Technology-Rich Innovative Learning Environments

Jennifer S. Groff
jgroff@mit.edu

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INTRODUCTION

Our rapidly changing world has posed the long-standing question to education,

> *"How can today's schools be transformed so as to become environments of teaching and learning that makes individuals lifelong learners and prepare them for the 21st Century?"*

The response to this question is the focus of the OECD project, *Innovative Learning Environments*, and has produced a sampling of the rich array of new visions for education around the world. As one might imagine, many learning environments have looked to technology in their efforts to redesign teaching and learning. While technology integration has long been a key area of concern in education, the intersection of technology with our rapidly transforming educational landscape is framing the nature of technology in education in profound, new ways. New and emerging technologies are provoking a re-conceptualization of teaching and learning, while also serving as catalysts for transformation and innovation.

Successfully preparing all learners with the skills and capacities for 21st century citizenship—global awareness, creativity, collaborative problem-solving, self-directed learning—is no small order, and many educational leaders are finding that the traditional forms of education that have evolved through the end of the last century are simply inadequate for achieving these goals. At the same time, while our outer world was transforming, considerable advances have been made in the learning sciences, forcing educators to reconsider how they approach learning, instruction, and the environments created to foster these. Finally, dramatic advances in educational technology have inspired powerful new ways for learners to engage with all kinds of content and activities in their own self-direct learning experiences. The juxtaposition of these three events creates a very interesting challenge and opportunity—a space to reconsider, re-imagine, and re-invent learning environments able to prepare and excel each individual for effective life-long learning.

THE DRIVE OF TECHNOLOGY FOR SCHOOL CHANGE

While many, if not all, systems of education seek to at least improve and advance (and some even seek to radically transform), this does not necessarily mean one has to leverage technology to do so. However, there are several key drivers pushing technology as a key component for educational system change, and these serve as central reasons that educators and education stakeholders should consider the growing relevance and implications of technology and technology-based school innovations (OECD, 2010):

- Technology can perform several key functions in the change process, including opening up new opportunities that improve teaching and learning—particularly with the affordance of customization of learning to individual learner needs, which is highly supported by the learning sciences;

- The skills for an adult life include technological literacy, and people who do not acquire and master these competencies may suffer from a new form of the digital divide, which will impact their capacity to effectively operate and thrive in the new knowledge economy;

- Technology is an integral part to accessing the higher-order competencies often referred to as 21st Century Skills, which are also necessary to be productive in today's society.

The New Millennium Learners (NML) work of the OECD over the last several years has contributed to these foundational elements, by describing the fundamental nature of learners in today's world. Increasingly "connected," students today are constantly surrounded by a constellation of digital devices. As described in this work, new millennium learners' lives are "highly dependent on technology up to the extent that their social and cultural practices would not be as they are if digital media were not available anytime, anywhere to them"; this body of work also describes the educational implications the NML research, explaining that "students are not only accessing, managing, creating and sharing knowledge in dramatically different ways as their teachers often do, but also have radically new expectations regarding what a quality learning experience should be" (Pedro, 2009, p.2). As a result, students are bringing attitudes, beliefs and perceptions to learning environments around their own learning experiences there, and the role that technology should play in it.

Technology Use in Education and the *New* Digital Divide

Alarmingly though, the PISA found that the frequency of ICT use at home is not paralleled by use at school, and in most OECD countries, more than 80% of 15 year-olds use computers frequently yet a majority do not use them much in school (OECD, 2010a). While most schools are equipped with computers and internet access, this disparity between school and home use is immense, and suggests that the old digital divide has been replaced with a new one—those who can develop the appropriate competencies with ICT, often occurring outside of school. Much of this at-home use is oriented towards entertainment, suggesting there is an increasing role of schools to help learners engage with and leverage new

technologies for *learning*. Exposure, access and fluency with ICT matters, as PISA analysis demonstrates once socio-economic background is accounted for (OECD, 2010a).

The Opportunity

Once thought of as just a part of 'resources', we've come to see how technology can be so much more than that. It can play a key role, and at times a leading role, in all elements of the teaching and learning environment. Technology can shape, and reshape, who is the learner and who is the teacher. It can open up knowledge and content that otherwise would be less accessible, through access to open educational resources for example. It obviously is part of 'resources', but it is clearly integral to the 'organisation' component insofar as it offers a critical mediating medium for those relationships of pedagogy and assessment inherent in organisation.

The depth and breadth of technologies available today affords learning environments much diversity and opportunity for leveraging ICT as a throughline for educational change. Intersecting that with the incredible array of learning environments across the globe, we are left with a spectrum of examples of this—thereby giving us a complex picture of what technology-rich learning environments are, and could, be. UNESCO's Institute for Information Technology has evaluated the degree to which ICT has been integrated in an educational system by applying 'Morel's Matrix'—a model that proposes an educational system moves between four distinct phases: (a) emerging, (b) applying, (c) integrating, and (d) transforming (UNESCO, 2003). A given learning environment or education system can be mapped onto the matrix by being evaluated on various dimensions, such as content, pedagogy, curriculum, etc. (see Table 1).

Criteria/Phase	Emerging	Applying	Integrating	Transforming
Vision	limited, pragmatic, dominated by interested individuals	driven by ICTs specialists	driven-by subject specialists	entire learning community involved
Learning Pedagogy	teacher-centred	teacher-centred; ICTs are separate subject	learner-centred; collaborative	critical thinking; preferred learning styles; collaborative, experimental
Development plan and policies	accidental, restrictive, no planned funding	limited; centralized policies	individual subject plans for ICTs; permissive policies	ICTs is integral to overall school development plan (budget, professional development, etc.)
Facilities and resources	limited and non-current digital resources; restricted access	diverse and varying in model, platform; aligned with specific content and pedagogies	diffused access to various digital resources; supports to implement these in various ways	whole school learning and diverse learning environments; web-based learning spaces, distance education, student self-management software
Understanding of curriculum	ICT literacy; responsibility of individual teachers	use of software and applications in discrete subjects (isolated)	integrated; resource-based learning, problem-solving project methodology	Virtual and real time contexts, modeling; integrated curriculum delivery via the Web
Professional Development	individual interest	training on ICT applications; unplanned	subject-specific; evolving	Integrated learning community; innovative; self-managed, personal vision and plan
Community	accidental	some parental and community involvement	subject-based community, providing occasional guidance;	broad-based learning community involving families, business, industry,

			global and local networked communities	organizations, universities, etc.; school as a learning resources for the community
Assessment	responsibility of individual teacher; didactic; paper-and-pencil based	teacher-centred; subject-focused	learner-centred; subject-oriented; integrated; multiple media to demonstrate alignment	continuous; holistic, open-ended, project-based; learning community involvement

Table 1. Examples of Stages in Morel's Matrix (adapted from Centre for Research on Lifelong Learning, 2009).

Evolving • Transforming • Reinventing

These stages offer us a lens through which we can observe how ICT has leveraged incremental and deep change in learning environments (see Figure 1a). The first three stages represent learning environments using technology to *evolve*—using technology, at varying degrees, as a means to make advances towards more digitally-rich, 21st century learning environment. Schools that seek a more holistic change and dramatically overhaul the existing environment have leveraged technology to completely *transform*—where all elements of the learning environment become new as they drive towards this new vision.

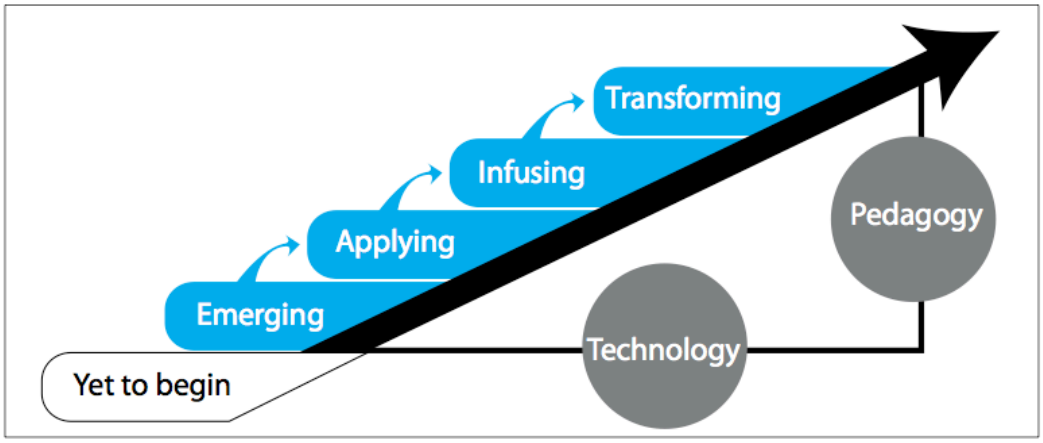

Figure 1a. Stages of ICT Integration in Education. Reprinted from Anderson, J. – UNESCO Bangkok, 2010; based on Anderson and van Weert (2002) and Majumdar (2005).

Be it big or small, emerging new evidence of technology use or completely transforming whole learning environments, education systems and schools that fall into these categories are using technology at varying degrees to move in the direction of the 21st century. However, there are a number of learning environments going beyond this, to *reinvent* the fundamental model that drives their organization of learning and teaching. In this way, they transcend 'transformation through technology' because technology is not used as a lever, but rather, used to appropriately fill in the methods and approaches in their redesign (see Figure 1b).

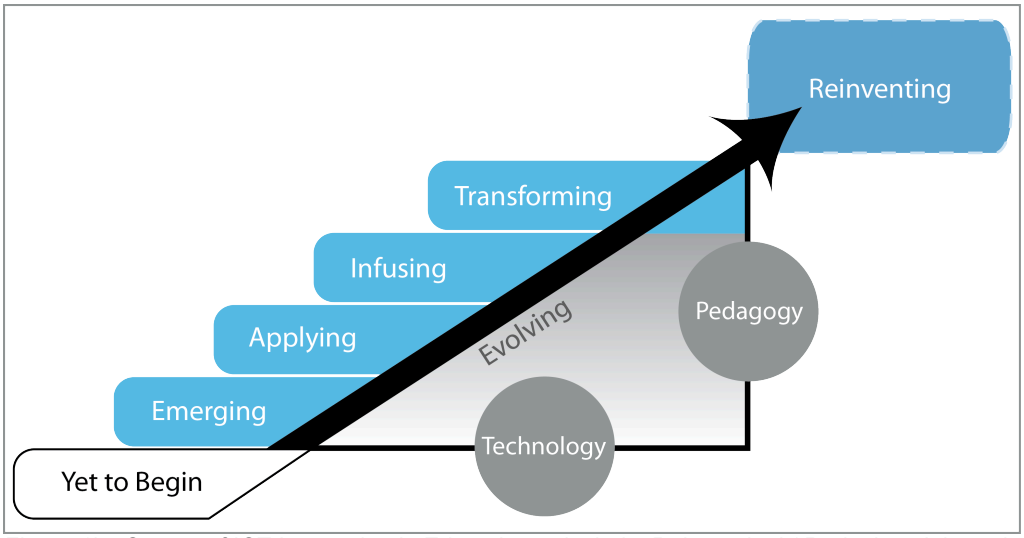

Figure 1b. Stages of ICT Integration in Education to include 'Reinventing' / Redesign. Adapted from Anderson (2010).

TECHNOLOGY *EVOLVING* LEARNING ENVIRONMENTS

Meeting this challenge and opportunity for current schools operating in existing systems—that are inherently bounded by instituted policies and structures—can be quite difficult. For these schools that wish to make dramatic advances in practice, new technologies and innovations can be critical levers for small changes that can ultimately lead to bigger change. Some of the web-based innovations that have become quite pervasive in the larger digital culture of our world fit seamlessly into current curricular structures and programs, and are often free and easily accessible. What we describe as 'first-order' innovations are prevalent among many technology-rich learning environments, being implemented under the notion that by leveraging many of these tools together produces a dramatically different educational climate. Other technologies are more 'disruptive innovations,' appearing on the periphery of the educational landscape and are just beginning to see their full potential. These 'second-order' innovations are slowly gaining attention and traction in the field, and will likely see increased development and application over the next decade (see Figure 2).

First-Order Innovations	Second-Order Innovations
blogs, wikis	augmented reality (AR)
social networking sites	simulations
virtual learning environments (VLE)	digital games
laptops, netbooks and tablet PCs	console games
interactive whiteboards	remote-response systems
Web apps	mobile/handheld computing
digital cameras, scanners, projectors	programming applications
e-Learning	pico projectors
digital portfolios	electronic books

Figure 2. Common and emerging innovations of technology-rich Innovative Learning Environments

Many of these first-order innovations fall in the category of "Web 2.0" technologies—a collective term for the "social web" representing the online tools that facilitate collaboration, communication, and interactivity. These tools access many of the key "21st Century Skills" and represent many of the activities for learners outside of the school. As a result, these technologies make a natural on-ramp for evolving a learning environment. Yet even more critically, Web 2.0 technologies embody the perspective of many educational technologists and theorists that learning best takes place within technology-supported environments where learners individually and collaboratively consume and create content (Selwyn, 2010).

Evolving Educational Change: *A la Carte Method*

For traditional learning environments and educational systems, these innovations offer powerful tools to improve teaching and learning within an existing structure, where other instructional elements (such as curriculum, assessment, etc.), may not have the freedom to be altered considerably. While many schools are selecting at least several of these first order innovations to keep their practice evolving, some schools are integrating an array of these and more in an effort to become a digital learning environment. Learning environments that have take the A La Carte approach often started in the 'emerging' phase, and have progressed to the 'adapting' and 'integrating' phases. **Saltash.net Community School** (UK) is an example of one such school, which has gone so far to become digital that they changed the school's actual name to match their website address. At Saltash.net, technology can be found everywhere:

- over 400 workstations, embedded with over 200 software applications
- 90 laptops and 40 netbooks, student-accessible on the school-wide wireless network
- interactive whiteboards
- media suite for video/audio production and editing
- integrated Moodle VLE
- school radio station

Saltash.net uses this technology to power student research projects, collaborations and inquiry projects with schools located internationally, and conduct learning both in and beyond the school boundaries. Schools like **Saltash.net** (UK), **St. Paul's Bay Primary** (Malta), and **Crescent Girls' School** (Singapore) are just a few examples of countless learning environments that have embraced new technologies in such a holistic manner. These learning environments are weaving technology into the school, evolving the teaching and learning to provide more opportunities, via contemporary methods, at achieving 21st century learning aims. Successes and impacts at schools like these are feeding back into the larger systems in which they are situated, assisting in the further progression of that educational system and other learning environments within it.

As highlighted by research conducted at many schools such as these, success with integrating first-order and second-order innovations largely depended on the rigidity or flexibility of the school curriculum. In fact, many are finding the need to redesign curricula models that are less prescribed and driven more by learner needs using Web 2.0 technologies; all of this requires educators to expand their visions of pedagogy and learning (Selwyn, 2010).

Evolving Educational Change: *Technology as Backbone*

Other learning environments have latched on to one of these innovations and made the key catalyst in changing practice. In this approach, the learning environment mostly likely began their approach in the 'applying' or quick often, the 'integrating', phase. A prime example of this approach is demonstrated by the many schools that have engaged in a 1-to-1 laptop initiative—where every learner in the school is given (or has daily access to) a laptop. In such learning environments, this certainly drastically changes what types of learning experiences are possible, and preferable. A prominent example of this is the US state of ***Maine's Learning Technology Initiative***, which has been active for nearly a decade and garnered much attention in the west on the impact of ICT at this level of integration. This program has grown and evolved over that time, placing varying technologies in the individual hands of all learners in grades 7-12. The cost versus outcomes for such initiatives has been the focus of much debate, as is whether programs like this have really achieved the 4th stage, 'transformation,' and whether this serves as a strong example of *evolutional* or *transformational* change. Maine's initiative and other 1-to-1 programs are discussed more fully in Figure 3 on page 15.

A very different and intriguing example of the impact of embracing one of these innovative technologies is the sweeping trend of console-gaming in Scottish schools. Scotland has long been known for its innovative practices and integrated curriculum, so while many of these Scottish schools were strong learning environments prior to adopting game-based learning (GBL), this new pedagogy has helped evolve these schools to digital, integrated and engaging 21st century learning environments. Operating on the belief that console games afford incredible pedagogical opportunities, ***Scotland's Consolarium*** is a centre that has supported GBL in more than 20 schools across the country. This government organization seeks to examine games for educational uses and supports teachers in their exploration of these technologies. Examples and uses of GBL vary widely—from 4 year olds learning care-taking and visio-spatial skills with the game EyePet—to using Guitar Hero as the engagement tool, around which a complex project is built where teams of 13-year-olds form 'bands' and manage everything from the bands logo to its touring schedule and budget. With such a strong, engaging and motivating storyline, teachers have been able to construct robust interdisciplinary modules where students are gaining digital literacies, collaborative problem-solving, creativity and many other skills, while interacting with the latest technologies.

Schools adopting game-based learning are finding increased engagement and motivation amongst students, greater connections in the curriculum and transfer of learning demonstrated by students, improvement in collaboration strategies with students, and dramatic increases in the quality and quantity of student writing—especially amongst boys. How can a video game do all that? According to the experience of these schools, it comes the pedagogical approach applied with many of these games, where the game serves as the hook and storyline to connect the learning objectives and activities defined by the curriculum. (Groff, Howells & Cranmer, 2012). Games like Guitar Hero are used to set the stage, where students are placed in groups of four, or 'bands', and are charged with the making their band a success—everything from designing a band logo and first CD cover, to structuring a budget for the world tour and using online websites to arrange the travel required to make the tour happen. With the game as a thread line, teachers are reporting

seemingly endless opportunities to construct and connect rich learning experiences that connect to the project objectives. Actual game-play time is intermixed throughout each school week, with less than 5% of class time consumed by this activity—yet that is enough motivation and engagement to have students taking classroom tasks home to continue their development, above and beyond class goals. Many schools that have piloted this pedagogy are so inspired by the success it is quickly becoming the lifeblood of the school, and has led the Consolarium to consider further ways to integrate and diffuse this technology.

Whether laptops or console games, a powerful technology combined with a strong pedagogy is a recipe for advanced teaching and learning—and the vast array of innovations and technologies available and continuing to emerge leaves the potential for endless possibilities for evolving education. However, as often understood by most educational technologists, the key is to put the horse before the cart, and understand the type of *learning experiences* and therefore pedagogies that are sought, following by asking the question as to what type of technology can enable that.

Learning environments using the *a la carte* method might generally find themselves in the first two stages, 'emerging' and 'applying,' although it is clear that schools profiled here have moved to the 'integrating' stage. However, systems that use *technology as backbone* for the work, more frequently need to engage at stage 3 – integrating – with practices generally present at stages 1 and 2 being lumped into the work.

TECHNOLOGY *TRANSFORMING* SCHOOLS

Innovative technologies not only have the potential to evolve pedagogical practice, but also completely transform entire learning environments. When technology is leveraged with a very strategic vision and change management plan, the results can be revolutionary. **Intermediate School 339** (USA) is one learning environment that has demonstrated this potential, transforming itself from some of the lowest performing schools in the region, to one of the most successful. A struggling school in the heart of New York City, Intermediate School 339 is situated in a difficult community culture—faced low test scores, violence and gang behavior in school. In 2005, only 9% of students were performing at adequate levels in mathematics. The school decided to infuse technology into teaching and learning by supplying every student with a laptop and implementing Google Docs as the main form of content management. With the laptops, students would complete homework online, manage their blogs, collaboratively manage data and use teacher-created online platforms to support project work. Interactive whiteboards in the classroom allow students to seamlessly share their work with the entire class. After three years, math scores have gone up to 62% and violence and behavior issues have decreased dramatically. Students have reported increased motivation to do school work because the technology, and the work, is more stimulating—resulting in a demonstrated greater investment in their educational journey. Intermediate School 339's success is leading the way for school change for other schools in the New York City area.

The innovative **Silverton Primary School** (Australia) has a similar story. Faced with countless challenges and low-performing students, this struggling learning environment decided to capitalize on the statewide learning revolution led by the government that was

bringing with it a massive infrastructure investment and embarked on a large-scale transformation initiative and along with it institute a comprehensive plan for change. Silverton garnered many of the aforementioned first-order innovations, but Principal Tony Bryant's vision didn't just include technology. He envisioned, and subsequently engineered, a complete overhaul of every component of the learning environment—from classroom layout to teacher learning structures and support. Replacing traditional classrooms with flexible learning centres, students have access to digital music players, voice recorders, games consoles, digital cameras and notepad computers. They are even charged with the task of running a 24-hour local FM radio station.

Yet what makes Silverton Primary's transformation so dramatic is the change initiated in other critical areas of the learning environment. Along with a strategic teaching and learning transformation through new learning spaces, new technologies and new curricular approaches, Silverton Primary instituted a comprehensive teacher change and development scheme. This included enveloping new teachers in an intensive training program, to ongoing and long-term programs to support all educators as they continue to improve and refine their practice. All staff members are involved in a formal "Critical Friends" program where observation of each other's teaching is an essential component—videotaping each other and meeting regularly with Teaching and Learning Coaches and ICT Peer Coaches for regular feedback. Teachers even partake in action research projects, in order to more deeply engage in their practice. Today, Silverton Primary is one of 12 global mentor schools in the Microsoft Innovative Schools program, where they mentor schools in Portugal, the Netherlands, Ireland, Sri Lanka, Malta and Israel through fortnightly online meetings. Programs such as these not only help ensure that Silverton Primary's teachers are continually improving and refining their craft, but that they grow and evolve as the world they operate in does as well.

Such dramatic changes in so many areas of the learning environment wouldn't be possible without technology. In fact, technology can be used to structure innovations, *as well as innovating* – practices and approaches to continually created and testing new methodologies and ways of doing things – into a learning environment, which is an incredibly powerful means for approaching transformation. The **Shady Hill School** in Cambridge, Massachusetts (USA) used a two-year technology-infusion project – injecting laptops, projectors and various other digital technologies into the classroom – to also infuse the practice of *innovating* into the campus. In the first year of this project as the new technology was rolling out across campus, 13 teachers were selected to participate in the "Tiger Team"—a rogue set of teachers scattered across the grade levels charged with creating and engaging with new ideas for teaching and learning, and vetting them via "innovation cycles" of testing, reviewing, refining, and disseminating—both good practices, and failures, with digital technologies. These teachers receive considerable support and training as they explore innovative practices, and the school rotates who participates on the Tiger Team each year—systematically developing innovative practices into the very heart of the learning environment. The school even created its own "teachers-only" space fully decked-out with new technologies and at least one tech-integration specialist at all times. Affectionately called The Garage, it was designed to be a free play space, where it was safe for all teachers to explore, mess up, create and learn with new technologies. These practices not only make places like Silverton Primary and Shady Hill Innovative Learning Environments, but also continually *Innovating* Learning Environments.

There are countless examples of schools, situated in challenging contexts, which have made leaps and bounds progress by becoming a tech-rich learning environment. When properly integrated and strategically tied together, technology time and again shows to be a meaningful and powerful way to engage and motivate students in the learning process, *as well as* a means of catalyzing strategic change in pedagogy and practice.

These case studies also demonstrate the power of technology not only to change but also to *continually change* by structuring in the very nature of innovating as a collective system. While they may have started the process at Stage 1 (Emerging) or even Stage 2 (Applying), they have forged along in their journeys to arrive at Stage 3 (Integrating) and ultimately at Stage 4, *Transformation*. Silverton Primary best embodies this evolution amongst the stages, having gone from a challenging context with little student success, to testing new technologies to increase student engagement and learning, which ultimately triggered strategic modification of every element of the learning environment—from curriculum and time structures, to professional development. Truly, for this school, technology became the catalyst for completely transforming itself.

REINVENTING LEARNING ENVIRONMENTS

The examples thus far of leveraging technology to facilitate incremental and transformative change of existing learning environments is indeed inspirational. Yet what type of learning is possible beyond the boundaries of existing systems and policies? What is possible when existing paradigms and old frames of mind can be discarded, and potential new possibilities take their place? Going back to our original question, *How can today's schools be transformed so as to become environments of teaching and learning that makes individuals lifelong learners and prepare them for the 21st Century?*, it's clear that the answers to this question may not come from existing educational systems. In answering this question, educational innovators and social entrepreneurs are continuing to reinvent what 21st century learning might look like, as well as the learning environments to support it. For these reinvented learning environments, meeting this aim inherently means leveraging technology to do so. Unlike the cases presented thus far, the learning environments presented in this section did not move along the stages of ICT Integration to arrive at an innovation place, rather they took to the drawing boards and designed new environments, strategically, from the ground up. In this way, technology is not used as a lever to produce changes, great or small. Rather, the learning environment is strategically designed to align the desired elements and ultimately produce the desired outcomes, and technology is often found as one of the enablers for that reality.

Over the last several years there has been a steady increase in the approach of redesign of learning environments—both old and new. What is redesign? It is the strategic and holistic design of elements in a system to align with our understanding of best practices and current needs to produce desired outcomes (Groff, 2009). What does this look like in practice? A prominent example is the work of 2Revolutions, an education design firm in the US that works with existing learning environments to "unthink school to rethink learning". Operating under the belief that the traditional models of schools were designed to meet needs that no longer suit us, 2Revolutions takes select schools through a process of rethinking *all* elements of their current educational model—from classrooms to grades to curriculum, everything is on the table for redesign. The schools go through a rich process of

learning about current technologies and pedagogies, as well as innovative best practices, and ultimately put together a new design where all of the newly designed elements work together to create a "2.0" version of the learning environment.[1]

Meeting Students Where They Are, Wherever They Are: Virtual Schools

With an ever-increasing number of struggling students, matched by the challenge of a growing number of students dropping out of school or unable to attend for various reasons, the state of Florida faced a significant challenge: how to provide appropriate learning environments for all learners, not just the mainstream. The agreed upon solution was to create a *virtual school* – one of the first in the world at that time – to be part of the public statewide education system. Since its genesis in 1997, the **Florida Virtual School** (or FLVS) (USA) has grown considerably, with more 1400 staff members offering more than 110 online courses to students ages 12-18, which are free to Florida middle and high school students.

Priority is given to students who need expanded access to courses to meet their educational goals—such as home-schooled students as well as those at low-performing schools or those at schools with limited offerings. In the 2010-11 school year alone, FLVS has served over 122,000 students in the United States and 57 other countries. FLVS's success has allowed the learning environment to expand its model, offering courses to those around the world for a tuition fee, and has inspired the creation of many similar online learning platforms, particularly in other US states. Yet with the success comes inherent challenges, including teacher training for online course facilitation, which often requires more individualized attention than is typically given in a traditional learning environment, as well as monitoring course quality—which can vary considerably in the diverse menu offered by FLVS.

While the online platform loses the social classroom component, learners gain considerable flexibility in how to meet their learning goals—making the real success of the FLVS model that it allows students to *learn at any time, any place, any path, and any pace*. This flexibility is often found to be most successful with independent, motivated learners. Although individual learners tend to seek out these courses on their own, more and more schools in Florida and beyond are taking a *blended learning* approach—mixing traditional classroom learning with online courses to augment each learner's individual learning journey. Such an approach retains the countless benefits of a real-world learning institution, often felt to be a critical component to any community, while better serving the needs and goals of each individual learner.

The e-Classroom at **Primary School Škofja Loka-City** (Slovenia) is an excellent example of such blending learning for younger learners. The e-Classroom provides a virtual environment for more diverse activities and differentiated learning opportunities, connected to classroom study. It provides an additional vehicle for communicating with students, and

[1] See http://www.2revolutions.net/future-of-learning.html for more information.

amongst students themselves. This platform has assisted in helping learners acquire key competencies in numerous content areas as well as critical skills such as communication and self-initiative.

One of the strongest benefits of an online learning platform is reaching marginalized populations, such as teenage mothers, those who may be quick to exit school prematurely or those who have repeatedly failed completing compulsory education. **Escola Móvel** (Portugal) is a distance-learning project that provides learners with access to a learning environment that supports the national curriculum. With the opportunity presented by this new platform, Escola Móvel has also innovated in other ways as well—including the creation of new interdisciplinary pedagogies and compulsory tutoring periods, which allow for the personalization of curriculum, instruction and assessment, thereby increasing the students' likelihood of success. Virtual and blended learning models will become increasingly prevalent in education as educators seek to better individualize learning for all learners.

Building Learning, One Tile at a Time: LUMIAR Schools (Brazil)

Who needs teachers, classrooms or traditional curricula? Based on the success demonstrated thus far, Lumiar Schools don't. The founders of the Lumiar Institute came together to devise a new approach to education—one where students' innate capacity to learn is allowed to flourish, and students will develop the skills and capacities necessary for our knowledge society. After much planning, designing, and the creation of technological tools, the first Lumiar School in São Paulo was opened in 2002, built on this fundamental assumption: learning is the *individual* building and expanding of competencies and skills. Consequently, the "curriculum" is a Competency Matrix, which encompasses the learning expectations for all students. As students engage in various learning projects, the appropriate competencies are observed, assessed and documented in their Learning Portfolio, which is then used to help guide selection and adaption of future learning experiences for that learner.

There are no classrooms at Lumiar, just open spaces where student inquiry can take place. Various types of technologies, including interactive whiteboards and laptops, are the central tools in these learning spaces. Likewise, there are no teachers in the traditional sense—rather this role has been divided to two groups at Lumiar: Tutors and Masters. Tutors are the academic managers for the same group of students, year after year, to monitor and assist them in their work and development. Masters are employed short-term, are experts in the areas of research and study embarked upon by the students, and lead a specific project or unit of enquiry. The Project Database contains a growing set of learning projects to be facilitated by Masters—the vehicle for helping each student cultivate his or her competencies.

Without traditional structures such as a formal curriculum and classrooms, how can teaching and learning be organized and managed over long periods of time? The answer lies in Lumiar's lifeblood technology—*Mosaic*. This complex learning platform developed in collaboration with Microsoft, connects the Competency Matrix, Project Database, and Learning Portfolio to assist in mapping the skills and competencies covered in the matrix over time for each learner. Such an integrated toolset has allowed Lumiar to become increasingly effective at personalising learning for all. As a result of this impact, the Lumiar

approach has been well-received by the São Paulo community and the larger educational field. This preliminary success has led the Lumiar Institute to partner with two additional schools in the São Paulo area, with plans to continue expanding and developing the Mosaic model.

Taking Students Everywhere: THINK Global School (International)

How do you build a global citizen? You entrench them in rich learning experiences around the globe of course. That's the ambitious aim of THINK Global School (TGS)—a private high school that travels around the world, providing students with the opportunity to study in three different international cities each academic year. After extensive design and development, the school is now ready to officially launch in the fall of 2010. Students were selected from around the globe to attend this school, and developing global competencies such as curiosity, tolerance and resilience are the core aims. While TGS has coordinated a venue at a host school in each city to provide space for classroom study, the world truly is their classroom—where learning is cultivated by exploring the local culture, contexts, and challenges of each site. Therefore much learning will take place outside traditional classroom walls and occur directly "in the field." In designing TGS, it was clear that being mobile on both the micro and macro level meant no room for textbooks. Each learner is equipped with the latest MacBooks and iPhones to record, report and share experiences in real time via the TGS educational social networking program. Students will be able to access their content and learning materials anywhere, anytime. Like many professional workers in today's business world, these technologies will become extensions of their work and cognition—essential to completing their academic work. The integration of these tools provides a seamless connected web of learning that has the potential to become an internalized extension of their cognitive journey around the world.

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These reinvented learning environments are just a handful of the emerging new models of how learning and education can be achieved in the 21st century. In these examples, one or (often more) multiple facets of the system have been completely *reinvented* and *redesigned*. Assumptions that a certain element (such as curriculum or assessment) must 'look' a certain way are removed and instead the questions "what do we want to achieve?" followed by "how might we achieve it?" become the drivers for designing new learning environments. It's clear that getting to the answers of the former question are unlikely without technology being involved in the answers to the latter.

OPPORTUNITIES & CHALLENGES OF EVOLVING, TRANSFORMING, AND REINVENTING LEARNING ENVIRONMENTS

Each of these approaches are very different, and bring their own opportunities, benefits, costs and challenges to a given situation, and therefore each learning environment that seeks to make change will likely be better suited for one approach versus the others, depending on their current context, goals, vision for the future, etc.

Learning environments that seek to *evolve* by integrating or implementing new technologies and technology-based pedagogies with old ones usually find less resistance from the current system, as this is the least disruptive of the approaches. Since the professional staff in a given context generally has a range of aptitude and comfort level with new technologies and approaches, the evolution approach allows each professional member of the staff to find 'on ramps' to new technologies in a way that is easiest and most accessible to them. For example, the science teacher may feel most drawn to simulations that relate to her curriculum, while a primary teacher may personally use Web 2.0 technologies quite frequently, and therefore see how to easily integrate them into his classroom. While often more approachable for the organisation as a whole, in some instances this can become an 'ad hoc' endeavor where there is little strategy or synergy across the organisation in the leveraging of new technologies—unless other supports are put in place, such as a tech-integration teams who can coordinate the sharing of practices and overall strategy of the organisation. With or without external supports and strategies, and whether or not a learning environment takes an *a la carte* approach by integrating new technologies and methodologies here and there, or a more systemic approach around one specific initiative such as game-based learning, the evolutionary approach is often very slow-moving and will take years to produce extensive change. Additionally, effectiveness of such approaches is often dictated by institutional factors, such as the rigidity or flexibility of the curriculum (Selwyn, 2010). As a result, many of these innovations conform to the shape of the existing system – many times at the detriment to their effectiveness – rather than helping to change the shape of the existing organisation. The research on one-to-one laptop programs has even demonstrated, depending on the approach and implementation, even sites where the primary goal and work is to redesign the other elements of the learning environment using the laptops as the lever and backbone of the work, the central organisational structures will not change (Bebell & Kay, 2010).

This, in part, pushes advocacy towards *transformative* or *reinvention* of learning environments—not only as a lever of deep change, but also to successfully integrate new technologies and 21st Century Skills. As described by Neil Selwyn in the recent OECD publication, *Inspired by Technology, Driven by Pedagogy*, "the education technology academic literature, at least, is increasingly featuring the promotion of reasoned arguments that all of the structural impediments and challenges to technology (*i.e.* school) must be removed in order to facilitate the realization of the digital transformation of education" (OECD, 2010, p. 29). Although not a universally-applying statement, the evidence from observing many learning environments' attempts to *evolve* is that true effectiveness comes from coordinating and/or redesigning all of the parts of the infrastructure in concert together.

Learning environments that ultimately seek transformation will need a well thought-through approach to the process, garnering the resources (both human and technical) needed to support the school's advancement through the stages, that is, most importantly, underwritten by a clear and collectively-agreed-upon philosophy of how students do and will learn there. While no large-scale change project can be inherently planned from the beginning, what schools like Silverton Primary demonstrate is the creation of steadfast vision of what the learning environment might become, and an unwavering passion and commitment to do what it takes to see it through. Detailing this is beyond the scope of this paper, yet what we wish to underscore is that true *transformation* is possible, and while certainly hard work is required, such a goal is within reach for any learning environment.

Yet, what about *reinvention*? Is this relevant for existing learning environments? Schools like the ***RSA Academy*** (UK) show that it is. Formerly Willingsworth High School, the RSA Academy is an independent school sponsored by Britain's Royal Society of the Arts took over the school in the mid-late 2000s. After having spent the better part of a decade working on collectively redesigning what a new curriculum might look like that prepared today's young people with the competencies needed in the 21st century, they called this curricula "Opening Minds", and it became the life-force around which a school was to be designed. All the organisational structures of the school, such as scheduling and student grouping, supported the design of the curricula. In 2008, the new Academy opened in the building that was formerly a public secondary school with great success. Just three years later, the school opened it new building, designed fully to support the learning experiences shaped by the Opening Minds curriculum. As of date, student performance has been outstanding with 100% of the school's students achieving the highest level on their national exams (the GCSE).

The RSA Academy is just one example of what is possible by holistically and cohesively redesigning all of the elements that interact to create a learning environment, and the outcomes of the school demonstrate that it was well worth the time and effort.

The Opportunity-Cost of the Investment

Undoubtedly, technology often implies a significant investment, both financial as well as in human capital. Although there is a general recognition that ICT is pervasive in our world, and therefore of use to some degree to students, there is still considerable debate amongst various education stakeholders and policy-makers as to the need and degree of investment of ICT in education, and the value of the return on that investment. While the learning environment examples presented may feel like outliers of the mainstream and more than what is possible/likely for most schools, rather they are holistic depictions of the implications of ICT observed across many learning environments as illustrated by the research. Numerous far-reaching analyses of the impact of ICT in education have demonstrated significant positive outcomes on teaching practices, leadership and school organisation. The PILOT program in Norway is one such example. This four-year research study involving over 120 primary and secondary schools showed that the schools handled the implementation if ICT in very different ways, and numerous positive outcomes manifested, including increased writing activities and competencies with ICT, and ease of transition between school levels (for full discussion of the outcomes, see Erstad 2009). This has, however, been one of the more robust studies of the impact of ICT in education, and the lack of coherent knowledge base around this has been a central argument in the debate about ICT (Kikis, Scheuermann & Villalba, 2009). Likewise, connections between home and school ICT use and student performance on items like the PISA are complex and undefined. Many have attributed this to the complexities of the dynamics in the system and the need for more and better methodologies and indicators (Trucano, 2005).

INDIVIDUAL ACCESS TO TECHNOLOGY: A LOOK AT 1-TO-1 PROGRAMS

Many have understood the need for individual use and adoption of technology in learning environments, and "one-to-one" initiatives – where each student has access to a laptop, tablet, etc. – have become a popular approach in the past decade. As the name might suggest, they are expensive and intensive to create, deploy, manage and effectively leverage for increased student learning. However, the results on their effectiveness have been mixed.

Some positive effects demonstrated have been more engaged learners, observing a decrease in disciplinary problems, increased technology skills, as well as improved writing and math scores (Shapley et al. 2009). Yet, for example, it is difficult to differentiate whether these improved scores came from the use of the technology in teaching and learning, or from the advanced teacher training that was instituted with the program—or both. Additionally, some large-scale evaluations have shown disappointing results. For example, five years into the ***state of Maine's laptop initiative*** (the largest in the United States), showed little effect on student achievement in general discipline areas such reading; however, the evaluators note that the metrics used did not measure the "21st Century Skills" that the initiative espouses to promote (Silvernail & Gritter, 2007). Evaluations from other large-scale initiatives in the US demonstrate mixed results, noting some improvement in various areas of each of the sites. These conflicting results leave researchers timid to wholeheartedly endorse large investments in ICT in education, and they reinforce the notion that these programs are only as effective as the system that is implementing it. In fact, one evaluation explained, "It is impossible to overstate the power of individual teachers in the success or failure of 1:1 computing" (Bebell & Kay, 2010, p. 47). So, like many other technologies and technology-initiatives before one-to-one programs, it is much less about the technology and much more about how it is used. Therefore, the conclusions on one-to-one initiatives are framed well by Bryan Goodwin (2011, p. 79): "Rather than being a cure-all or silver bullet, one-to-one laptop programs may simply amplify what's already occurring—for better or worse."

Figure 3. The insights gained from 1-to-1 initiatives.

Additional analyses of extensive investments in ICT in education like those of 1-to-1 programs described in Figure 3 are certainly "cloudy" in their implications. However, this literature does in fact co-exist with the aforementioned findings of other ICT initiatives, along with a considerable array of other research studies (more often qualitative) that ICT can in fact improve children's knowledge, skills and competencies (Blamire, 2009). In fact, an in-depth analysis of the available knowledge base of ICT in education has shown that attainment improves only if certain pedagogical conditions are met (Kulik, 2003)—which supports the findings described in Figure 3. This debunks the myth that technology itself is a magic bullet. ICT is often a catalyst for change but does not itself determine the direction for change (Kikis, Scheuermann & Villalba, 2009). Dubbed the 'student productivity paradox' (Peslak, 2005; Hikmet, Taylor & Davis, 2008), it is the observation that technology can be used for a variety of purposes in education, yet whether that is linked to educational performance or not depends on the improvements associated with changes in methodology, which require appropriate technical and pedagogical support (OECD, 2010a).

This reinforces the notion that the philosophy of learning and pedagogical approaches truly embodied by a learning environment at its core is what ultimately impacts student learning; however, technology has demonstrated its ability to leverage powerful learning

methodologies in ways that are much more difficult, or impossible, without it. This is evidenced countless times by the cases presented here.

The benefits of ICT-driven education outlined in this paper – *engagement & motivation, student-driven learning & inquiry, interactivity & collaboration, personalisation & flexibility,* and *innovating* – are all enabled and enhanced with ICT. They are of course possible without ICT—you can still engage and motivate, personalise learning and facilitate collaboration, without any technology at all. However, at scale, technology greatly increases our opportunity and capacity for these outcomes. Yet, what affordances and opportunities are only possible through technology? Some we have identified include:

I. **Specific & Alternate Experiences** – Some learning experiences are just impossible (or nearly so) without technology. For example, with new advancements in simulation technology, every student can have the chance to conduct the dissection of a pig heart—something that would be very difficult if even possible for every school to conduct in reality. Or, students could investigate the spill of an unknown substance on MIT's campus, as is created by the augmented reality game *Environmental Detectives.* Online immersive world's such *The River City Project* allow students to virtually time travel and interact with avatars from a different era in order to solve a problem.

II. **Distant Communication, Connection & Collaboration** – Before, student groups were largely confined to those within proximity—those in your school or local community, or perhaps another classroom on the other side of the globe with whom you were a pen pal. Now, however, schools can easily connect to share information and collaborate via free tools like Skype. A student interested in studying the migration patterns of a certain bird may have been confined to personal study before; today they can join an online affinity group and easily get mentorship from the world's top expert in this area. New technologies create connections and collaborations that before would not have been possible.

III. **Mobility** – Education generally consisted of going to where the learning is; but today, you can take the learning with you. Schools like THINK Global were unimaginable just 10 years ago. New technologies are mobile, and free the learner from being constrained to traditional learning environments—as also evidenced by augmented reality, where digital information arrives on mobile phones to students who are in a real-world environment outside of school.

IV. **Access** – Along the lines of mobility, ICT now brings access to educational materials and experiences of a richness and kind that previously would not have been possible, or accessible only in discrete locations (such as a university library).

WHAT TECHNOLOGY BRINGS TO THE TABLE: Richer, Deeper, *New* learning

The research discussed here explains that when designed and integrated properly, ICT can be a critical vehicle for accessing what we know to be the keys to deep learning, and the payoffs come performing new functions and experiences that are reflected in

transformations of processes (OECD, 2010a). The aforementioned examples of tech-rich learning environments have demonstrated how the appropriate design and leveraging of technology has impacted multiple dimensions of learning, teaching and practices in education:

Engagement & Motivation. Set foot inside any one of these tech-rich learning environments and the engagement level of students is through the roof. There is extensive evidence that ICT increases motivation, confidence and engagement (Blamire, 2009). For students, the technologies listed in Figure 1 are exciting and stimulating in their own right—but even more so when appropriately linked with their own innate curiosities. Schools like Silverton Primary and Intermediate School 339 cite this as one of the core reasons student achievement has risen, and student violence and disruptive behavior has decreased. The impact of game-based learning in Scotland has demonstrated the same outcome of dramatically increased engagement and motivation—illustrated by the large extent that students' work on academic projects outside of school time, often above and beyond what was required. Several students involved in this game-based learning initiative even noted the curious effect of decreased game play at home, explaining that playing games at home has become less enjoyable than what they do in school because it lacks the collaborative project associated with the school game play—such as accurately plotting the band's budget to ensure success in the Guitar Hero project, or understanding exactly "what was the fish we came across" while playing *Endless Ocean*[2] in class (Groff, Howells & Cranmer, 2010).

Technology is of course innately eye-catching to most individuals; however it is especially so to young minds, particularly since these young minds have only known a digital world. In other words, it's engaging because it's what they know, and therefore if much of their *modus operandi* in school is not digitally-based, it can be considerably challenging for learners to stay engaged. To them, there is no world without digital technologies. So it is no wonder then that students' engagement and motivation would skyrocket if they suddenly had ubiquitous, or even semi-ubiquitous, access to digital technologies in their daily life as a learner.

Student-driven learning & ***Inquiry***. While technology alone may be engaging and motivating, deep and lasting learning certainly requires more than just exposing students to such innovations. The way learning experiences are structured with technology is the key, and clearly it is what the Scottish students were referencing when they described the level of enjoyment of game-play in classroom versus at home. Dubbed "authentic" learning, student-driven inquiry is seen as being able to engage learners more deeply on more complex tasks than other types of pedagogy. More and more research is not only demonstrating that student-inquiry leads to lasting learning and higher performance, but it is the pedagogy necessary to access 21st century skills like collaborative problem-solving and critical thinking (Barron & Darling Hammond, 2010). Such pedagogies are often also referred to as *project-* or *problem-based learning*. While technology is certainly not mandatory in order to access this kind of pedagogy, it most certainly helps, and in three distinct ways: *tools*, *means*, and *mechanism*:

[2] Endless Ocean is a video game for the Nintendo Wii where the player takes on the role of a scuba diver, progressively exploring various aspects of ocean life as the player becomes more experienced at scuba diving.

Tools. When conducting a student-driven, inquiry-based project, technology can provide the tools necessary to complete the investigation. Digital cameras and video recorders can collect real-time data, while laptops can offer easy access to online searches and mobile computing. The available toolkit of digital technologies to be used in this way will continue to grow and better facilitate this pedagogy.

Means. Technology can also be the means of inquiry-based learning—providing a collaborative working space or mechanism for progressing the work over time—as individual learners, groups of learners, and collectively as a whole class. A Virtual Learning Environment (or VLE) is an excellent example of this. An online space where students can organize their own learning and work, the can also collaborate with others around a problem or project and collectively grow the knowledge and outputs that define a true 'community of learners.' This is of course the goal of blended learning environments, where online platforms are purposefully created to augment the real-world learning experience. Likewise, the THINK Global School is an excellent example of how technology can be used to provide the tools and means for accessing student-driven enquiry. The endowed Macbooks and iPhones given to each student will be their learning tools in the "field" as well as the classroom, and the school-created social networking and collaboration platform will be the vehicle through which the learning is managed over time and space as the school travels around the globe.

Mechanism. Finally, technology can be the mechanism upon which inquiry-based learning is built—creating the on-ramp to the problem or project itself. In the example of game-based learning supported by the Consolarium in Scotland, the game is most often not inquiry-based at all, but provides the storyline or context upon which the project and inquiry are structured. Augmented reality games, online simulations and many other technologies provide similar mechanisms for structuring inquiry-based learning in a very engaging, and relevant, way.

Interactivity & Collaboration. Tech-rich learning environments also demonstrate the increased interaction with technology itself as well as other learners, and the increased collaboration in the learning process afforded by some digital technologies and pedagogies. Students working in teams to explore an interactive online simulation or co-construct a wiki of terms covered in the current lesson is a long ways away from learning from books that occurs with learners seated in rows; and this type of collaborative learning and construction is a central skill considered critical for the 21st century. It is akin to what is framed as the much coveted 'cooperative learning'—structured team learning that allows for individual inquiry that is synergistically connected to collaborative learning tasks, which produces deep, meaningful learning for all students (Slavin, 2010). This type of pedagogy is increasingly well-documented, and is viewed as a powerful strategy for increasing student achievement—particularly with 21st century skills and capacities.

Good teaching and learning can produce this type of interactivity and collaboration with less digital "technologies" but the ever-growing possibilities created by current digital technologies makes creating this type of study even more accessible to teachers and learners. Interestingly, many of the teachers involved in the Scottish GBL initiative had received training on cooperative learning several years prior to using console-games in the classroom, reporting that the game worked excellently for that pedagogy and that marrying the two

was a large part of the initiative's success. As our examples of tech-rich ILEs keep demonstrating, *combining documented learning theory and effective pedagogies with powerful digital technologies is a recipe for success.*

Personalisation & Flexibility. The essence of personalisation has been described as *the system conforming to the learner, rather than the learner to the system* (Green et al, 2005). Learning environments that are oriented towards personalisation are "highly sensitive to what the different students within it already know and can do, and actively builds on this sensitivity and knowledge – that is, it is highly adapted to individual differences *and* gives tailored and detailed feedback that both challenges the quick learners and supports those facing difficulties" (Istance & Dumont, 2010, p. 250). As most learning environments have experienced, this is a very challenging goal. Yet from a learning sciences perspective, it makes a profound difference, and we should be reminded that learners are already making personalized learning environments for themselves in their lives outside of school, through the use of digital technologies (Green et al, 2005). The proliferation of existing digital technologies, and the prospect of what could be created, provides outstanding possibilities for personalising education—be it with audio playback of a learner's tone and pronunciation that can be played back on a portable MP3 player as a he or she continues to improve their verbal reading skills, or a customized set of simulations for a given learner, based on their performance on an online questionnaire designed to test their existing conceptions of science concepts. Likewise, this personalisation effect is also possible in the area of assessments, which can also be more sophisticated as a result new advances in ICT-based assessments (Blamire, 2009).

The potential is immense, yet we are reminded of two caveats: one, investment in ICT does not directly and automatically correlate to personalised learning; and two, the infusion of technology into a learning environment can reinforce existing inequities in a given system (Green et al, 2005). Those withstanding, digital technologies offer an array of means for engaging with, and continuing to engage with, learning experiences. In learning environments where a menu of digital technologies is made available and is properly supported by teachers and learning facilitators, the classroom becomes a flexible learning environment that is able to adapt and conform to the needs, goals and motivations of each student. It goes without saying that no technology can replace a teacher, however digital technologies can be powerful tools to help teachers do their jobs, in a more effective and personalised way.

Innovating. The day when education no longer needs to *reframe – redesign – reinvent* itself is certainly not on the horizon; and indeed, that day may never come, as no organization remains successful when it stops learning, growing and innovating. Being an innovative organisation means much more than acquiring the latest technologies or trying a new approach. It means systematically structuring in programs and practices that promote healthy change, and new and improved approaches and the ongoing creative and productive advancement of both individuals and the organisation as a whole. Strategic 'innovating' practices include *implementing an "innovation cycle"* where new ideas are generated, implemented, tested and the knowledge is disseminated, *enabling champions*), and *changing professional development programs* from receiving knowledge through a workshop format to creating knowledge through *professional enquiry and research programs*. For existing learning environments that seek to become 21st learning environments, integrating such

practices and programs are the only way to truly achieve transformation (Sutch, Rudd & Facer, 2008). Technology can help facilitate innovating at the local context by bringing new ideas to educators, documenting and sharing practices, and connecting with other schools and professionals around the globe.

Digital Learning. Even if all of these benefits to leveraging technology-rich instruction weren't true, there's still one fundamental reason to pursue developing a technology-rich learning environment: *we live in a digital world.* The digital transformation is an unending tidal wave continuing to change how we work, communicate, play and conduct our daily lives. Not only is this the world our learners are currently immersed in, it will continue to progress and the world that is their future will be digital in ways we can't even begin to imagine. Learning environments today must be at least partially digital, not only to provide students with access to the tools and ways of operating that are infused in our world, but also to engage them in modes of learning that mirror their personal activity. The pedagogies and learning experiences described thus far connect with numerous cognitive competencies and capacities, but also with digital literacy—helping to develop critical skills to engaging with, consuming and producing digital media (Hobbs, 2010).

IMPLICATIONS FOR STAKEHOLDERS

At the very heart of any effective learning environment is *learning*—rich, deep, applied and transferable—building the capacity to be a lifelong successful endeavor for every person. Technology isn't necessarily an absolute requirement in order to access that goal, but it clearly can provide incredible support in doing so. As learners move through our learning environments and education systems, it can be a tremendous challenge to ensure such learning day in and day out for every learner. Technologies and innovations are an ever growing set of tools that learning environments cannot ignore—particularly in our digital world.

Why educational change – with technology – matters

Globally, there is a considerable need for educational systems to rethink their approaches. Investing in ICT in education goes beyond just making a more efficient or effective means of delivering education—it can produce an environment that creates and sustains an effective citizenry (OECD, 2006). The PISA, the OECD-led Programme for International Student Assessment, which evaluates the quality, equity and efficiency of school systems in some 70 countries, underscores *in particular* "the need for many advanced countries to tackle educational underperformance so that as many members of their future workforces as possible are equipped with at least the baseline competencies and skills that enable them to participate in social and economic development" (OECD, 2011, p. 3). This relates to the skills and competencies afforded by technology and digital literacy. The PISA demonstrates that many of the world's best-performing education systems are,

- guided by clear and ambitious standards aligned with high-stakes gateways and instruction systems,
- with a focus on the acquisition of complex,

- higher-order thinking skills;

- additionally, these systems "have moved from bureaucratic 'command and control' environments towards school systems in which the people at the frontline have much more control of the way resources are used, people are deployed, the work is organized and the way in which work gets done" (OECD, 2011, p. 4).

If systems of education seek to continually move in the direction of these characteristics, it will require systemically rethinking how we structure learning environments that embody them. Fortunately, the PISA and the examples of innovative learning environments included here show that there are many on-ramps towards moving in this direction.

Today's students present a paradox in helping us understand the best practices for moving forward and enabling their learning. As mentioned previously, the OECD's work on New Millennium Learners demonstrates an increasingly digitally-connected population, who use of new technologies shows a gravitation towards more personalized technology and experiences (Langridge, 2003). Effectively engaging and supporting today's students will mean reaching them in a more personalized manner, through today's digital technologies. Additionally, the research evidence suggests that there are varying profiles of how students interact with and leverage technology for personal and academic use (Pedro, 2009)—only further reinforcing the need for personalization. However, some research suggests that higher education students' technology use in general may be ever-increasing, but their beliefs about technology use for teaching and learning fall along a wide spectrum, and that some "students appear far more reluctant to technology adoption in teaching and learning than their levels of digital media exposure would suggest" (Pedro, 2009, p. 20). In fact, students' underlying beliefs about learning and learning experiences can present barriers to effectively using educational innovations and technologies in the classroom (Groff & Mouza, 2008). Taken together, these two elements initially present a challenge for understanding how to move forward. However, since the gap between students' everyday practices with digital technologies and those they experience in school should not and cannot persist, this would suggest that they also will need to be brought along on the pedagogical evolution (or revolution) that a learning environment and system may pursue. As a recent British report explained, like many educators, "students do not fully understand how ICT and learning can work together" (Ipsos Mor, 2007, p. 31), and their expectations of learning methods appear to be influenced more by prior experiences of learning in formal situations than by students' personal use of technology outside of educational settings (Littlejohn, Margaryan & Vojt, 2010). Although they may not have a clear vision of the new future of learning with digital technologies and they may or may not expect much variation in how we create learning experiences, it doesn't mean there isn't a gap often between their outside of school way of being in the world and what they experience in schools—as evidenced by challenges with engagement and motivation (Gutnick, Robb, Takeuchi, Kotler, 2011). Therefore, it is imperative that students are included in the co-construction of the vision of new learning environments and their subsequent change work and deployment. In this way, technology becomes not only a critical means for innovative learning opportunities, it becomes the vehicle by which learners, educators and all community stakeholders can partake in the evolution and transformation of the learning environment.

Overall, the dramatic changes in our society due to the impact of technology emphasise the need for collaborative, public debate and exploration of the implications for learning environments. As we seek to further digitally-enrich our learning environments, this agenda should include such items as learners' diversity, digital literacy, the new digital divides, the blurring boundaries between formal and informal learning, and the use of technology for monitoring and assessing learning (OECD, 2012).

Policy-makers

Generally, it has been observed that the broad array of ICT influence in education has had a systemic impact at the national level, demonstrating a "trickle-up" on national curriculum and policy. As learning environments continue to evolve, transform or reinvent themselves, it has forced the focus beyond understanding how we change a single school (meso level) to both the micro and macro levels—how ICT can deeply impact the transactions between teachers and learners, and how school systems experience change by implementing ICT (Erstad, 2009).

The contention over the existence and availability of robust data on the effectiveness of ICT in education and internationally comparable indicators is still ongoing. Many policy documents assert that the existing research data is inconclusive and insufficient to draw effective conclusions, while many other educational technology proponents argue that this proof does exist and we are wasting valuable time for support students' transformed digital learning. Combine this with the diversity of systems and the applications of ICT for learning, and it leaves a complex and confusing picture for policy-makers. However, we suggest the policy debate around ICT in education needs re-framing, to focus on more tailored educational policies and the systemic requirements for educational change. At the same time, policies must be rethought to support students who are unable to develop the competencies required to enhance their education by implementing technical skills on their own; this is what is meant those who argue for addressing the 'digital use divide' (OECD, 2010a).

The increasing push of evidence-based policy-making has been a large driver behind increasing efforts to generate evidence on the impact of ICT in student performance. While the complexity of the dynamics in this system has been the central reason the field has not produced more evidence, for or against ICT in this area, we cannot put our educational systems on hold while we wait for it. As the systems highlighted in this text have demonstrated, powerful results can be achieved by leveraging technology for learning environment innovation. At the same time, collectively we will benefit from building what Johannessen has described as "a sustainable and flexible knowledge base [which] requires a combination of quantitative and qualitative methods" (2009, p. 17). This intensified focus at both the micro and macro levels, in context with more evidence-based policy-making, has raised new national objectives for many systems, including further curriculum development, solidifying and standardizing technical infrastructure, and national indicators; Erstad (2009, p. 25) further articulates these as:

- a focus on how ICT can contribute to an increased quality in teaching and learning;

- an increased use of new ICT-based means for cooperation and interchange of knowledge and experience at all levels of the educational system;
- a broad access to learning materials and the development of new and varied forms of learning in order to stimulate activity, independence and cooperation;
- an increased focus on students' critical reflection with respect to the use of ICT in teaching and learning and in society in general;
- an increased focus on how to avoid creating digital divides.

Many of these elements are interrelated and span across levels, therefore developing analyses that span across these levels will further enhance the knowledge supporting this work, and avoiding reducing 'ICT in education' down to whether or not students learn better now than before (Erstad, 2009).

Most importantly, these objectives must be pursued in light of the outcomes identify by PISA discussed earlier; they offer the following policy implications (OECD, 2010a):

- raise awareness among educators, parents and policy-makers of the consequences of increasing ICT familiarity;
- promote greater computer use at school and experimental research on its effects;
- identify and foster the development of 21st century skills and competencies, addressing the second digital divide;
- adopt holistic policy approaches to ICT in education; *and*
- adapt school learning environments as computer ratios improve and digital learning resources increase.

Policy for meta-knowledge and sustainability, and the need to make learning environments increasingly adaptive and effective, requires a focus on monitoring and assessing what works in education and disseminating that information in ways that are meaningful to teachers and sustainable for scaling-up (OECD, 2010a). Within an unclear picture of what the future of learning environments looks like, policies that promote flexibility and innovative-practices for driving this change have been the approach of numerous systems with considerable success (Fullan, 2011).

Practitioners

Coordinating knowledge and efforts amongst the levels of the system will support and enable changes at the classroom level. Teachers and students need framework(s) that support their practical change, be it incremental or transformational, in their everyday work. Frameworks on digital/ICT literacies have provided this to a certain degree in some contexts, however for deeper, more systemic change this work needs to be coordinated in larger initiatives.

At the micro level, individual practitioners can, and many have been, innovating in their own classrooms and engaging with the *evolutionary* approach by applying first-order and second-order innovations in their own practice. While there may be barriers to the effectiveness of this, some are within an individual educator's control and can be at least partially mitigated when embarking on using a new technology for learning (see the i^5 tool in Groff & Mouza, 2008). At the same time, practitioners can work to make *innovating* a part of their collaborative professional practice—actively making exploring new ideas, with colleagues, and vetting them for effectiveness together, will increase the momentum of any given organisation, exponentially so as the number of participating faculty increases (for ideas in this area, see Sutch, Rudd & Facer, 2008).

The leadership at the local level of a given learning environment is critical to leading this change. The taxonomy and examples here offer insights in the path a leader might co-construct and trail-blaze with their educational community. Collaborating with and learning from other leaders, operating in both similar and different contexts, can offer vital insights, ideas, advice and support for an educational change endeavor. Tangibly, it can be useful to start by assessing where your learning environment currently stands—are the educators in your school demonstrating emergent use of first-order and/or second-order innovations? Or do you find that many diverse innovations are already represented? What are your educators and students visions of what the future of learning could, and should, look like?

The most effective change happens when all stakeholders engage in the change process together; and that include our students. As noted earlier, students may live in our current digital world, but they very likely have less of a handle on how that digital climate translates into transformed learning experiences. Many learners are not as strong at being self-directed learners, which many believe is the primary goal of education in the 21st century (OECD, 2010c; Morgan et al., 2008). Together, educators and students can collaboratively create the destination while cooperatively laying the train track to get there.

Researchers

As tied to the discussion on the implications for policy-makers, researchers are challenged with facing a new complexity of analysis, and garnering a more holistic picture of the dynamics of ICT in education. As learning environments continue to evolve, transform or reinvent themselves, it has forced the focus beyond understanding how we change a single school (meso level) to both the micro and macro levels—how ICT can deeply impact the transactions between teachers and learners, and how school systems experience change by implementing ICT (Erstad, 2009). Better capturing this reality will lead to a deeper, more nuanced understanding of how we can support learning systems as they seek to move into the 21st century. A research agenda focused on these areas can have a significant impact on policy development by creating a more robust picture of the realities of the different levels of the system and how they will need to be coordinated.

Additionally, the need for better indicators that can be internationally compared will better support policy-makers in understanding the dynamics of this complexity and impact of existing policy. Although it must be noted that indicators have their limitations and only provide information about a specific moment in time, this knowledge provides easy-to-use data the policy-makers can build on. This might include *input indicators*, which analyse

national policy, investment and use of ICT both in school and at home, as well as *utilisation indicators* which measure the types and purpose of ICT use for teaching and learning (Kikis, Scheuermann & Villalba, 2009). Further discussion on indicators and conceptual frameworks for research are available in the OECD/European Commission Joint Research Centre's publication, *Assessing the effects of ICT in education: Indicators, criteria and benchmarks for international comparisons.*

Researchers can support the collective movement towards educational transformation by making the knowledge generated by their research more accessible and usable to practitioners and policy-makers. Clearly and succinctly communicating the findings and implications for both policy-makers *as well as* practitioners, will help close the loop on the knowledge-generation and implementation cycle.

CONCLUSIONS & FUTURE DIRECTIONS

The trajectory chosen by any system will need to be designed and adapted for the unique context, goals and visions of that system. While the future is always uncertain, systems of education can find confidence in their generated pathway if it steers towards what we know to be effective learning from evidence from the learning sciences. This research is the foundation of the OECD Innovative Learning Environments (ILE) project, which looked at the intersection of our robust advancements in the learning sciences and the needs and demands (both current and projected) of the 21st century, and has generated 'principles' for designing effective learning environments based on this research. These principles are outlined in the Practitioner Guide[3] and explained more deeply in the ILE project's foundational reader, *The Nature of Learning* (2010):

- The learning environment recognises the learners as its core participants, encourages their active engagement and develops in them an understanding of their own activity as learners.
- The learning environment is founded on the social nature of learning and actively encourages well-organised co-operative learning.
- The learning professionals within the learning environment are highly attuned to the learners' motivations and the key role of emotions in achievement.
- The learning environment is accurately sensitive to the individual differences among the learners in it, including their prior knowledge.
- The learning environment devises programmes that demand hard work and challenge from all without excessive overload.

[3] See http://www.oecd.org/edu/ceri/50300814.pdf

- The learning environment operates with clarity of expectations and deploys assessment strategies consistent with these expectations; there is a strong emphasis on formative feedback to support learning.

- The learning environment strongly promotes "horizontal connectedness" across areas of knowledge and subjects as well as to the community and the wider world.

One may note that there is no mention of technology in these principles—since of course it is not a requisite for deep learning. However, as demonstrated by the examples in this paper, technology may be just a vehicle—but it is a powerful one. And it is a vehicle that is central to our work and personal lives, as well as society in general. As a vehicle, technology can not only act as a lever for systemic change in the design of learning environment, it also impacts teaching and learning at the micro level by creating powerfully different learning experiences. Therefore, the *content* that is delivered via this vehicle is immensely important. Also known as digital learning resources (DLR), content materials such as simulations, animations and digital textbooks have made incredible strides in the last several decades. However, we need further development and benchmarking for DLR and their impact on learning (Johannessen, 2009). DLRs fall in an intersection between technology, pedagogy, and the private sector, and must be explored, developed and studied in a voracious way in order to fully realize the potential of digital technology for the very individualized cognitive act of learning. In this way, DLR shines an important light on the discourse about technology in education:

> *We can no longer continue to speak about technology in education in general terms. It is clear that ICT has a central role in our lives and also our learning. We must get more specific, exploring how different technologies and resources make significant gains in key areas that have thus far demonstrating pedagogical challenges. We must seek to understand how technology and DLRs can make a significant impact on advancing learners in areas that often prove to be chasms or barriers in their developmental pathway.*

In it's simplest terms, we live in a digital world, where many of our students are 'connected' a majority of the time, and education has not yet caught up. This raises many question, concerns, and unknowns that should matter to both policymakers and educators—all of them stemming from the fact that education has the responsibility to equip young people with the necessary skills and values that will allow them to cope with the challenges that connectedness is currently posing to them. The imperative for discussion and exploration around key issues such as learners' diversity, digital literacy, the new digital divides, the blurring boundaries between formal and informal learning, and the use of technology for monitoring and assessing learning must take priority in our work.

Where do you start? You get started. There is no perfect storm coming that will make it definitively clear the path to forge ahead, and we cannot wait for the barriers and challenges to this work to be removed. In reality, there is no perfect method that's right for all, or even just one, learning environment. There will always be barriers, there will always be failures. The key is to always be on the alert for those barriers and plan for them as best you can, to embrace failures and use them as learning opportunities to recalibrate, and engage your learners on the journey of created digital, technology-rich learning environments.

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APPENDIX – *Annex of Learning Environments*

Listed Alphabetically

Consolarium
Games-based Learning
Learning and Teaching Scotland
The Optima, 58 Robertson Street
Glasgow, G2 8DU
UNITED KINGDOM

+44 08700 100 297
enquiries@LTScotland.org.uk

Learn more at http://www.ltscotland.org.uk/ictineducation/gamesbasedlearning

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Crescent Girls' School
357 Tanglin Road
Singapore 247961
SINGAPORE

crescentgirl@moe.edu.sg
+ 65 6475 8711

Learn more at http://www.crescent.edu.sg

Escola Móvel
AV. 24 de Julho, 140 - 4º Andar
1399-025 Lisboa
PORTUGAL

escolamovel@dgidc.min-edu.pt
00 351 213934559

Learn more at http://www.escolamovel.min-edu.pt

Intermediate School 339
1600 Webster Ave
Bronx, NY 10457
USA

+011 718 583 6767

Maine's Learning Technology Initiative
23 State House Station
Augusta ME 04333
USA

stephen.bowen@maine.gov
+1 207-624-6746

Learn more at http://www.maine.gov/mlti

Lumiar Institute
Rua Dom Aguirre, 438
Jardim Marajoara - 04671-903
São Paulo – SP
BRAZIL

institute@lumiar.org
+55 (11) 3576-2100

Learn more at http://www.lumiar.org

RSA Academy
Bilston Road
Tipton
West Midlands, DY4 0BZ
UNITED KINGDOM
info@rsaacademy.org
+44 0121 556 1351
Learn more at http://www.rsaacademy.net

Primary School Škofja Loka–Mesto
Osnovna šola Škofja Loka – Mesto
Šolska ulica 1
4220 Škofja Loka
SLOVENIA
os.sl-mesto@guest.arnes.si
+386 4 506 00 11
Learn more at http://www.o-sl-mesto.kr.edus.si

Saltash.net Community School
Wearde Road
Saltash
Cornwall, PL12 4AY
UNITED KINGDOM
enquiries@saltash.cornwall.sch.uk
+44 0 1752 843715
Learn more at http://www.saltash.net

Shady Hill School
178 Coolidge Hill
Cambridge, MA 02138
USA
+011 617 520 5260
Learn more at http://www.shs.org

Silverton Primary
77-123 Jacksons Road
Noble Park North, VIC 3174
AUSTRALIA
+03 9795 5033
Learn more at http://www.silverton-ps.vic.edu.au

St. Paul's Bay Primary
Maria Regina College
School Street
St. Paul's Bay SPB09
MALTA
stpaulsbay.primary.c@gov.mt
+ 356 21573194
Learn more at http://mrcstpaulsbayprimary.wordpress.com

THINK Global School – Head Office
One Embarcadero Center, Suite 500
San Francisco, CA 94111
USA
info@ThinkGlobalSchool.com
+011 415-315-1593
Learn more at http://www.thinkglobalschool.com