

Leveraging Technology in Education

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1. Executive Summary

In the past few decades, technology has enriched our lives and has been the driving force behind productivity improvements and communications efficiency unforeseen in the human lifespan. The advent of the internet, and the subsequent proliferation of connected devices, is democratizing learning and levelling the playing field for all. Recently, a vision to transform, revamp and retool the educational system by leveraging technology has emerged and several classrooms around the country are ushering in this new and necessary phase in education. While the potential benefits of effective Educational Technology (EdTech) employment are invaluable, the challenges of navigating this uncharted territory and the high monetary cost of failure at the expense of student learning warrant a close examination of effective EdTech implementation.

While different sectors of the economy have adopted technology at varying speeds, the education sector in particular has remained cautious, largely relying on traditional teacher-student interaction in the classroom setting. Public carping at the introduction of technology in education is not a new occurrence. *“Students today depend on paper too much. They don’t know how to write on a slate...what will they do when they run out of paper?”* exclaimed a school principal in 1815, expressing concerns on the incorporation of books into the curriculum¹. While we have come a long way in EdTech since then, this newest phase of leveraging technology in education also has its critics. However, it is clear from the various

district wide initiatives and classroom EdTech solutions implemented across the country, that as technology becomes ubiquitous in society, it is also becoming increasingly pervasive in education’s present and future.

In our research we found that schools in almost every state in the US are piloting “tablet programs”. With the rapid expansion of existing programs and adoption by other school districts across the country, investment in EdTech is showing no signs of slowing down. However, some of these programs have famously faced challenges. In addition, the limited deployment history prevents statistically relevant research results on student performance. Other challenges include the fact that only a small sub-set of the 55 million K-12 students in the United States² have a school sanctioned device. This is a huge impediment given many of these students do not have the means to afford devices or connectivity at home. Another factor hindering success of the pilot programs is the limited support to teachers. This sub-optimizes the deployment by leaving it to the teachers to explore solutions on their own, and experiment with them in the classroom.

At the classroom level, we found teachers are self-learning and employing a diverse range of EdTech solutions to fit their needs at varying levels of sophistication. We have learned through a number of recent PwC hosted events that teachers are already making use of web-based applications. At one specific event, a

¹ Toppo, Greg. “A different way to think about technology in education: Greg Toppo at TEDxAshburn”. TEDx. November 2012. Lecture.

² “K-12 Facts.” *Center For Education Reform*, 2011. Web. 02 Feb 2014. <<http://www.edreform.com/2012/04/k-12-facts/>>

panel awarded one of 10 education technology start-ups deployment funding. Several teachers were asked which technologies were already deployed in their classrooms and each teacher easily named multiple solutions. The ease of technology deployment is driven by low entry level costs, the emergence of a multitude of cloud-based solutions and the availability of connected mobile devices.

PwC initiated this paper with the goal of helping the public, specifically school districts, benefit from learnings of other technology projects across the nation. We set out with the goal of finding answers to the following two questions:

1. What and how can we learn from schools that have experimented with technology in education and disseminate lessons learned to other schools?
2. How do we translate these learnings into practical guidance for schools with technology projects?

In this paper, we begin with a background on the current technology landscape of K-12 education, a discussion on the benefits of EdTech and an assessment of the current state of technology deployment in classrooms. We then introduce the three pillars that define the purpose of an initiative, followed by proposing investment and design considerations for future EdTech implementation. We conclude with a discussion on the challenges of EdTech implementation and recommendations on mitigating

strategies, including a phase wise migration of current state to new generation technologies.

Our research indicated that the evolution to the future state is expected to occur when technology is integrated in the social fabric of the educational process and all stakeholders—teachers, administration and parents—are invested in the enhancement of the current educational system by leveraging technology in the classroom. To that end, a re-consideration of current technology investments to “smarter solutions” should be undertaken and meager resources freed up to be appropriately deployed.

2. Current Landscape of K-12 Education

The K-12 education landscape in the United States is evolving and a number of changes are converging and acting as catalysts in an EdTech enabled transition. Two key catalysts include a move to reconsider the current curriculum and implement a homogeneous set of learning standards (the “Common Core”), and the deployment of smarter assessments (such as Computer Adaptive Testing or CAT) of student performance and progress. Both these driving forces aim to better leverage available EdTech solutions and improve workplace readiness of students.

Catalysts in Action

Common Core Standards

The Common Core State Standards are a move to set homogenized learning expectations at each grade level, oriented to real-world readiness and global competitiveness of the American student. Published in 2010, the Common Core State Standards were developed by the Council of Chief State School Officers (CCSSO) and the National Governors Association Centre for Best Practices (NGA Centre) in collaboration with a wide range of educators, content experts, researchers, national organizations and community groups. Simply put, the Standards were created so that students have a clear set of expectations, and a prescription for the skills they are expected to master at different ages. Implementation of the Common Core requires not only a standardized curriculum, but also new ways of delivering it. The expectation is that Common Core curriculum will be delivered via multimedia platforms,

adaptive learning applications, and other EdTech solutions, thus increasing a school’s need for technology infrastructure and knowledge.

In terms of workplace readiness, it would be hard to argue that technology would not be part of most professionals’ lives. The Common Core recognizes this with the objective to be “robust and relevant to the real world, reflecting the knowledge and skills that young people need to succeed in college, in their careers, and position them well to compete successfully in the global economy”.³ While the Common Core Standards have enjoyed strong sponsorship from the likes of President Barack Obama and the Gates Foundation as an important move to close the education gap between low-income and wealthy students, questions remain on the quality of the research founding the Common Core and whether it truly enables global competitiveness. Critics also argue that the Common Core Standards amount to a federal takeover of education.⁴ While the jury is still out on the ultimate success of Common Core, the increased engagement of public figures in the education conversation can only improve student achievement in the long term.

³ *Common Core State Standards*. Web. 02 Feb 14. <<http://www.corestandards.org/>>

⁴ Baker, Al. “Common Core Curriculum Now Has Critics on the Left”. *New York Times*. New York Times, 16 Feb. 2014. Web. 16 Feb. 2014.

Smarter Balanced Assessments

Concurrent with the Common Core Standards is the rollout of the Department of Education funded Smarter Balanced Assessments, “next generation” English language arts/literacy and Mathematics assessments powered by online Computer Adaptive Testing (CAT) technology. Geared towards grades 3–8, and 11, the assessments are aligned to the Standards and planned for implementation in the 2014–15 academic year across public schools in the United States.⁵ Common arguments for Computer Adaptive Testing are that it provides uniformly precise scores for most test takers, while also shortening the test time. Thus, teachers get more accurate results, faster, and schools can then tailor educational content to a student’s needs. While this is a positive goal and could improve student achievement, it’s important to note that administration of CAT also requires a software system, with appropriate performance, be available to students. Once again the importance of technology in the classroom will only be heightened.

Impact on Schools

While the recent changes in the educational landscape with the move toward Common Core standards and

Smarter Balanced Assessments has accelerated the need for technology adoption in K-12 educational institutions, the biggest factor driving the adoption of technology in the classroom is the omnipresent role of technology in our lives. As it penetrates ever deeper into our everyday tasks, and technological aptitude becomes a prerequisite at the workplace, technological dexterity has become synonymous with real world and workplace readiness. It is this readiness that many of the aforementioned changes in education aim to achieve.

When you combine this drive towards technical aptitude with better, cheaper, connectivity, rapid software innovation, and an explosion of open source and commercial EdTech solutions, it’s clear how the move towards technology-enabled education is actionable.

While some schools have been ahead of the curve, it is the rollout of several district wide EdTech initiatives across the country in recent years that has truly heralded this new phase. Based on our research we found that almost every school district across the country has deployed tablets in classrooms in recent years, or are currently scoping such a deployment.

We found that the objective of these

EdTech initiatives can range from enhanced content delivery and student engagement, to improved performance and progress assessment, to collaborative communication between students, teachers and parents, or even simply migrating away from paper.

We also found that currently EdTech solutions are predominantly engaged to supplement traditional forms of instruction and assessment, as opposed to replacing them. It was evident that schools and school districts are attempting to leverage technology at different speeds and that there exists a spectrum in the degree of sophistication of EdTech initiatives implemented across the country. These attempts have not been without challenges, pushing some initiatives to the news headlines.

A significant challenge arises from the “distraction dilemma”, the duality of technology as both a source of facilitation and distraction from learning. Naturally enough, students who have thus far used these devices for entertainment and content consumption are tempted to do the same in the classroom. The tricky trade-off between stiff controls, which in some cases have been famously undermined by tech-savvy students, and encouraging self-discipline

⁵ Smarter Balanced Assessment Consortium. Web. 02 Feb 2014. < <http://www.smarterbalanced.org/>>

and “technological etiquette”, adds additional complexity to the problem.

Further, those parents who have struggled with the challenges of the seductive power of technology and policing a child’s use can be less enthusiastic about the introduction of devices like the tablet in the classroom. Given the nascent nature of these initiatives, the link between the use of technology and its effects on student performance, while currently under research, is yet to be substantiated. All these factors, exacerbated by negative media coverage on the influence of technology on children, further affect a parent’s perception of the benefits of EdTech.

Teachers play a crucial role in pushing forward technology enabled enhancements in student performance. However, disengagement from overworked or tech-shy teachers throws more sand in the gears of the drive to seamlessly and productively incorporate EdTech in the curriculum.

A crucial component of enabling students, teachers and schools with technology is the presence of the appropriate IT infrastructure and support. Currently, many schools handle their technology requirements off a server rack in a closet; even

fewer have data centers, IT Directors and Managers, or sufficient levels of support for implemented devices, software systems and applications. A smooth user experience of teachers and students will continue to be critical to the acceptance of technology in the classroom. This warrants a balanced investment in both infrastructure and application support and management.

New advances in Software Defined data center solutions could enable schools to realize a two-fold benefit. “Software Defined” refers to the abstraction of the software and hardware layers, in this case, of a storage appliance, where the software is then independently developed and licensed. Software Defined Storage solutions work with any kind of industry standard hardware, support architectural flexibility, and increase choice of hardware vendors to match user requirements. For schools, this could lead to lower costs and greater manageability, and consequently, effective and efficient data centers that free up resources for education application investments.

Developing a Strategic Approach

We found that these challenges are being navigated by each school and school district in a different way

with varying degree of success. It is safe to expect other challenges to emerge along the way as this new territory is charted and the suite of EdTech solutions evolve over time. The complexity of these challenges warrants a strategic approach in implementing EdTech solutions in the classroom, and the examination of emerging technologies like Software Defined data centers to leapfrog up the technology maturity curve. Successful implementation will likely reduce costs and, most importantly, enable students and teachers to reap the many benefits of leveraging technology in education.

3. Benefits of EdTech

The value in leveraging technology in the classroom is manifold and has the promise of benefitting both students and teachers. Several studies have examined the transformational effect of technology on students and teachers.⁶ We set out to explore the benefits of EdTech through research of ongoing EdTech initiatives around the country.

Students

The real strength of educational technology lies in its ability to unlock student learning through enhanced engagement, personalized education and equal access for all.

EdTech has potential in boosting engagement by promoting interest and participation through the enablement and enforcement of interaction between the students, the student and the teacher, and the student and the content. Techniques as simple as assigning content creation like videos, or the more sophisticated implementation of “gamification”, are all instances where the gravitational pull of technology has been wielded into combating student apathy. It is great when tools enable a student’s natural curiosity to learn. Khan Academy has put thousands of lessons in subjects from biology to art history online. Pratham, an India based

not-for-profit organization, tested a computer program that presented math questions in an arcade game like format and found that when students used it for two hours a week, it had a considerable positive impact on math test scores. Similarly, there are various other initiatives and organizations, like the MIND Research Institute’s ST Math, that are leveraging technology to make learning fun and interesting for students.

Technology is also transforming the one size fits all approach of instruction into a personalized learning experience of self-paced education where the availability of resources allows students to absorb information at their own pace. For instance, a student can revisit a complex concept in a Khan Academy video, empowered by the ability to pause and repeat as necessary. This can make all the difference to those self-conscious about asking for help. Some schools have implemented this in the form of “flipped classrooms”, a format where students learn new concepts at their own pace at home and apply their learning, through exercises or discussions, in the classroom. This format also transforms the teacher’s role from a “sage on the stage” to that of a coach. Similarly, schools across the country are experimenting with other innovative models to enable student learning on a daily basis to identify what works best for their students.

⁶ Examples include “Technology and Classroom Practices: An International Study” by Robert Kozma (Journal of Research on Technology in Education, 2003) and the Second Information Technology in Education Study by Law, Pelgrum, & Plomp (Springer, 2008)

A study by educational psychologist Benjamin Bloom in 1984 concluded that students who were provided one-on-one tutoring performed significantly better (by two standard deviations or 98%) than those who were taught through conventional classroom instructional methods. This study, called Bloom's 2 sigma problem, is widely accepted to substantiate the link between one-on-one attention and student performance.⁷ By the same logic, in an environment with a limited number of teachers, technology enabled "automated tutoring" can simulate the one-on-one tutoring experience for those who need it, potentially allowing them to succeed where otherwise they would have failed.

In addition, access to education, a necessary stepping stone to unlock learning for the severely disadvantaged, would be further enabled though the use of appropriate technologies.

Lastly, in an age where technical know-how is expected in the workplace and schools around the world are churning out students adept at technology, exposure through an EdTech enriched classroom is the first step to developing students with technological capabilities for workplace readiness and increased international acumen. The drive of adopting "ability to

program" in the middle school years, is now seen as a fundamental skill, for all students, irrespective of the future career choice.

Teachers

Implemented and utilized effectively, EdTech can arm teachers with enhanced and virtually real-time visibility into student performance. They are better equipped to hone in on student skill level, strengths and weaknesses, and to provide targeted and personalized help. For instance, CAT driven assessments are tailored to identify each student's learning level of a concept, and monitoring the progress in that understanding over time. This ability also allows teachers to recognize and nimbly correct gaps in a student's understanding, bolster strengths and assist in areas of weakness.

Technology also provides robust means of communication between teachers, students and parents. It allows for timely and efficient distribution and collection of work, the sharing of a wealth of learning material and resources, as well as collaboration and an exchange of educational dialogue between teachers and students. Many classrooms leverage forums through which students can ask questions and their fellow classmates provide answers and share information, learning from each other. It also gives

parents easier, quicker and clearer insight into their child's areas of strengths and weaknesses, reinforcing their ability to assist at home.

EdTech also has the potential of facilitating an efficient allocation of assets by making a range of solutions available and getting around resource and time constraints. In many classrooms across the nation, teachers have the autonomy to decide on the technology they incorporate into the curriculum. Even in district-wide EdTech initiatives, like a tablet rollout program, it is the teachers who decide how the device is utilized in the classroom. Since every classroom is different, thanks to the abundance of options, teachers can now take a selective approach in acquiring resources that best fit the course content, learning expectations as stated in the Core Standards and, most importantly, students' needs. In an environment with growing classrooms, the scalability of EdTech can alleviate the pressure on teachers to be omnipresent. As mentioned earlier, the performance benefits of one-on-one assistance are well established. "Automated tutoring" enabled by educational technology can provide students the personal assistance they otherwise might not have. Also, in instances where the introduction of new concepts is supplemented with resources like Khan Academy, teachers

⁷ Bloom, Benjamin S. "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring". *Educational Researcher* Vol. 13, No. 6. (Jun.—Jul., 1984): 4–16 Print.

are transitioning from a “sage on the stage to a coach on the side”, making it possible for them to focus more time and energy on personal assistance than ever before. This effectively increases the student to quality time with teacher ratio. This pressure on resources can be further alleviated through student to student collaboration mentioned above, where classmates learn from each other. In Los Gatos, California’s Hillbrook High, tech savvy students are assigned to be “tablet doctors” who provide their fellow classmates and teachers with technical assistance. Such a concept not only reduces the teacher’s or school administration’s time and effort dedicated to addressing technical issues, but such peer collaboration can also succeed in keeping students invested where other attempts have failed.

The role of teachers in the efficacy of educational technology is invaluable as they hold the key to unlocking the many benefits to students discussed earlier. Therefore, it behooves teachers to avail themselves of the benefits of educational technology. As the true vanguards in this transitional period, it is also a tough role. Changing habits and entrenched practices, overcoming tech-shyness and developing new skills and knowledge, and adapting to changes adds further complexity to the inherently challenging job of a teacher. Consequently, it is imperative that the

necessary support be duly provided to them as they navigate new territory.

All of these elements are poised to engage students, give them the support they need, boost confidence and catapult student learning. For schools, this could lead to lower costs and greater manageability, and consequently, effective and efficient data centers that free up resources for education application investments. For example, an instructor may restructure a class into a group activity, having students conduct online research to boost their understanding. With such a vast reference tool, the students might pose questions that no one in the class, not even the teacher, can answer. Many teachers and schools choose to avoid this situation by discouraging the use of computers for the benefit of a controlled lesson. Their latest shipment of technology equipment stays locked in a closet as they struggle to find the time to effectively incorporate it into the curriculum plan.

Despite the many benefits of EdTech, sustainability and scalability of the positive outcomes discussed above across all schools can be challenging.⁸ Integrating computers in the classroom is hard work and is likely to succeed only when the basics are already in place. When teachers are well-trained and motivated, and when computer use

is embedded in well-designed lesson plans, information technology can be a useful adjunct to teaching. In addition, autonomous technology selection, be it applications, devices or other EdTech solutions, will likely find the greatest success when the initiative is designed to flexibly support user requirements. By designing the architecture up front to support a wide range of teacher and students’ needs, and enabling its implementation with flexible, software-defined solutions, the resulting technology infrastructure will likely be future proof for the requirements of EdTech today and tomorrow. Lastly, technology is no silver bullet. Systemic education reform is complex, arduous work—and it can’t be done solely with a tablet either. The benefits highlighted in the section above are presented with the caveat that educational technology is no substitute for teachers with the flexibility and incentive to teach, backed up by parents with a commitment that their kids learn.

8 OECD (2010). *Assessing the effects of ICT in education: Indicators, criteria and benchmarks for international comparisons*. Paris, France: Joint Research Centre—European Commission.

4. Purpose Driven Initiative

All successful initiatives must first define their purpose, scope and measures of success. Otherwise, one risks plowing through substantial effort and financial means without achieving the desired objectives. Technology in the field of education has several benefits outlined earlier in the paper, thus a program should highlight the benefits it seeks to achieve and the resulting impact. The benefits can be categorized by measure of their impact in two ways:

- a) Direct and short-term impact e.g., Student Achievement
- b) Indirect and potentially long term impact e.g., Improved Social Communities and GDP Macro Benefits

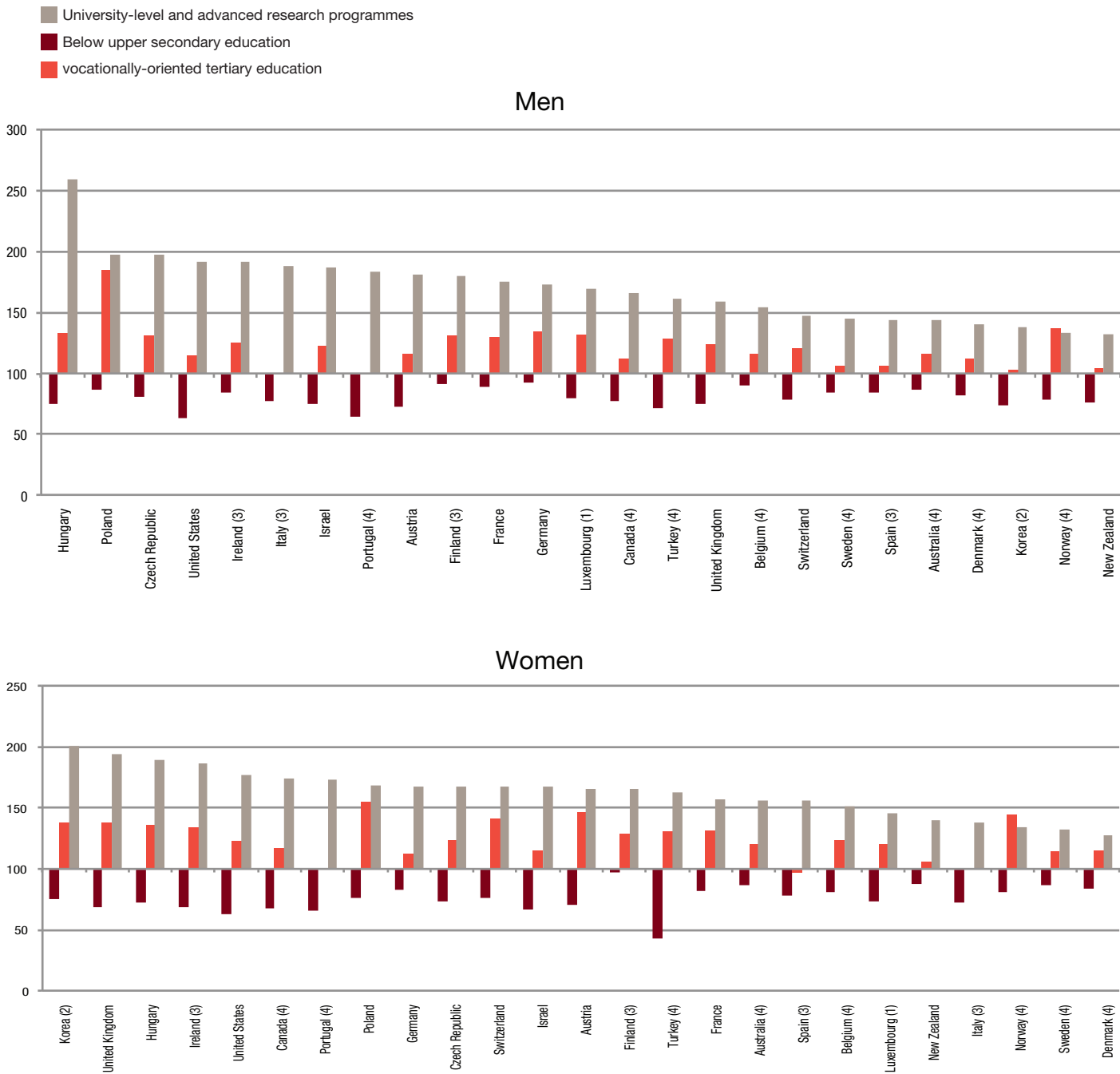
In addition, all EdTech initiatives should focus on the strategic purpose of future proofing the investments by making technology choices that are stable, scalable and offer the flexibility to adapt to changing future needs. Technology flexibility and adoptability should be considered as one of the measures of success. This is what we refer to as “Future Proofing EdTech”.

A) Direct and Short Term Impact Student Achievement

Helping students succeed in their academic endeavors will likely help them pursue a livelihood with a higher quality of life. This includes improved skills for the knowledge based economy, high potential of attending college, and improved employment potential. Several studies have consistently demonstrated that improved education results in higher earnings.⁹

⁹ OECD (2008), Education at a Glance 2008, Table A9.1.a, available at <http://dx.doi.org/10.1787/401781614508>

Figure 1: Relative Earnings from Employment by Level of Education, 2006
 (Y-axis represents relative earnings)



B) Indirect and Potentially Long term Impact

Improved Social Communities

If students spend more time attending classes and performing school tasks, then communities should benefit from having fewer children outside of schools. As students move on to college or to higher paying and stable employment, it likely creates more stable social communities with less crime and a stable environment for new generations to thrive. There is strong correlation, as demonstrated by research conducted by Enrico Morretti in his book “New Geography of Jobs,” that people with better and higher quality education tend to concentrate socially and economically, in specific zip codes, which also happen to be zip codes with better quality of life, lower crime rates and per capita incomes.

GDP Macro Benefits

On a macro-basis, technology doesn’t come for free. However, initiatives should focus on delivering the technology solution for the least amount of funds. This should result in more efficient public costs, which are funded through tax collections. In the long term, students performing better and earning higher incomes, should result in a higher tax base, and less government spending on fighting crime and social welfare to support inflicted communities. Thus in the long term, the benefits to the macro economy are substantial relative to the investment. In fact, a PlosOne paper examined the impact of Information and Communication Technology (ICT) use on economic growth in 159

countries over the period 2000 to 2009. The results indicate that there is a positive relationship between growth rate of real GDP per capita and ICT use index (as measured by the number of internet users, fixed broadband internet subscribers and the number of mobile subscriptions per 100 inhabitants). The paper also found that the effect of ICT use on economic growth is higher in high income group rather than other groups. This implies that if these countries seek to enhance their economic growth, they need to implement specific policies that facilitate ICT use.

Schools in the United States are historically challenged with securing enough funding to pay teachers and to maintain their facilities, making investment in technology challenging when times are tight. With scarce resources at hand, yet with strong demand for EdTech solutions, and a clear line of sight to the potential benefits, school districts and educators have challenges in determining how—and how much—of their funds to release on behalf of technology programs. The resulting programs should have direct student impact, lasting results, and accrue over a significant period of time to make the return on investment (ROI) worthwhile.

In this paper, we have taken the approach of designing a conceptual framework that focuses on all three pillars. With that in mind, we are providing the following PwC analysis on the representative measures

of success. School boards should explicitly state the vision and purpose of their initiatives, and define how success will be measured. Below is a representative framework. The following sections will highlight how to design a thorough program that aims to achieve these measures of success.

Figure 2: Measures of Success for EdTech Initiatives

Timeframe	Measures	Direct and Short Term Impact	Indirect and Long Term Impact	
		Student Achievement	Improved Social Communities	GDP Macro Benefits
Short-term (within 1 year)	Improved student attendance	●	●	
	Fewer course repeats	●		●
	Increased task at hand	●	●	
Medium-term (2 to 5 years)	Improved English and math proficiency	●		
	Lower highschool dropout rate	●	●	●
	IT cost per student for comprehensive program			●
	Empowered teachers resulting in higher job satisfaction	●		●
Long-term (beyond 5 years)	Increased average income earned 3 years post graduation		●	●
	Increase attendance to post-secondary educational institution		●	●

5. What does “good” look like in EdTech ?

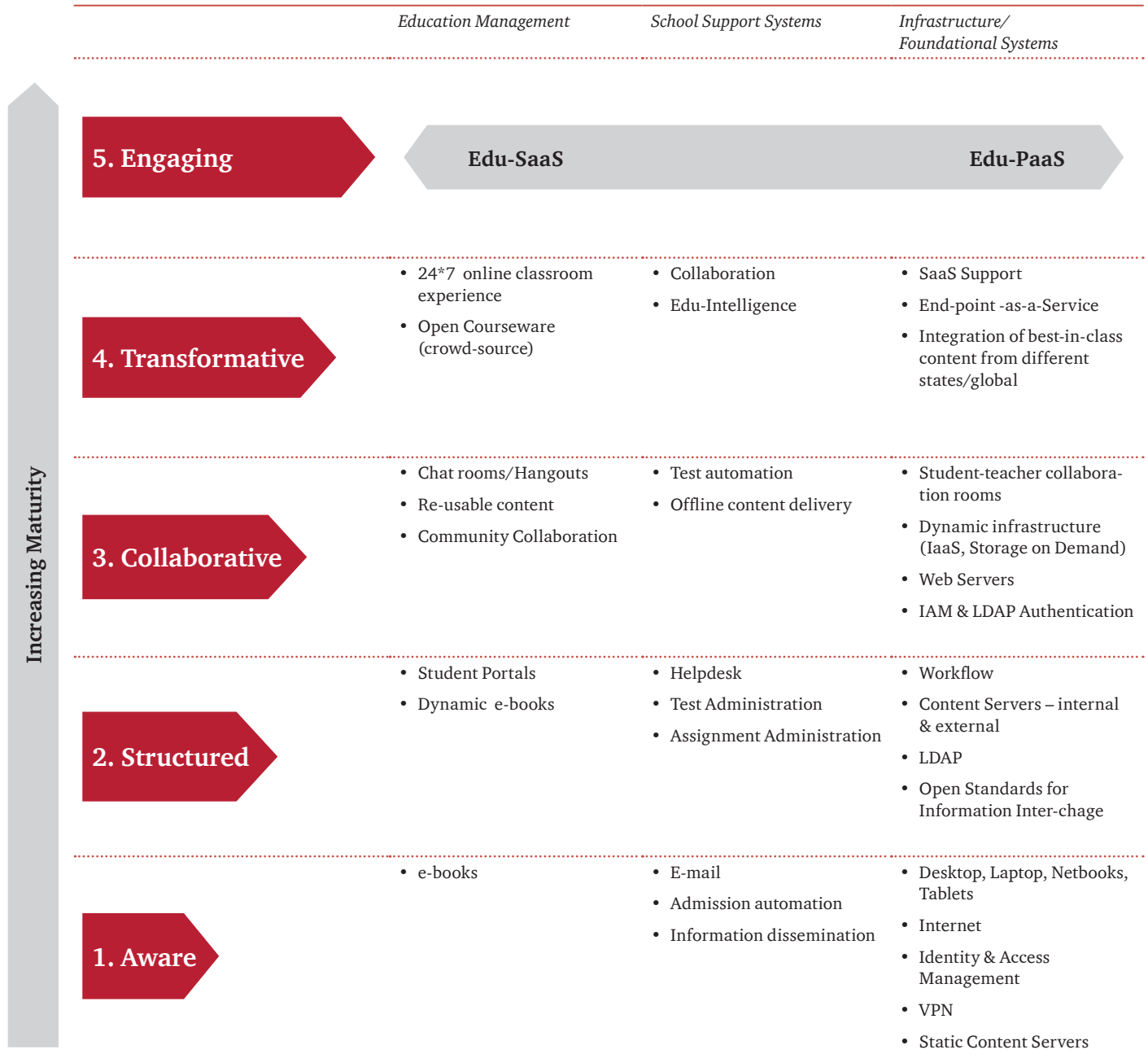
Although technologies have not yet transformed schools at the scale some might have expected, they have led to irreversible changes in how we work, live, communicate and play. Technology has transformed and developed new industries, new laws, and new areas of scientific inquiry. This section of the paper first aims to examine the gap between technology trends and the use of technology in schools, and then sets out a vision of where technology investments should be focused to impact enhanced learning experiences for students. The emphasis here is not on the use of technology per se, but rather on how technology may serve as a foundation and mediator for the transformation of practices in schools.

Based on our market analysis of current EdTech standards, we adapted a technology maturity framework to assess the level of adoption of the existing EdTech solution in school districts. We categorized the adoption of EdTech components based on their level of maturity as well as based on their intended purpose. This EdTech maturity model allowed us to assess the relative position of technology adoption in school districts vis-à-vis areas on which they can focus in the future, and include relevant technology advances into the K-12 educational delivery framework.

This maturity framework only looks at the technology and associated components, when analyzing the relative positioning of school districts and shouldn't be construed as an all-encompassing maturity model covering all dimensions of educational management of K-12 school districts. For effective and efficient impact, the entire eco-system needs to work in concert to deliver the impact, and technology alone will not be able to address the core issues around K-12 education.

The EdTech Maturity Curve is an adaption and variant of maturity models which exist in the software industry. The EdTech Maturity curve has 5 levels of maturity similar to the ones commonly adopted for Software Technology Maturity (Carnegie Innovations CMMI+) to plot the current state of technology adoption in school districts and provide a vision for continuous improvement. The Maturity Curve takes into consideration foundational technology elements and integrates them with emerging trends such as social technology, to provide a vision to continuously improve technology adoption in K-12 educations and thereby enabling the universal access of education, across school districts.

Figure 3: PwC Analysis—Education Technology Maturity Curve



The Five levels of technology maturity were defined as:

Maturity Level	Description
<i>Aware</i>	Fundamental adoption of hardware has been established in the school district
<i>Structured</i>	Some form of education delivery and education management is being driven through systems and software defined processes
<i>Collaborative</i>	Interaction of various systems, people and processes is being demonstrated
<i>Transformative</i>	Data is driving decisions and actions and analytics are driving continuous improvement
<i>Engaging</i>	Ecosystem is being engaged to deliver an open-source, global and engaging education experience

The existing technology assets in K-12 standards were analyzed by classifying currently existing environments into three categories

Technology Component	Description
<i>Educational Management</i>	Applications that are used directly by students, teachers and support staff towards enhancing student learning
<i>School Support Systems</i>	Applications to facilitate administrative activities in schools
<i>Infrastructure/ Foundational Systems</i>	Infrastructure and foundational components required to support the use of educational and support applications in school

Current assets were plotted on the five levels of maturity, to analyze the current state of technology adoption in K-12 standards, and opportunities for improvement.

We found that most school districts are in the 'Aware' phase in the EdTech Technology Maturity Curve. Currently Educational Management is primarily handled by teachers, with their selection of EdTech solutions and applications determining the technology in-use in classrooms and

the supporting technology needs. School Support Systems selections are made by school administrators with the support of a District IT Director. Both of these components influence the Infrastructure/ Foundational Systems which impact the performance, availability, and utility of the other components. Many EdTech initiatives on infrastructure have focused on putting devices in the hands of students, yet too few focus on the impact of upstream decisions on downstream systems.

6. Current K-12 Technology Landscape

The use of technology in the educational sector is growing. Many K-12 schools across the country have already adopted, or are in the process of adopting, various kinds of technology. These technological components vary in their level of maturity and sophistication. As a response to the growing influence of technology, schools and school districts are embracing technology to better prepare their students for the 21st century marketplace.

While devices and tablets often make the headlines, most of the current technology investments in the school districts fall under the infrastructure/foundational systems category. This technology infrastructure/foundational systems category includes web and application servers, file servers, network components, computer hardware and accessories as well as a few basic foundational applications. The level of adoption and usage of these technologies varies when benchmarked against the EdTech Maturity Curve. Evidence from school districts suggests that most of the investments are being directed towards setting up the proper foundational infrastructure to support technology for education, including the distribution of end user computing devices like laptops. We found that comparatively fewer investments are currently focused towards the education management that directly impact student learning.

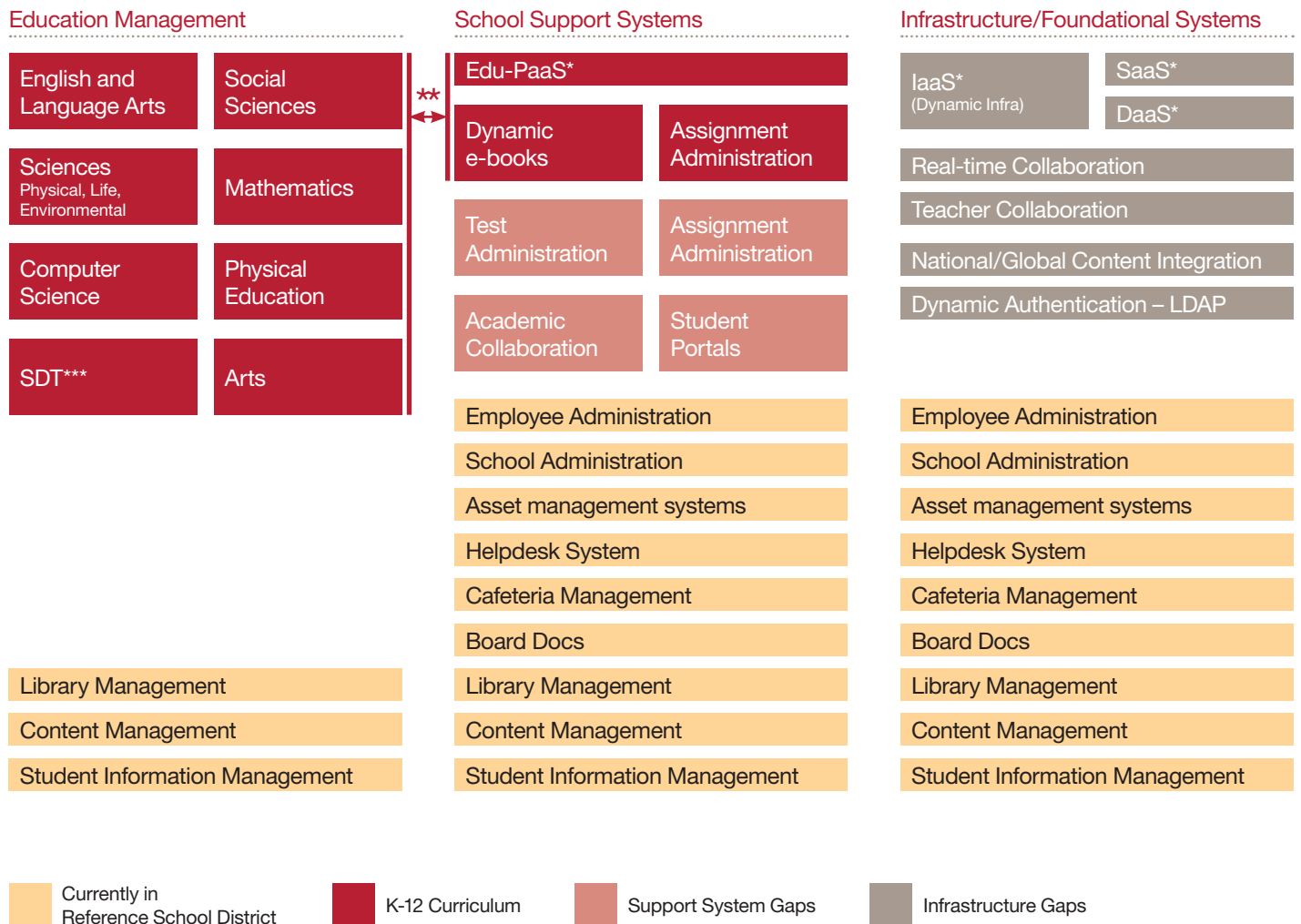
Schools have started setting up technology infrastructure on their premises. Some schools are also sharing these resources with other schools within the district,

to efficiently use the technology funding and budget available. These infrastructures include physical as well as virtual servers for hosting different applications, databases for storing student data, network management infrastructure, web filtering and web security infrastructure. Examples of infrastructure technologies used by schools include Barracuda appliances, Deploy Studio, Apple Filemaker Server, VMWare, and Unity v7.0. Some schools have also rolled out programs where they provide portable devices such as tablets to their students for use within, as well as, outside of the school.

Schools have also invested in school support systems to facilitate administrative activities using technology when possible. These support systems may include applications for school administration, food services management, call management, facility management, asset management and employee management. Examples of school support systems include Food Services, Bluebear, SEMS Sub Coord System.

To-date the investment focus of technology tools has been in the area of Infrastructural/Foundational and School Support systems components. To influence student learning, the investments should progress to “education management”. Our research indicates that very few technology investments have been made in the actual core-curriculum content area. Investments in core-curriculum, when coupled with appropriate teacher enablement, shall provide the desired impact to student learning, as measured by standardized test scores, global test scores such as PISA, long term employability and

Figure 4: PwC Analysis—Current K-12 technology landscape and gap analysis



* Infrastructure/Software/Desktop/Platform as a service

** The educational content can be enriched and delivered, through sophisticated mechanisms and enhanced using technologies such as dynamic e-books and Open courseware, thereby creating dynamic linkages between the different IT infrastructures in the education world.

*** SDT- Speech, Drama, Theatre

Source: Reference School Systems Portfolio List

national competitiveness.

Educational applications that have been made available by schools to students and teachers include cloud based applications accessible through the internet, in addition to applications purchased and installed to local desktops, laptops and tablets. Examples of existing applications used by students and teachers include Khan Academy, Gmail, School Loop, Catapult CMS, Follet Destiny and Board Docs.

While refocusing investments, education administrators should consider adopting asset-lite technologies, such as the IaaS for Foundational/Infrastructural areas to ensure that the basic infrastructure isn't compromised and is kept up-to-date and relevant. Additionally, in the area of School Support Systems, forming consortiums (multiple school districts joining hands and forming PaaS) and investing in common platforms for the top 10–15 systems should drive downward the overall investments required to keep the School Support Systems functioning smoothly.

The future of EdTech holds many possibilities for students, teachers and IT directors. Infrastructure may be on-premise, or in the cloud; applications

may reside on student devices, or also be cloud based. The potential solution could be a combination of both, and the permutations of possibilities are many and varied. To maximize the use of funds and make the most efficient and successful use of their investments, schools will likely benefit from developing comprehensive plans that help future-proof their investment for not only this year's technology selections but also for advancements the next decade may hold. Future-proofing EdTech means drawing the industry forward as a whole, improving its technical maturity and positioning education to take advantage of the latest trends around cloud, hybrid architectures, mobile, analytics, big data and software defined solutions, instead of lagging behind in these areas.

7. Portfolio approach to EdTech investments—where should investment be directed?

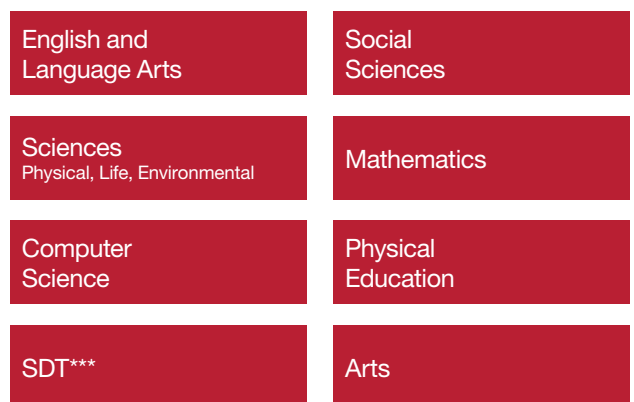
We observed that schools are eager to incorporate technology in the classroom and have made investments in setting up the technology infrastructure and support systems towards achieving those goals. However, the investment in developing and/or procuring educational applications that would be used by the students and teachers directly to

enhance student learning, is small compared to investment in technology infrastructure. The current investment strategy investment strategy results in a lower number of educational applications available to students and teachers, which limits the choices students and teachers can make when it comes to choosing the right learning approach and means.

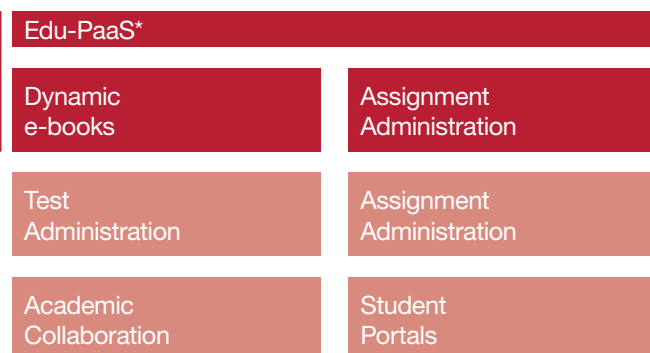
Figure 5: PwC Analysis—Educational Technology Blueprint

Focus of investments

Education Management



School Support Systems



**



* Infrastructure/Software/Desktop/Platform as a service

** The educational content can be enriched and delivered, through sophisticated mechanisms and enhanced using technologies such as dynamic e-books and Open courseware, thereby creating dynamic linkages between the different IT infrastructures in the education world.

*** SDT- Speech, Drama, Theatre

Source: Reference School Systems Portfolio List

It is in the interest of schools to invest more in educational applications that will be used directly by students and teachers. Increase in the number of educational applications made available to students will provide more flexibility to students in choosing the right applications for learning based on their individual needs. It will allow students to learn in their own ways and at their own pace. For example, some students might learn better from watching video modules, whereas other students might learn better through interactive methods such as answering questions, taking short quizzes and completing tests. Some students might prefer a combination of different techniques. Additionally, schools can formally engage students to help with developing in-house applications on different platforms to meet the school needs. Teachers will likely also benefit with this approach as they will be able to formulate lesson plans and teaching strategies based on the various options available to them.

Enabling schools to increase their investment in education applications implies moving funds out of other

areas. While significant investment has been made in infrastructure, it has primarily been for end user devices such as tablets, laptops, and PCs, to equip students to access the educational content they seek. Many schools have not yet invested in a formal data center, or in cloud technologies, although this type of infrastructure is what is needed to support the delivery of EdTech as a universal utility to students. The recommended solution to this dilemma is that near term greater investment needs to be made in EdTech; first and foremost to future-proof the data center bedrock on which these technologies rest, and then to identify, make available and support the best education applications. While software-defined technologies are not a panacea for education infrastructure, building a Software Defined Data Center will likely support long term architecture flexibility, the addition for fit-for purpose (and budget) hardware, and shall drive down the total cost of ownership. Thus the right foundation yields the better outcome for students, teachers, and schools.

8. Design Considerations for the Future State EdTech Architecture

Our future state view provides a reference architecture that school districts can leverage while building as well as maintaining their EdTech framework. We recommend that school districts leverage private or public clouds, with software-defined technologies, as the infrastructure

for the end points to host and access educational content. School districts can identify the core applications necessary for students, teachers and parents and make additional investments towards making these core applications available to students.

Figure 6: Future State Reference Architecture

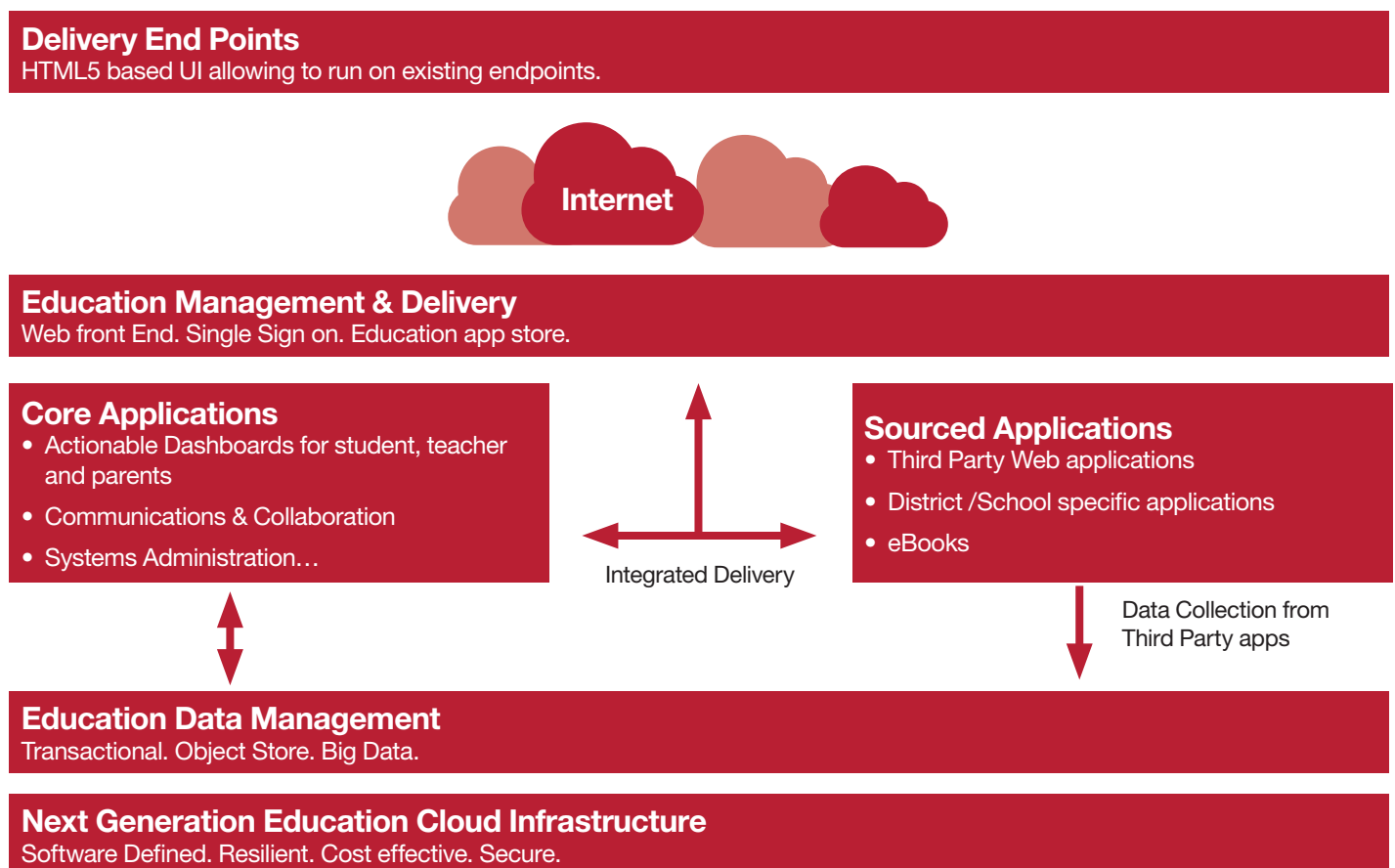
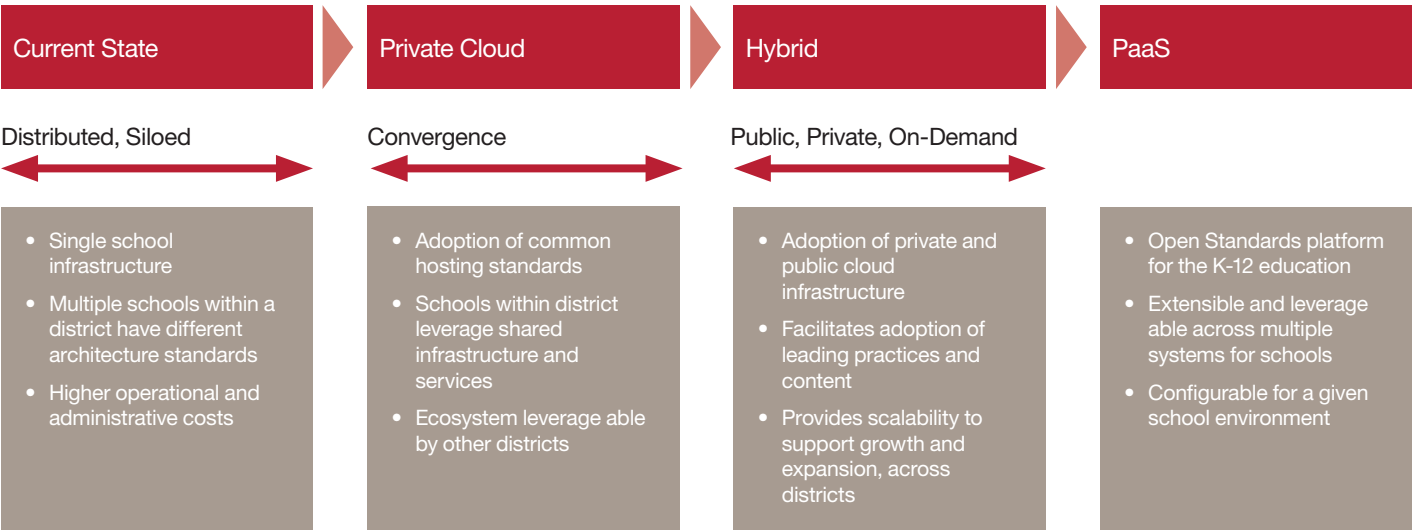


Figure 7: High-Level stages of Future State Architecture Implementation

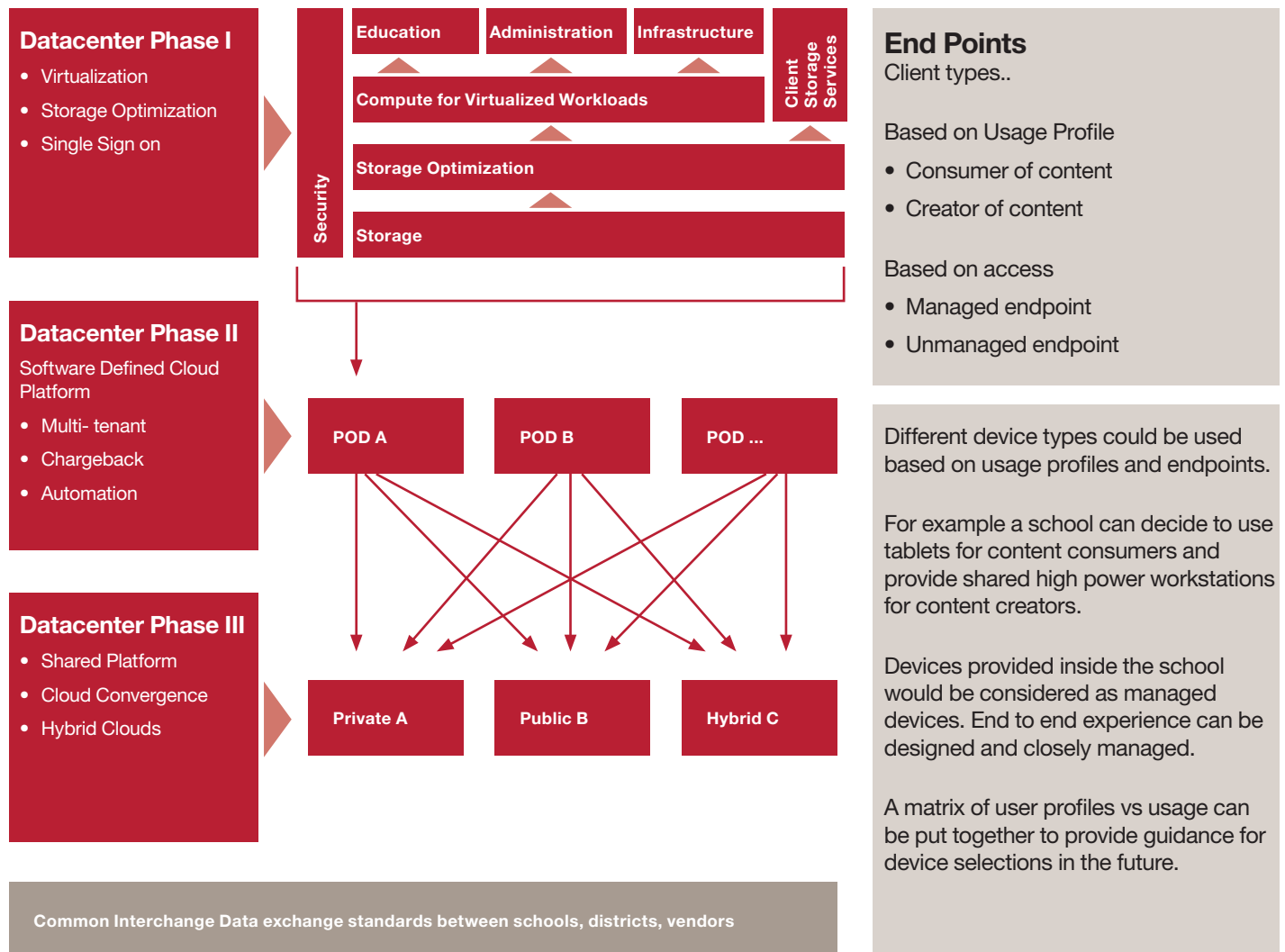


School districts may consider a phased approach to setup their EdTech Architecture. During the first phase, districts can focus on essential components such as identifying and setting up software defined storage, server virtualization and storage optimization technologies. They can also set up single sign-on technology which makes it easier for students, teachers and school staff to log into different applications without having to sign-in every time.

In phase 2, school districts can define model for IT systems chargeback. School districts can also invest in multi-tenancy architecture so that services on the cloud platform can be used by multiple tenants, in our case different schools.

In phase 3, school districts can start exploring strategies so that schools within the districts can use shared platforms for EdTech. School districts might also want to share resources with other districts. At the same time they can also identify how they can use hybrid cloud technology where some technology components will remain in-house in the schools whereas others will be migrated or added on the cloud.

Figure 8: PwC Analysis—Migration Approach for Future State Architecture







9. Challenges in Delivering EdTech Initiatives and Potential Mitigating Considerations

Due to the relatively recent new investment wave into EdTech, current initiatives are mostly in experimentation stages across the US with heterogeneous deployment of hardware/software, teacher/student readiness and performance tracking. The pan-US standardization of EdTech initiatives is predicted to be several years away, and during this strategic inflection point, there are bound to be challenges in identifying, deploying, adopting, tracking and continuously improving EdTech initiatives.

From interviews conducted with a diverse set of schools and associated administration, teachers and students as well as outside research, we have identified several key challenges in adopting and delivering EdTech initiatives. These challenges are not detrimental to continued growth of EdTech initiatives but, if overlooked by school administration, teachers and students, may lead to counter-productive results in EdTech deployment. Adequate mitigation strategies and alternate plans should be implemented in a timely fashion.

The challenges broadly fall under four areas—1) Teacher Adaptation 2) Student Adjustment 3) Technology Limitations 4) Effectiveness Tracking. The table below highlights certain key areas under each challenge category and the corresponding mitigation considerations.

Figure 9: EdTech Challenges and Mitigating Strategies

Key Challenge Area	Major Challenges	Mitigation Strategy
Teacher Adaptation 	<ul style="list-style-type: none"> • Comfort with technology use • Technical know-how • Understanding of education focused applications • Ability to leverage technology during class instruction • Increased accessibility/availability • Perception that technology is disintermediating the teaching profession and dislocating teacher identity 	<ul style="list-style-type: none"> • Increased awareness of benefits for teachers (less drudgery, duller tasks automated, and time to reorganize the classes) • Teacher training to precede technology introduction • Teacher involvement in technology decisions—increased ownership • Guidelines for communication with teachers (e.g., response SLAs) • Highlighting that across different industry sectors, technology has always been an enabler. It is not intended to replace the age old student–teacher interaction
Student Adjustment 	<ul style="list-style-type: none"> • Distraction factor • Affordability • Education focused usage 	<ul style="list-style-type: none"> • Parental buy-in and awareness • Lay out technology usage guidelines for school and home • Student training prior to technology introduction • Benefits awareness • Lock down devices for specific usage • Balance effective discipline through either self-discipline or technology controls.
Technology Limitations 	<ul style="list-style-type: none"> • Device limitations • Device security (physical and logical) • Typing/formatting issues • Thin vs. thick Clients • Device inter-operability • Technology Infrastructure at school/Home • Multiple points of failure (e.g., device, connectivity, infrastructure) 	<ul style="list-style-type: none"> • Have a concerted technology strategy • Evaluate and test interoperability of devices • Schools to provide neighborhood wi-fi coverage • Schools to introduce loaner programs
Effectiveness Tracking 	<ul style="list-style-type: none"> • Limited measurement • Impact on student achievement • Long term vs. short term impact measurement • Return on investment analysis 	<ul style="list-style-type: none"> • Track student performance thru test scores pre and post technology introduction • Technology focused surveys for teachers, students and school administration

10. Conclusions

Through this paper, we have highlighted the many direct and indirect benefits of EdTech that we found through our field-work, covering representative school districts, educators, teachers and students. These benefits have driven schools across the country to implement several large and small scale EdTech initiatives in recent years. The extent of benefits experienced is highly correlated to the enablement of teachers, and a broader technology enablement approach. Leveraging technology in the classroom has its challenges. Documentation of best practices on deployments is limited given the fast changing landscape of technology advancement in education. The current focus of several programs seems to have been limited to focus on deploying devices. A more comprehensive approach with an end-state vision in mind is required, that incorporates:

- Defined initiative scope and success factors: this aligns implementation programs to student achievement factors, with clarity on measures of success that influences program designs

- Leveraging best practices: avoid disproportionate and disparate investments. Implement a flexible framework, one that can expand and adapt to new requirements, and does so with limited economic impact. Limiting the cost of this framework will benefit from leveraging the latest in technology trends—cloud deployment, hybrid architectures, big data, and software defined solutions
- Implement a complete ecosystem: an integrated user experience for students, teachers, parents and administrators will achieve significantly better results. It incorporates infrastructure, devices, applications, curriculum changes and teacher training and development

The rapidly evolving nature of technology warrants future-proofing EdTech. We believe that the key trends identified in this paper will positively impact education forward and improve the maturity of education technology overall.

11. Acknowledgements

Accomplishing what we set out to do would not have been possible without the teachers, school administrators and education innovators who opened up their doors and candidly shared their experiences and perspective, and successes and challenges, allowing us to experience first-hand the exciting EdTech enabled changes happening in classrooms around the country. We would like to thank:

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- Don Orth from Los Gatos' Hillbrook School
- Karina Gerger and Carolyn Seaton from Manhattan Beach Unified School District
- Alyssa Gallagher, Kami Thordarson, Wendy Lu and Jackie Sigua from Los Altos School District
- Tracy Huebner from WestEd
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13. Appendix

Methodology

Through our research and analysis, we set out with the goal of finding answers to the following two questions:

1. What and how can we learn from schools that have experimented with technology in education and disseminate lessons learned to other schools?
2. How do we translate these learnings into practical guidance for schools with technology projects?

We embarked on the journey to seek answers to these questions by reaching out to stakeholders with knowledge and experience in the fields of education, technology or both:

- Administrators who have planned and implemented EdTech initiatives in their schools districts
- Teachers and coaches who have enabled district wide EdTech implementation and have exercised autonomy in employing EdTech solutions to their specific classroom needs
- Students, the end users of EdTech
- Experts in the education sector

Insights from the stakeholders noted above, decision makers, facilitators and end users of technology in education, were gathered over the course of a rigorous data collection exercise through 20+ interviews and focus group discussions spanning across multiple schools. We had the

pleasure of experiencing EdTech in the classroom firsthand through on-site tours, having in-depth discussions with several EdTech experts, and candid conversations with educators and users of EdTech including:

- Robert Ibarra and the teachers and social workers at East Side Unified High School District's Calero High School,
- Don Orth from Los Gatos' Hillbrook School,
- Karina Gerger and Carolyn Seaton from Manhattan Beach Unified School District,
- Alyssa Gallagher, Kami Thordarson, Wendy Lu and Jackie Sigua from Los Altos School District
- Tracy Huebner from WestEd

Takeaways from these discussions, and a review of 100+ published documents on EdTech, were the support for the benefits and challenges discussed in this paper and the basis for the desirable attributes of seamless EdTech implementation in the classroom. The latter was built upon with PwC's knowledge/experience and analyses to arrive at the investment and design recommendations put forth in this paper. The current state EdTech assessment was executed by PwC's analysis of results from surveying various school districts in Silicon Valley.

Glossary

- **+ CMMi**—Capability Maturity Model Integration, owned by CMMI Institute, a 100%-controlled subsidiary of Carnegie Innovations, Carnegie Mellon University's technology commercialization enterprise. www.cmmiinstitute.com.
- **IaaS**—Infrastructure—as—a—Service is a standardized, highly automated offering, where compute resources, complemented by storage and networking capabilities are owned and hosted by a service provider and offered to customers on-demand. Customers are able to self-provision this infrastructure, using a Web-based graphical user interface that serves as an IT operations management console for the overall environment. API access to the infrastructure may also be offered as an option.
PaaS—Platform—as—a—Service is a broad collection of application infrastructure (middleware) services (including application platform, integration, business process management and database services).

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about how this subject
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