier, can aid the improvement of authentic formative and summative assessment as well as learner self-assessment, and will ensure transparency in the teaching and learning process as demonstrated in Figure 12 below. We are at an inflection point where memorising, although important, is less vital with ubiquitous information and access to connectivity. Instead students need to apply critical thinking and creativity, understand how to find information and how to recognise the importance of questioning the reliability of the source and the validity of the information they find.

Figure 12 From stores of knowledge to streaming knowledge

4.1. 21st Century skills – essential skills for tomorrow's workplace and society

While relevant curriculum is important, 21st century skills are emerging as vital for the future of today's students. Many education systems are developing new curricula in digital literacy and computer science as essential 21st century literacies. Several international reports have determined that high levels of digital literacy are essential to prepare an individual to participate in the 21st century workforce and society. However, the European Commission has identified that 35 per cent of today's EU workforce do not have the ICT skills needed even for today's roles.[liv] Computer science has also been identified as another important science subject to be developed from late primary education onwards to help prepare the designers, developers and makers of the late 21st century[lv] and in the most recent Horizon report coding is suggested as a new literacy that could help alleviate the skills gap[lvi]. It is essential to distinguish between digital literacy, an essential skill and basic literacy for all to thrive in the 21st Century, and Computer Science and advanced IT skills which will be employed by the makers, shapers, developers, designers and engineers to continue to design and develop creative new products and services.

The World Economic Forum report mentioned earlier was one of two reports to explore the potential for educational technology to have a positive impact in schools. The first report explored the skills agenda and examined how and where technology could play a role in helping schools to develop those skills identified as vital as we approach the middle of the 21st century (see Figure 13). The list of skills is similar to other initiatives in this area including the U.S. based Partnership for 21st Century Skills.[lvii] The second report examined the role of technology in social and emotional learning (SEL)[ix].

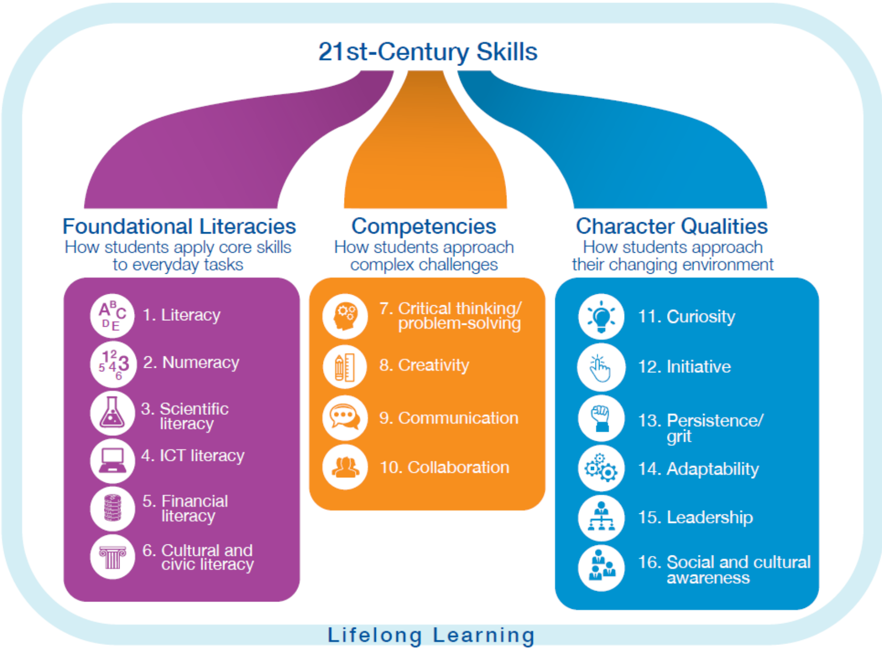


Figure 13 Students require 16 skills for the 21st century (Source: World Economic Forum, 2015)

In the OECD 2015 publication referred to earlier[lviii], technology has a significant role in developing these skills but cites the importance of preparing teachers for the associated pedagogies:

> *Technology can support new pedagogies that focus on learners as active participants with tools for inquiry-based pedagogies and collaborative workspaces. For example, technology can enhance experiential learning, foster project-based and inquiry-based pedagogies, facilitate hands-on activities and cooperative learning, deliver formative real-time assessment and support learning and teaching communities, with new tools such as remote and virtual labs, highly interactive non-linear courseware based on state-of-the-art instructional design, sophisticated software for experimentation and simulation, social media and serious games. (p4)*

The study found that on average across OECD countries, 72 per cent of students reported using desktop, laptop or tablet computers at school in 2012 (by comparison, 93 per cent of students reported that they use computers at home). The task most frequently performed on school computers was browsing the Internet for schoolwork, with 42 per cent of students, on average, doing so once a week or more often. The activity performed the least frequently was using simulations at school (11 per cent of students on average across OECD countries). The amount and nature of usage suggests that computers cannot make a difference if they are used so infrequently and, in general, they are not used to develop the skills described in the quote above. The use of technology to support the development of essential 21st century skills is therefore still limited.

However, Mørkhøj Skole in Denmark, one of the case study schools interviewed for this white paper, make extensive use of technology to develop students' 'essential skills'. They use another skills framework developed by Michael Fullan, known as the 6 Cs. These 21st century skills are:

- Character education: building resilience, empathy, confidence and wellbeing

- Citizenship: referencing global knowledge, cultural respect, environmental awareness
- Communication: getting students to apply their oral work, listening, writing and reading in varied contexts
- Critical-thinking: designing and managing projects which address specific problems and arrive at solutions using appropriate and diverse tool.
- Collaboration: working in teams so students can learn with/from others.
- Creativity and imagination: to develop qualities like enterprise, leadership, innovation

This school has a strong focus on the role of collaboration and communication which are vital skills highlighted in the second of the World Economic Forum's report on Social and Emotional Learning (SEL)[lix]. This report argues that social and emotional skills are critical to the workforce of the future. They also make the point that it is estimated that "*65 per cent of children entering grade school will ultimately work in jobs that don't exist today, putting creativity, initiative and adaptability at a premium"*. SEL was also found to support academic success. However, it was found that in addition to the already identified barriers to using technology in schools, teachers mainly regard technologies as tools for developing *"academic skills and improving class productivity, not for fostering social and emotional skills*".

Developing a computer science and modern ICT skills K12 curriculum

> *"Essential for the development of the professional engineers, technicians and developers who will be key contributors to our economies and drive the high value enterprises and start-ups for the second half of the of the 21st Century."*
>
> *Mary Cleary Joint CEO of Irish Computing Society*

As already outlined, modern digital literacy is now as essential as language literacy for all 21^{st} Century citizens and needs support across the K12 education system. In addition to this, a strong and growing pool of engineers, scientists and developers is required. Many studies describe the rapid changes occurring in the workplace and the growing skills gaps in this area, including the previous reference from the European Commission[lx]. Every nation needs to focus on building up this skill base in order to have a highly competitive 21^{st} century economy or risk slipping backwards against better prepared competitors.

Computer Science is now identified as an additional and important science to be developed from late primary education onwards to help prepare the designers, developers and 'makers' for the late 21^{st} Century.[lxi] This presents educators with challenges for curriculum, infrastructure, capability and skills development in our K12 education systems. The challenge is similar to the well documented need to improve both the learning and teaching and the take-up of the key STEM subjects. However, there is an even more significant gap in the capacity and capabilities needed to introduce a modern IT and computer science curriculum right through second-level schools and back into primary schools. This augments the challenges to improve the teaching and learning and take-up of the physical sciences, and the necessary improved skills in mathematics teaching needed right through the education system starting at primary level. The skill sets required include computer architecture, introduction to programming, maker, web and app development, all based on the development of logic and computational thinking skills (Figure 14).

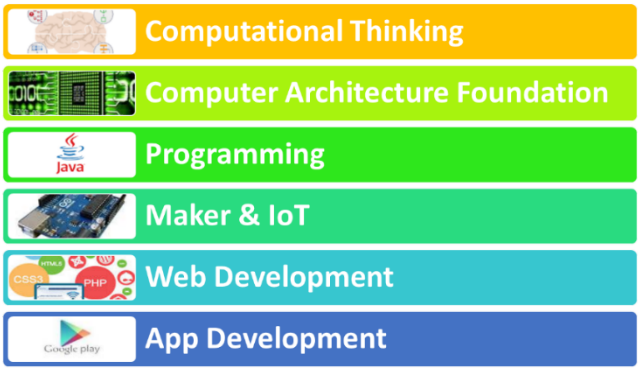


Figure 14 Computer Science and Advanced Modern ICT Skills

The Digital Promise Learning Studios programme sponsored by HP and Microsoft has attempted to address some of these challenges by increasing students' and teachers' access to advanced technologies for design centred and 'maker' learning. In a recently published report[lxii], it was shown that this access was associated with improvements in related skills as well as comfort with the technology. Many students reported increases in their sense of self as a designer or maker and in their confidence with design-centred and 'maker' learning activities, and there was significant improvement in some of the 21st century skills described earlier.

International benchmarks on assessment approaches are described in the research by Keane and McInerney[lxiii] and demonstrate how authentic assessment processes with a significant portion of portfolio assessment will be essential to encourage those students with the right aptitudes and skills for these subjects.

While the need for this curriculum development is clear there are many challenges facing our education systems:

- Design and implementation of appropriate curriculum that develops computational thinking and the development skills and mind-set in a timeless and future-proof manner
- Development of teaching capacity right through the system, together with appropriate teacher training and certification in the subject area
- Competition with business and industry for people with the skills to teach the subject
- Infrastructure and capacity in the school system to support the subject
- Secure digital assessment to support the assessment of student portfolio and artefacts

Planning for this new curriculum is an essential and challenging part of curriculum planning and preparation in order to be prepared for the needs of the 21st century.

Eight learning and teaching solutions with proven impact

The following are a selection of excellent examples of learning software solutions which create a new and dynamic approach to the teaching and learning modes outlined in Figure 11 above. These are mature solutions with proven classroom usage around the world. In most cases these solutions are backed up by independent academic research demonstrating a positive impact on learning. These solutions, together with the Cloud services providing full productivity suites as in Microsoft Office365 for Education and Google Suite for Education, offer a rich toolkit to support all the teaching and learning modes outlined in the figure.

GeoGebra: Dynamic mathematics for teaching and learning

GeoGebra is dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package. GeoGebra is widely used in classrooms worldwide with strong usage in Denmark, Netherlands, Germany, Finland and Ireland and rapidly expanding online community of millions of users. The GeoGebra open source software is freely available for non-commercial users and has become the leading provider of dynamic mathematics software, supporting STEM education and innovations in teaching and learning worldwide.

Impact studies in Malaysia investigating the effectiveness of using GeoGebra software show that students have a positive perception towards learning and have a better learning achievement using GeoGebra. In another study, students' mathematics achievement was measured at the end of the intervention. Independent sample T-test results showed that there was a significant difference in mean mathematical achievement between the GeoGebra group and the traditional teaching strategy group.

Other studies describe implementations of the software by teachers, and how its use improves teaching and students' learning. A large-scale study in Hungary, offering GeoGeobra lesson materials for K-12 schools and connected professional development for 2500 teachers in 950 schools, showed various uses of GeoGebra in classrooms with overwhelmingly positive responses on benefits to teaching practice and students' learning. GeoGebra is a recommended software for STEM teaching in the UK and included in the 2010 ICT report of the UK National Centre for Excellence in Teaching of Mathematics.

Edmodo: Communication, collaboration and coaching platform

Edmodo is an educational technology solution offering a communication, collaboration, and coaching platform to K-12 schools, colleges and teachers with over 70 million users worldwide. The Edmodo network enables teachers to share content, distribute quizzes, assignments, and manage communication with students, colleagues, and parents. Edmodo is very teacher-centric in design and philosophy: students and parents join Edmodo when invited to do so by a teacher. Teachers and students spend large amounts of time on the platform, both in and out of the classroom.

Al-Said's study (2015)[lxiv] examined how students engage in the use of Edmodo in the classroom. Focusing on university-level students, he found that Edmodo helped to support increased communication between teachers and students to support learning activities and increased time students spent engaging with material in a meaningful way. The study shows that incorporating Edmodo features into the learning environment encourages both student engagement and responsible learning.

Ingram VitalSource: Suite of solutions providing a complete course experience.

The VitalSource Bookshelf solution is the most widely used e-text platform solution providing a strong user experience to 6 million users worldwide and used by most of the major education publishers. VitalSource Bookshelf powers campus bookstore and learning solutions from Barnes and Noble, Follet, Macmillan and others. In addition, collections of teacher resources, OER and supplementary resources are supported by VitalSource Bridge, with new courseware solutions in development for a richer and more engaging course experience. All solutions integrate fully with LMS, data collection, grade book and assessment solutions to support a complete learning journey.

Learning by Questions (LbQ): Assessment for Learning Cloud Solution

The aim of LbQ is to transform teaching and learning using a pedagogical method with question sets that give automatic specific feedback to students and analysis for teachers during lessons. This enables teachers to instantly see individual understanding and provide additional support and make effective interventions. The LbQ pedagogy flips assessments, tests and marking from a mechanical process of measuring into a self-paced learning activity with feedback that addresses misconceptions and improves learning during lessons. Curriculum aligned question sets enable students to progress immediately or to try again if they answer incorrectly.

LbQ is a cloud-based platform providing instant login on student devices. It makes it practical and affordable to support students of mixed ability so that every student can work at their own pace on the same learning objective under the guidance of their teacher. The efficiency of the platform enables teachers and students to cover more questions than they would otherwise. Detailed guidance is provided on the teacher’s device so they can judge the effectiveness of their teaching and identify which problems and misconceptions are occurring, thus providing a valuable additional layer of feedback that teachers give through their interventions during lessons.

In the UK, the Institute for Effective Education (IEE) and the Education Endowment Foundation (EEF) have provided research-based input to the design of LbQ. Initial impact studies by IEE has shown that by using LbQ for just 10 minutes a day, learning could be boosted by more than 25 per cent over an academic year.

Bettermarks: Adaptive learning for mathematics

The Bettermarks solution has over 100 interactive mathematics books containing 100,000 questions with materials conforming to CBSE, ICSE, State Boards & International Baccalaureate standards.

Every type of learner can find an exercise to fit, starting with guided exercises, and then work step by step through series and topics that get progressively more difficult, with help available during and after every question. Bettermarks automatically recommends exercises to close the knowledge gaps it identifies, giving every student the opportunity to learn at their own pace. Automatic marking and result evaluation provide immediate feedback.

Intellisense Education: LabCamera and Fizika

Intellisense is an award-winning technology company providing educational, image processing and data acquisition solutions for schools who design and develop STEM software solutions. The LabCamera and Fizika software solutions were both awarded the *Academic's Choice Smart Media*

Award in the UK in 2015. LabCamera is a webcam based natural science exploration and data logging laboratory for STEM education. The software uses the PC's built-in camera to carry out scientific observations, experiments and measurements with multiple creative applications and lesson plans. Fizika is a physics simulator that combines classic theoretical teaching with hands on virtual physics simulations. The software enables students to experience physics in an enjoyable and engaging way with an entertaining and educational physics simulator.

A research study in Hungary investigated the effectiveness of using the simulation program Fizika with 163 students from five different schools. The objective was to test the hypothesis that this new computer-based method, and particularly the quantitative graphical analysations and problem-solving tasks connected to several simulations, might help students deepen their understanding in different aspects of the syllabus such as graph-analysis, graph-plotting and using graphs in problem solving. The hypothesis was correct: in four of the five schools the end of topic test results were measurably and statistically significantly higher for the Fizika group than the control group.

Plotagon Education: Creative digital animation

Plotagon Education is a digital animation tool where students can turn ordinary writing into creative, collaborate multimedia expression. Students and teachers create characters and avatars using a simple interface, pick scenes from dozens of different locations, write character dialogue, record voices, and watch movies come to life in 3D animation.

Teachers around the world are using Plotagon in their classrooms for topics like Language, Arts, English Language Learning, Foreign Languages, Social Studies and helping children with special needs understand and improve social skills. Teachers can access and share Plotagon lesson plans and videos. The highly innovative approach of Plotagon has won widely recognised international awards including the 2016 Software & Information Industry Association (SIIA) Most Innovative award and The Red Dot design award – Best of the best 2016

MOOC and Distance Learning Usage Models

Pressure on governments to provide adequate education opportunities for their citizens is greater than ever. Pressure will also come from another source: new knowledge is being created daily across all domains, and there is no longer an obvious cut-off point for education. Now and for the future, we need to become lifelong learners updating our knowledge and skills throughout our entire working lives. The additional buildings, equipment, teachers and trainers required to scale up the current model, are beyond the scope and resources of most governments. Thousands of MOOCs, together with distance learning and remote instruction models are helping governments and education agencies meet this challenge around the world. These solutions are providing greater access and flexibility to under-served learners around the world, providing a highly scalable cost-effective way for governments and education organizations to reach millions of people. In particular, this approach can uniquely bring specialised skills widely through a country to regions lacking in teachers and capacity for important subjects including STEM subjects such as mathematics, physics, chemistry, computer science and programming.

As well as being able to replicate aspects of the formal education model in terms of simple transfer of knowledge, MOOCs take into account the attributes of communications technology, encouraging learners to gather facts themselves and to creatively leverage them towards a learning objective. It is a model based on a spirit of inquiry which places an emphasis on the learning process rather than evaluation and accreditation – although many MOOC platforms now offer some level of assessment and certification for a fee to all learners. Guidance on preparing all of these elements using low-cost methodologies may be found at: http://course.oeru.org/moocs4all/

K-12 solutions include the Khan Academy[lxv] which is a form of MOOC, and many countries offer virtual schools for distance learning opportunities with tutor support for students unable to go to school such as those in hospital.

5. Recommendations/proof points

Based on the research in the white paper, we present a number of recommendations that will help to make for successful implementations of digital technology, either at scale or for individual or small groups of schools.

5.1 Country and region wide initiatives

As discussed earlier in the paper, there are many things that can go wrong with highly visible and politically charged large scale deployments. Learning from one's own mistakes is expensive and damaging at many levels, so prior learning from others and adapting to context are crucial to ensure that any investment in digital technology is going to have a beneficial and long-term impact on learning outcomes and students' preparation for their future. The recommendations here are based on exemplars of good practice as well as learnings derived from those mistakes others have made. They are divided into four areas (Figure 15).

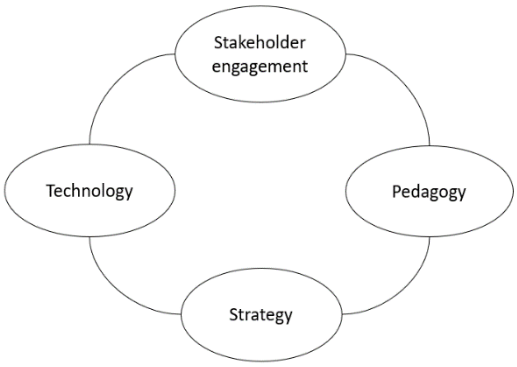


Figure 15 Large scale implementation recommendation categories

Stakeholders

- Strong stakeholder engagement at all levels from early in the planning
- Full justification to stakeholders of the investment and how other priorities are to be dealt with before, in parallel or afterwards
- Development of public private partnerships and donor engagement where relevant
- Strong and visionary leadership.

Pedagogy

- Strong focus on learning and teaching usage models and practice

- Regional Centres of Excellence to embed, share and spread good practice
- A usage model focused approach with investment in developing multimodal teaching and learning processes and tools, and the teaching and technical capacity to support them
- Professional development programmes in schools for principals and teachers as well as professional development for regional and national administrators.

Technology

- Considered evaluation of devices including fitness for purpose, robustness and repair
- Device allocation strategy to teacher and students
- Software, service and content strategy and plan based on education priorities and usage models
- Network, infrastructure, Cloud services and logistics planning including consideration of shared services with cost comparisons for alternative solutions
- High level of technical support for schools.

Strategy

- Considered order of implementation
- Phased implementation with deep experiential learning at each step to develop scalable models
- Phased technology investment to minimise obsolescence risk
- TCO accounted for and affordability of deployment is considered
- Phased monitoring and evaluation and course-correction
- Ideas of models for large scale deployment implemented in a systematic way with strong national, regional and local project management.

Michael Fullan *et a*l have developed an excellent framework for large scale implementations which examines collaboration between all those involved from school level up to the implementing jurisdictions (Figure 16) and fits the notion of regional centres of excellence above.

Figure 16 Implementation Framework

Fullan's paper suggests that it is important to:

- Design a set of common measures and tools to be used across school clusters
- Identify and share the best cases of new pedagogies and deep learning work
- Teachers to analyse, share and reflect on the best exemplars for both student work and learning activities as a key part of collective capacity-building efforts.

- Support capacity-building by ongoing measures of learning conditions and assessment outcomes, shared with schools and teachers through frequent feedback reporting to allow schools to focus on developing the learning conditions that produce stronger learning activities and student work.

> *"At the system level, this cycle of examining student work and learning activities in relation to learning conditions in schools will enable leaders to develop or expand specific policies and programmes that most effectively mobilize new pedagogies and deep learning, and to share those with other school clusters, enabling diffusion across systems. This ongoing collective capacity-building will accelerate partners' ability to learn from the work and rapidly respond. The cycle will be iterative, with refinements and development as the partnership learns and does." ibid (p22)*

5.2 School level initiatives

Based on the case studies presented here and on research evidence, it is clear that strong leadership with a focus on developing robust 21st century pedagogical practices, should lead any digital transformation strategy whether it be within a school or across a group of schools in a municipality. The comments made above about large scale implementations are also valid. With these in mind the recommendations are divided into these sections in Figure 17.

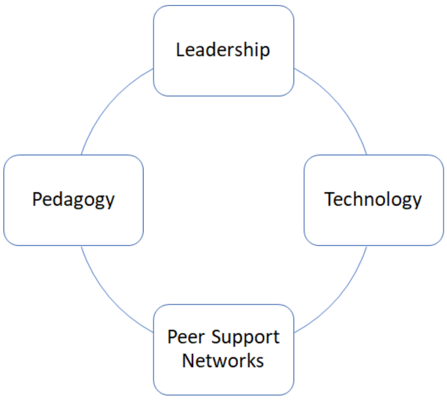


Figure 17 School implementation framework

Leadership

- Provide leadership training, direction and support
- Understand the needs and aspirations of the community in which the school is located
- Develop a vison and envision it
- Be prepared to constantly revise and reinvent to maintain a relevant learning environment while being mindful of and sensitive to the challenges that might create for teachers
- Share that vision with teachers and involve them in developing the strategy
- Develop the curriculum to provide students with the skills and a broad vision and understanding of the world in which they live and will work
- Seek advice on developing a clear rationale for the use and distribution of technology resources

- Consider the nature, order and timing of implementation for a smooth transition and ensure teachers are prepared, the infrastructure and support are in place, and devices are ready for allocation
- Give teachers space to be creative and innovate
- Provide professional development in the form of teacher exposure to exemplars, demonstrations and samples of deep learning, new pedagogies, new assessments and new technologies
- Engage both technical and pedagogical support for teachers to integrate technology that is school based and classroom focused
- Keep families informed and involved
- Build partnerships with industry, academic researchers and with other schools.

Pedagogy

- Build the development of students 21st century skills into curricular activities
- Integrate technology into classroom activities involving the use of online collaboration within school and between schools regionally, nationally and internationally
- Focus on usage models and develop the experience, capacity and support to make them work on the ground and foster a spirit of continuous improvement to find and refine the models which make a big difference
- Develop virtual field trips to provide greater exposure and relevance to the outside world
- Recognise each student as an individual
- Encourage student creativity
- Develop an authentic learning environment that engages and motivates students
- Develop inquiry and project based learning activities
- Design strategies for students to take responsibility for their learning and for setting and evaluating their own goals
- Develop assessment for learning strategies that utilise the technology
- Redesign learning spaces for independent and group learning that are technology friendly and not always teacher centric
- Collaborate with other teachers to share planning and develop pedagogical ideas and practices
- Develop a variety of teaching models from exposition to individual, pairs and group learning and including blended and flipped learning
- Allow students to demonstrate and be assessed on their understanding through a range of media
- Teach safe searching and critical awareness of the Internet.

Technology

- Invest in sufficient and reliable network bandwidth into and within the school to cater for all the demands of the school
- Ensure there are sufficient Wi-Fi access points and coverage for all students to be online when required
- Develop a clear device policy including the use of smartphones with a clear rationale for the selection and ratio of devices per student

- Draw up an acceptable use policy that is strictly adhered to and ensures students are aware of the potential problems surrounding social media and internet searches
- Ensure there is good technical support, service and back up plans
- Invest in a secure Cloud solution and utilise the leading Cloud tools for services and applications
- Seek out local support and funding for digital transformation or for special technology focused initiatives.

Peer networks

- Identify and develop programmes and models relevant to the specific needs of individual schools or clusters. This might involve participation in a cross-cluster experimentation 'hubs' focused on aspects of pedagogy, learning conditions, technology or policy.
- Develop collaborative capacity-building processes within and across clusters to support the adoption of new models, including support structures such as teacher networks, collaboration summits, professional and leadership development, tools and continuous evaluation.
- Consider the establishment of centres of excellence to help support, train and encourage local schools, and develop, advance and continuously improve the usage models.

6. Conclusion

There is an imperative for immediate action in our education systems to address skills, workforce and societal needs for the second half of the 21st Century; digital technology is integral to that process**.** A defined organisational change strategy is needed, whether it be for large scale implementations or at the individual school level, backed up by strong governance processes where a framework, the roadmap and priorities are outlined. Baseline studies and clear and meaningful evaluation criteria are also crucial if the improvements in learning outcomes and student preparedness for their future are to be measured.

Well-defined teaching and learning usage models supported by sustainable and replicable operating and business models can help pilot initiatives to be successfully scaled. Replicability, sustainability and scalability have proven to be significant challenges for most development projects in education. Countries around the world have piloted many projects and used the findings to inform policy. However, many have found that in implementing an effective country-wide deployment of technology infrastructure, content and teacher training the use of digital technology is improving but it is not yet becoming embedded in the curriculum universally despite the level of funding e.g. Becta, 2006[lxvi].

Support and leadership is required from ministerial agencies with national and local businesses and sponsorship all working together to identify innovative ways of acquiring and deploying digital tools and resources in schools, and to find ways of sharing and spreading exemplary practice effectively. Local support for schools and teachers is critically important with a strategy to develop strong peer support networks and regional centres of excellence ideal.

This white paper has demonstrated the positive impact of technology in schools when other key factors required for success are in place and developed alongside the deployment. These factors include strong leadership, curriculum and assessment realignment and *'reimagining'* for 21st century learning, adequate resources and the pedagogical shifts to support the *'essential skills'*, creativity and critical thinking necessary for our societal and economic development in the rapidly changing world anticipated in the late 21st Century.

We need teaching and learning processes that will prepare the creative 'makers and shapers' of our economies and societies for the second half of the 21st Century and support prosperous, stable and equal societies throughout the world.

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EdTech Ventures (www.edtech-ventures.com) is a network providing leadership consultancy for K20 and corporate sector digital education worldwide in strategy development, solution design and innovation, program management and curriculum design. Team members have extensive experience designing and supporting education programs in Europe, North America, the Middle East, Africa, Latin America, India and South-East Asia.

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