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Education outcomes enhanced by the use of digital technology: Reimagining the school learning ecology

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Executive summary

This report explores some of the factors that influence the transformative use of digital technology in schools, with a particular focus on innovations that contribute to enhanced educational outcomes. The underlying assumption is that digitisation is one of the greatest challenges and opportunities of today's world and that digital competence has become essential for successfully living, working and learning in the 21st century. After all, schools do not exist to only prepare the next generation of workers and nor can they be expected to fix all the problems of an ever-changing society. The report seeks to extend current discussions about the use of digital technology in schools in relation to the following questions:

- How can digital technology support and enhance teaching and learning?
- What are the enablers for successful digital technology use in school education?
- What are the implications for education policy, in terms of harnessing the potential of digital technology in schools?

The report builds on the seminal 2015 OECD report, which helps to frame the significance of recent changes and the impact of digital technologies on school education. It largely supports the OECD's assertion that connections between students, computers and learning are neither simple nor hard-wired; and the real contributions technology can make have yet to be fully realised. However, there are many examples of innovative practice and we need to be realistic about what we can expect from schools as there is no single off-the-shelf solution for harnessing the potential of digital technologies.

A theoretical lens guides the focus of the report, which consists of six elements:

- First, it is evident from the literature that digital technologies have the potential to enhance and transform traditional ways of teaching, learning and assessment. Although there are indications that teaching practices are changing, pedagogical practices remain overall resistant to innovation.
- Second, despite the promising potential of digital technologies, the quality and effectiveness of pedagogy and related educational outcomes is heavily dependent on the way teachers use and mediate the technology in their classrooms.
- Third, new digital technologies are emerging all the time, such as Augmented Reality (AR) and Artificial Intelligence (AI) and these clearly have significant implications for teaching and learning.
- Fourth, digitally enhanced learning offers a variety of opportunities to improve educational outcomes. Despite these opportunities, there is limited evidence of the extent to which the majority of schools in Europe have made substantive progress in adapting their delivery models accordingly, although there are examples of excellence.
- Fifth, traditional models of instruction and assessment still dominate the sector and serve as significant barriers to wider conceptions of educational outcomes, although again there is evidence that this is changing.
- Sixth, it is particularly difficult to establish direct causal relationships between pedagogy and technology interventions. Therefore, the report is cognisant of the many situational factors mediating success and the risks of drawing causal inferences. The relationship between pedagogy and technology interventions is both contextual and dynamic; the teacher's role being crucial in determining how digital technology is used in school education.

The report then describes the nature of today's digital society. The report discusses and critiques the trustworthiness of many claims taken for granted regarding a number of themes: the changing nature of

work, the concept of the 'millennial generation', the wide spectrum of learning activities, resources and educational offerings, the changing role of teachers and learners, and the potential impact of new and emergent technologies. It argues that there are a number of competing and co-existing mindsets or perspectives influencing the pressure on schools to use new digital technologies. The report argues that the affordances of digital technologies differ according to the technology and the educational contexts in which they are used for teaching and learning. It argues that the use of digital technologies in schools is not a single entity and that today's educational context is complex and dynamic and digital technologies add to this complexity; i.e. there is a complex ecology of digital technologies in schools.

A number of frameworks for effective and innovative pedagogy are described and the report argues there is no single pedagogical or theoretical model in terms of guiding the successful use of digital technologies in schools. More to the point, the adoption of learning-driven approaches to school education which seek to embed digital technologies at the heart of the curriculum require an intentional combination of pedagogies that respond to a complex inter-play between the particular context, nature of the learners, learning intentions, discipline cultures, and so on. In looking to the future of learning, the report describes a number of new and emergent developments in digital technologies which might be able to help reimagine the curriculum. It argues that, in the future, students will be likely to learn across a range of formal, non-formal and informal contexts, with increasing digital leakage across different places and spaces of learning. Examples of the ways in which digital technologies might provide engaging learning environments are provided, along with some scenarios for the future. The report demonstrates the potential opportunities technologies can offer, but argues that the field is still dominated by hype, hope and disappointment.

A key message throughout the report is that the teacher's role is vital in the effective design, delivery and support of learning interventions. With respect to this, the report confirms the centrality/importance of teacher education in harnessing the educational potential of digital technologies. Some of the principles of effective Teacher Professional Learning (TPL) are introduced along with the importance of addressing teachers' mindsets or deep-seated pedagogical beliefs if the goal is to go beyond merely taming new digital technologies based on traditional practices.

The discussion of barriers and enablers illustrates that there is no simple answer to overcoming the reasons why schools and teachers do not fully embrace the educational opportunities made possible by new digital technologies. Arguably, one important lesson is that policy-makers and educational leaders would benefit from more explicitly framing discussions about the use of digital technology for solving real problems faced by teachers, rather than falling into the trap of promoting digital solutions in search of problems.

The report concludes with a set of key principles:

1. Research on digital technologies in schools must **take greater account of the complexity of the learning ecology**. A deeper and more nuanced understanding is needed of how different affordances of digital technologies support pedagogical combinations known to enhance educational outcomes.

2. Designs for effective learning with digital technologies should **promote a variety of intentional pedagogical approaches** that most appropriately support learners' needs, intended educational outcomes, subject discipline requirements, and instructional and institutional contexts.

3. Teachers' mindsets mediate technology implementation. Professional learning opportunities must **encourage teachers to critically reflect on their mindsets and pedagogical beliefs** in the context of their practice in order to support them to reap the opportunities of digital technologies.

4. Assessment needs to support deep learning. Where appropriate, **technologies should be woven throughout formative and summative assessment**, including final examinations, to support active, authentic and meaningful learning.

5. Leadership and institutional cultures have a strong impact on change. Institutional factors known to influence successful implementation of technologies should be the focus of **targeted professional learning for educational leaders** and shared widely within their existing communities of practice.

6. Refocusing on education *for* the future. Future policies designed to enable the effective use of digital technologies in school education need to shift the current discourse away from the language of education *in* change to **focussing on education *for* change with a longer-term horizon**.

Résumé analytique

Ce rapport explore les facteurs qui influencent l'utilisation de la technologie numérique dans les écoles et se concentre particulièrement sur les innovations qui contribuent à l'amélioration des résultats d'apprentissage. L'hypothèse sous-jacente est que la numérisation représente l'un des plus grands défis et l'une des plus grandes opportunités du monde d'aujourd'hui et que les compétences numériques sont devenues essentielles pour vivre, travailler et apprendre au 21ème siècle. Après tout, l'école n'existe pas seulement pour préparer la prochaine génération de travailleurs et on ne peut non plus attendre d'elle de résoudre tous les problèmes d'une société en constante mutation. Le rapport tente d'élargir les débats actuels sur l'utilisation de la technologie numérique au sein de l'école en posant les questions suivantes :

- Comment la technologie numérique peut-elle soutenir et améliorer l'enseignement et l'apprentissage ?
- Quels éléments facilitent une utilisation réussie de la technologie numérique dans l'enseignement scolaire ?
- Quelles sont les conséquences pour les politiques éducatives, en ce qui concerne l'exploitation du potentiel de la technologie numérique dans l'école ?

Ce rapport s'appuie sur le rapport de l'OCDE de 2015, qui a contribué à poser un cadre à l'importance des changements récents et à l'impact des technologies numériques sur l'enseignement scolaire. Il soutient fortement l'OCDE lorsqu'il affirme que les liens entre les élèves, les ordinateurs et l'apprentissage ne sont ni simples ni innés et que les réelles contributions pouvant être apportées par la technologie doivent encore être pleinement réalisées. Cependant, il existe un grand nombre de pratiques innovantes et il faut être réaliste sur ce que l'on peut attendre de l'école car il n'existe pas de solution unique et standardisée pour exploiter le potentiel des technologies numériques.
Un regard théorique guide le rapport, et comprend six éléments.

- Premièrement, il est évident d'après la littérature que les technologies numériques ont le potentiel d'améliorer et de transformer les méthodes traditionnelles d'enseignement, d'apprentissage et d'évaluation. Bien que l'on observe des signes de changement, les pratiques pédagogiques continuent globalement de résister à l'innovation.
- Deuxièmement, même si les technologies numériques soient prometteuses , la qualité et l'efficacité pédagogique et de l'appretissage qui en découlent dépendent fortement de la façon dont les enseignants utilisent la technologie dans les classes.
- Troisièmement, de nouvelles technologies numériques telles que la réalité augmentée (RA) et l'intelligence artificielle (IA) voient constamment le jour, et elles ont clairement des conséquences importantes sur l'enseignement et l'apprentissage.
- Quatrièmement, l'apprentissage optimisé par le numérique offre d'amples opportunités pour améliorer les résultats scolaires. Malgré ceci, et bien qu'il existe des exemples d'excellence, il n'y a que peu d'éléments factuels pour indiquer comment les écoles ont progressé dans l'adaptation de leurs modèles.
- Cinquièmement, les modèles traditionnels d'enseignement et d'évaluation dominent encore le secteur et constituent des obstacles importants à des conceptions plus larges des résultats scolaires, bien qu'il existe là aussi des preuves d'évolution.
- Sixièmement, il est particulièrement difficile d'établir un lien direct de cause à effet entre pédagogie et interventions de la technologie. Le rapport est ainsi conscient des nombreux facteurs conjoncturels déterminant la réussite et du risque d'effectuer des inférences causales. La relation entre la pédagogie et les interventions technologiques est à la fois contextuelle et

dynamique, le rôle de l'enseignant étant crucial dans la détermination de l'utilisation faite de la technologie numérique dans l'enseignement scolaire.

Le rapport décrit ensuite la nature de la société numérique d'aujourd'hui. Il aborde et critique la fiabilité de nombreuses affirmations tenues pour acquises concernant un certain nombre de thèmes : la nature changeante du travail, le concept de « génération Y », le large spectre des activités d'apprentissage, des ressources et des offres pédagogiques, le rôle changeant des enseignants et des élèves, et l'impact potentiel des technologies nouvelles et émergentes. Il soutient qu'il existe un certain nombre de mentalités ou de points de vue concurrents et coexistants ayant un impact sur la pression faite aux écoles d'utiliser les technologies numériques. Le rapport affirme que les mises à disposition des technologies numériques diffèrent selon la technologie et les contextes éducatifs dans lesquels elles sont utilisées. Il soutient que l'utilisation des technologies numériques dans les écoles ne représente pas une entité unique, que le contexte éducatif actuel est complexe et dynamique et que les technologies numériques ajoutent à cette complexité. En d'autres termes, il existe un environnement complexe des technologies numériques dans les écoles.

Plusieurs cadres pour une pédagogie efficace et innovante sont décrits et le rapport affirme qu'il n'existe pas de modèle unique pédagogique ou théorique en termes d'accompagnement de l'utilisation réussie des technologies numériques à l'école. Un point encore plus important est que l'adoption d'approches éducatives centrées sur l'apprentissage cherchant à intégrer les technologies numériques au cœur des programmes scolaires nécessite un mélange volontaire de pédagogies répondant aux interactions complexes entre le contexte particulier, la nature des élèves, les intentions d'apprentissage, les cultures des disciplines etc. En ce qui concerne l'avenir de l'apprentissage, le rapport décrit un certain nombre de développements nouveaux et émergents au sein des technologies numériques qui pourraient contribuer à réinventer les programmes scolaires. Il soutient qu'à l'avenir, les étudiants apprendront probablement dans une variété de contextes formels, non-formels et informels, avec une fuite digitale en hausse au sein des différents lieux et espaces d'apprentissage. Des exemples de moyens par lesquels les technologies numériques pourraient fournir des environnements d'apprentissage engageants sont présentés, ainsi que des scénarios pour l'avenir. Le rapport expose les opportunités potentielles offertes par la technologie mais affirme que le secteur est encore dominé par des effets de mode, par l'espoir et la déception.

Un message clé tout au long du rapport est que le rôle de l'enseignant est essentiel à la conception, à l'exécution et au soutien efficaces des interventions d'apprentissage. À cet égard, le rapport confirme l'importance et le rôle central de la formation des enseignants à l'exploitation du potentiel éducatif des technologies numériques. Certains principes de la Formation Professionnelle des Enseignants (FPE) sont présentés, ainsi que l'importance d'aborder les mentalités des enseignants ou leurs convictions pédagogiques si l'objectif est d'aller au-delà d'un simple apprivoisement des technologies numériques basées sur des pratiques traditionnelles.

Le débat sur les freins et les catalyseurs illustre bien le fait qu'il n'existe pas de réponse simple pour dépasser les raisons pour lesquelles les écoles et les enseignants ne se saisissent pas pleinement des opportunités rendues possibles par les nouvelles technologies numériques. Une leçon sans doute importante à retenir est qu'il serait bénéfique pour les décideurs et les spécialistes de l'éducation de cadrer plus explicitement le débat autour de l'utilisation du numérique pour régler les problèmes concrets rencontrés par les enseignants, plutôt que de tomber dans le piège de la promotion des solutions numériques pour identifier ces problèmes.

Le rapport conclut par une série de principes clés en lien avec les questions posées lors de cette recherche :

1. La recherche relative aux technologies numériques au sein de l'école doit mieux **tenir compte de la complexité de l'environnement d'apprentissage**. Une compréhension approfondie et nuancée de la manière dont les mises à disposition des technologies numériques soutiennent les choix pédagogiques est nécessaire afin d'améliorer les résultats scolaires.

2. La conception d'apprentissages à l'aide de technologies numériques devrait **promouvoir une variété d'approches pédagogiques** qui soutiennent réellement les besoins des élèves, les résultats scolaires, les exigences des disciplines et les contextes éducatifs et institutionnels.

3. Les mentalités des enseignants déterminent la mise en œuvre de la technologie. Les opportunités de formation professionnelle doivent **encourager les enseignants à s'engager dans une réflexion critique** sur leur pratique, afin de les aider à bénéficier des opportunités offertes par les technologies numériques.

4. L'évaluation doit soutenir un apprentissage approfondi. Le cas échéant, les technologies doivent être intégrées à l'ossature de l'évaluation formative et sommative, y compris aux examens finaux, afin de soutenir un apprentissage actif, authentique et ayant du sens.

5. L'encadrement et les cultures institutionnelles ont d'importantes répercussions sur le changement. Les facteurs institutionnels connus pour influencer la réussite de la mise en œuvre des technologies devraient faire l'objet d'une **formation professionnelle ciblée pour les responsables éducatifs** et être largement partagés au sein de leurs communautés de pratique existantes.

6. Recentrer l'attention sur l'éducation *pour* le futur. Les politiques futures conçues afin de permettre une utilisation efficace des technologies numériques dans l'enseignement scolaire doivent éloigner les échanges actuels du langage de l'éducation *dans* le changement et **se concentrer sur l'éducation *pour* le changement, avec un horizon à plus long terme**.

Kurzversion

Dieser Bericht untersucht einige der Faktoren, welche die transformative Nutzung digitaler Technologien in der Schule beeinflussen und konzentriert sich dabei besonders auf Innovationen, die zur Verbesserung der Bildungsergebnisse beitragen. Die Untersuchung geht von der Annahme aus, dass die Digitalisierung zu den größten Herausforderungen und Chancen der heutigen Zeit zählt und digitale Kompetenzen für erfolgreiches Leben, Arbeiten und Lernen im 21. Jahrhundert unentbehrlich sind. Die Schule dient nicht nur dazu, die nächste Generation von Arbeitnehmern und Arbeitnehmerinnen auszubilden; ebenso wenig kann sie alle Probleme einer sich ständig wandelnden Gesellschaft lösen. In diesem Bericht soll die aktuelle Debatte über die Nutzung digitaler Technologien in Schulen um folgende Fragestellungen erweitert werden:

- Wie können digitale Technologien Unterrichts- und Lernmethoden unterstützen und verbessern?
- Welche Faktoren begünstigen die erfolgreiche Nutzung digitaler Technologien in der schulischen Bildung?
- Was muss die Bildungspolitik tun, um das Potenzial digitaler Technologien für die Schule nutzbar zu machen?

Dieser Bericht basiert auf dem wegweisenden OECD-Bericht aus dem Jahr 2015, der entscheidend zur Einordnung aktueller Entwicklungen und der Auswirkung digitaler Technologien auf die schulische Bildung beigetragen hat. Er bestätigt im Wesentlichen die Annahme der OECD, dass die Zusammenhänge zwischen Schülern, Computern und Lernen weder einfach noch unveränderlich ist und der potenzielle Beitrag dieser Technologien noch lange nicht voll ausgeschöpft wurde. Es gibt jedoch zahlreiche innovative Verfahren mit Vorbildcharakter und angesichts der Komplexität von Veränderungsprozessen im Bildungswesen müssen wir realistisch einschätzen, was Schule überhaupt leisten kann. Denn es gibt keine einheitliche Lösung, mit der das Potenzial der digitalen Technik umgesetzt werden kann.

Die theoretische Perspektive dieses Berichts besteht aus sechs Elementen. Erstens zeigt die Forschungsliteratur, dass digitale Technologien das Potenzial haben, herkömmliche Unterrichts-, Lern- und Prüfverfahren zu verbessern und zu transformieren. Doch trotz zahlreicher neuer Geräte und Programme zeigt sich die pädagogische Praxis insgesamt recht reformresistent. Dennoch gibt es Hinweise darauf, dass sich die Unterrichtspraxis langsam verändert. Zweitens bieten digitale Technologien zwar vielversprechende Lösungen für innovative Unterrichts- und Lernmethoden. Qualität und Erfolg des Unterrichts und die dadurch erzielten Bildungsergebnisse hängen jedoch stark davon ab, wie Lehrer und Lehrerinnen die Technologien im Klassenzimmer einsetzen und vermitteln. Drittens entstehen ständig neue digitale Technologien, wie erweiterte Realität (ER) und künstliche Intelligenz (KI) mit wichtigen Implikationen für Unterricht und Lernerfahrung. Viertens bietet digital unterstütztes Lernen unterschiedlichste Wege zu besseren Bildungsergebnissen. Trotz dieser Möglichkeiten gibt es, abgesehen von einzelnen besonders vorbildlichen Projekten, noch kaum Daten dazu, ob die Mehrzahl der Schulen in Europa bei der Anpassung ihrer Vermittlungsmodelle wesentliche Fortschritte erzielt hat. Seit 2014 gibt es zwar einen europaweiten Trend zur Überarbeitung von Lehrplänen, diese Veränderungen kommen aber nicht immer im Regelunterricht an. Fünftens sind im Bildungswesen trotz des mehrdimensionalen Versprechens digitaler Technologien immer noch traditionelle Unterrichts- und Prüfmodelle vorherrschend, die ein weiter gefasstes Verständnis des Begriffs „Bildungsergebnis“ erheblich behindern, auch wenn in diesem Bereich ebenfalls Veränderungen sichtbar sind. Sechstens lässt sich ein unmittelbarer kausaler Zusammenhang zwischen

Pädagogik und technologischen Maßnahmen nur sehr schwer herstellen. Deshalb ist sich die Autorin dieses Berichts der vielen situationsbedingten Faktoren, die den Lernerfolg beeinflussen, und der Risiken kausaler Schlussfolgerungen bewusst. Der Zusammenhang zwischen Pädagogik und technologischen Maßnahmen ist dynamisch und hängt stark vom jeweiligen Kontext ab. Dabei sind die Lehrkräfte der wichtigste Faktor für die erfolgreiche Nutzung digitaler Technologien in der schulischen Bildung.

Der Bericht beschreibt auch die Merkmale der heutigen digitalen Gesellschaft. In diesem Zusammenhang werden gängige Behauptungen zu den folgenden Themen untersucht und hinterfragt: der Wandel der Arbeitswelt, die Vorstellung einer „Millenium-Generation", die große Bandbreite von Lernmethoden und -ressourcen und Bildungsangeboten, die sich wandelnden Rollen von Lehrenden und Lernenden und die potenziellen Auswirkungen neuer und entstehender Technologien. Der Bericht stellt fest, dass der Druck auf die Schulen, neue digitale Technologien zu nutzen, von mehreren miteinander konkurrierenden oder sich ergänzenden Denkweisen oder Perspektiven ausgeht. Er vertritt die Auffassung, dass der Angebotscharakter digitaler Technologien stark von der jeweiligen Technologie und dem Bildungskontext abhängt, in dem diese Technologie für Unterrichts- und Lernzwecke genutzt wird. Der Einsatz digitaler Technologien in der Schule ist kein einheitliches Ganzes, moderne Bildungskontexte sind komplex und dynamisch und digitale Technologien verstärken diese Komplexität weiter, d. h. das Umfeld der digitalen Technologien in der Schule ist vielschichtig.

Der Bericht beschreibt verschiedene Rahmenbedingungen einer funktionierenden und innovativen Pädagogik und stellt fest, dass es nicht das eine pädagogische oder theoretische Modell gibt, das eine erfolgreiche Nutzung digitaler Technologien in der Schule garantiert. Genauer gesagt erfordert die Umsetzung lernzentrierter Ansätze für die schulische Bildung, die eine Integration digitaler Technologien im Zentrum der Lehrpläne anstreben, die bewusste Kombination unterschiedlicher pädagogischer Methoden, die auf die komplexe Interaktion zwischen dem jeweiligen Kontext, dem Wesen der Lernenden, den Lernzielen, Erziehungstraditionen und anderer Faktoren reagieren. Auf der Suche nach den Lernmethoden der Zukunft beschreibt der Bericht mehrere neue und aufstrebende Entwicklungen im Bereich der digitalen Technologie, die zu einer Neugestaltung der Lehrpläne beitragen können. Der Bericht kommt zu dem Schluss, dass Schüler und Schülerinnen künftig vermutlich in ganz unterschiedlichen formalen, außerschulischen und informellen Zusammenhängen lernen werden, mit zunehmender digitaler Durchdringung zwischen den unterschiedlichen Lernorten und -räumen. Neben verschiedenen Zukunftsszenarien wird auch beispielhaft beschrieben, wie mit Hilfe digitaler Technologien ansprechende Lernumfelder geschaffen werden können. Der Bericht zeigt das Potenzial dieser Technologien, stellt aber auch fest, dass der Bereich immer noch von Aufbauschung, Hoffnung und Enttäuschung geprägt ist.

Eine Kernaussage des Berichts ist die entscheidende Rolle des Lehrers und der Lehrerin bei der Gestaltung, Vermittlung und Förderungen effizienter Lernmaßnahmen. In dieser Beziehung bestätigt der Bericht die zentrale Stellung bzw. Bedeutung der Lehrer- und Lehrerinnenausbildung für die Nutzbarmachung des Potenzials digitaler Technologien in der Bildung. Der Bericht stellt einige Grundsätze der erfolgreichen beruflichen Weiterbildung für Lehrer und Lehrerinnen vor und zeigt, wie wichtig es ist, die Einstellungen oder tief verankerten pädagogischen Überzeugungen der Lehrenden anzusprechen, damit neue digitale Technologien nicht nur für herkömmliche Unterrichtsmethoden „gezähmt" werden.

Dann werden die wichtigsten primären und sekundären Hindernisse und Wegbereiter für den effizienten Einsatz digitaler Technologien in Schulen behandelt, die verbesserte Bildungsergebnisse beeinflussen.

Diese Analyse günstiger und ungünstiger Faktoren zeigt, dass es keine einfache Antwort auf die Frage gibt, warum Schulen und Lehrende die pädagogischen Möglichkeiten neuer digitaler Technologien nicht voll ausschöpfen. Eine wichtige Lehre ist hier aber wohl, dass Entscheidungsträger und Entscheidungsträgerinnen aus Politik und Bildungswesen bei der Diskussion digitaler Technologien klarer deren Potenzial zur Lösung echter Probleme benennen sollten, die Lehrende im Schulalltag erleben, anstatt der Verlockung zu erliegen, digitale Lösungen für jedes Problem zu fordern. Zum Schluss führt der Bericht ein paar wichtige Grundsätze an, die sich auf die Forschungsfragen beziehen:

1. Forschung über digitale Technologien in Schulen muss die Komplexität von Lernumfeldern stärker berücksichtigen. Wir brauchen ein besseres und stärker nuanciertes Verständnis, wie die unterschiedlichen Eigenschaften digitaler Technologien pädagogische Kombinationen unterstützen können, die Bildungsergebnisse nachweislich verbessern.

2. Systeme zum erfolgreichen Lernen mit digitalen Technologien sollten eine Bandbreite bewusst gewählter pädagogischer Ansätze fördern, die den Bedürfnissen der Lernenden, den gewünschten Lernzielen, den Anforderungen des jeweiligen Unterrichtsfachs und dem Unterrichts- und Schulkontext am besten entsprechen.

3. Der Schlüssel zur erfolgreichen Umsetzung von Technologien liegt in der Mentalität der Lehrenden. Angebote der beruflichen Weiterbildung müssen die Lehrenden dazu ermutigen, ihre bisherigen Einstellungen und pädagogischen Überzeugungen im Kontext der eigenen Praxis kritisch zu hinterfragen, um sie dabei zu unterstützen, die Chancen digitaler Technologien voll zu nutzen.

4. Prüfungen sollten auf tiefgehendes Lernen (Deep Learning) ausgerichtet sein. Um aktives, echtes und sinnvolles Lernen zu unterstützen, sollten zur formativen und summativen Beurteilung, auch bei Abschlussprüfungen, wenn möglich, Technologien mit eingebunden werden.

5. Die Rolle der Schulleitung und der Schulkultur. Institutionelle Faktoren, die nachweislich zur erfolgreichen Umsetzung von Technologien beitragen, sollten Führungskräften im Bildungsbereich durch gezielte Weiterbildungsmaßnahmen vermittelt und innerhalb bestehender beruflicher Netzwerke weitergegeben werden.

6. Bildung *für* die Zukunft in den Mittelpunkt stellen. Künftige Strategien, mit denen die erfolgreiche Nutzung digitaler Technologien in der schulischen Bildung gefördert werden soll, müssen die im bisherigen Diskurs vorherrschende Sprache über Bildung *im* Wandel durch eine Bildung *für* den Wandel mit einem langfristigen Zeithorizont ersetzen.

1. Introduction

Digital skills have become increasingly essential for successfully living, working and learning in the 21st Century. There as two aspects of Information and Communication Technologies (ICT), acquiring digital skills and the use of technology for acquiring other skills. The need for a European-level response to the challenges and opportunities of digitalisation in schools is reflected in recent country initiatives and the Digital Education Action Plan (European Commission, 2018). While this Action Plan provides an important backdrop to this report, there remains a lot of hype, misinformation and unsubstantiated claims about the transformative impact of new digital technologies on schools.

Cuban (2018) seriously questions whether or not the use of digital technology has resulted in transformed teaching and learning in classrooms. He argues that evidence of progress arises from gradual or incremental changes and the cross-pollination of ideas about new ways of teaching and learning rather than from top-down policy mandates. Metaphorically speaking, Cuban (2018) describes this change as the 'flight of a butterfly rather than the path of a bullet'. This lesson is relevant to the European context, as Cuban's research illustrates the complex interrelations of policy and practice, and the many – often unintended – consequences of educational reforms and initiatives through digital education.

Set against this wider international backdrop, the focus of this report is to explore the link between teaching, learning and assessment and digital technology in schools. More specifically, the report asks what are the conditions for the successful use of digital technology in schools, with a particular focus on innovations that contribute to enhanced educational outcomes. The report seeks to support and extend current discussions about the use of digital technology in schools in relation to the following questions:

- How does digital technology enhance teaching and learning?
- What are the enablers for successful digital technology use in school education?
- What are the implications for policy and transformative curriculum reforms in terms of harnessing the potential of digital technology in schools?

As the above questions indicate, the focus is primarily on curriculum and pedagogy and conditions for the effective, successful and transformative use of digital technology in schools rather than administrative efficiencies. The key question woven throughout the report is whether the investment in digital technology in schools contributes to an improvement in educational outcomes and, if so, what are the conditions needed for success? In addressing this overarching question, we note that there are important opportunity costs of implementing digital technology in schools. While the drivers for doing so are well documented, the longer-term benefits of digitalisation need to be evaluated against what enhanced educational outcomes might be achieved through the adoption of alternative educational interventions.

Given that these opportunity costs are difficult to calculate, this speculative line of discussion is beyond the scope of this report. There remains, nevertheless, a need to better understand the wider return on investment of digital technology in schools.

There are a number of advantages to using technologies in the classroom. The first is that technologies enable teachers to experiment more with pedagogy and provide students with more immediate feedback. The second is that technologies can help to facilitate greater participation. The third is that free resources, such as Open Educational Resources (OER) and Massive Open Online Courses (MOOCs) have potential in terms of enhancing education, freeing up time from administrative duties, augmenting classroom resources and make learning more fun and effective (McGreal, 2017). However, there appears to be little data on how OER and MOOCs are actually being used by teachers and students in schools. The fourth is that technology can be used to automate tedious tasks, such as administration (Donnelly, 2017) and hence free up the teachers to adopt more innovative approaches. The fifth is that technologies give students access to fresh and up-to-date information on a topic, to supplement their learning experience. Finally, it is evident that digital technologies are core aspects of everyday life and hence an important life skill that students need to learn.

However, as mentioned above, there are a number of disadvantages to using technologies in the classroom. First, technology can be a distraction. Second, technology can disconnect students from social interactions. Third, technology can foster cheating in class and on assignments. Fourth, students do not necessarily have equal access to technology resources, resulting in a digital divide (Selwyn, 2004). Fifth, the quality of resources available may not be high and students may lack the digital literacy skills needed to make informed judgements about them. Finally, planning lessons using technologies can be more labour intensive.

2. Guiding methodology

The methodology guiding this report involved a combination of search strategies. Firstly, a systematic search of the published literature in academic and professional journals was undertaken using a range of relevant terms. A separate systematic analysis of relevant open access journals not always identified in educational databases was also carried out. Additionally, we sought to locate major meta-analyses published since 2016 and conducted a search of the websites of major European government agencies, international bodies and professional associations. The literature review was also augmented by other sources of grey literature, including relevant blog posts from leading thought leaders.

The report covers many different aspects of the implementation of digital technology in schools, including more recent developments such as the use of laptops, mobile devices, virtual and augmented realities, gaming technologies, and the emergence of Artificial Intelligence. In addition, to help ground the report in current practice, the European Schoolnet website was drawn on to provide valuable case studies of innovation from across member countries. In particular, The European Schoolnet Open Book of Education (Licht et al., 2017) provides over 100 insightful case studies of innovation in the use of digital technology in schools.

3. Foregrounding literature

In attempting to provide a concise synthesis of the literature, the report is cognisant of the fact that this is not the first study to explore some of the aforementioned questions. Accordingly, this section introduces a number of seminal works which foreground the report. The OECD's (2015) research in this area helps to frame the significance of recent changes and the impact on school education:

> Information and communication technology (ICT) has revolutionised virtually every aspect of our life and work. Students unable to navigate through a complex digital landscape will no longer be able to

> participate fully in the economic, social and cultural life around them. Those responsible for educating today's "connected" learners are confronted with challenging issues, from information overload to plagiarism, from protecting children from online risks such as fraud, violations of privacy or online bullying to setting an adequate and appropriate media diet. We expect schools to educate our children to become critical consumers of Internet services and electronic media, helping them to make informed choices and avoid harmful behaviours. And we expect schools to raise awareness about the risks that children face online and how to avoid them (p.3).

In 2012, 96% of 15-year-old students in OECD countries reported that they had a computer at home, but only 72% reported that they use a desktop, laptop or tablet computer at school (OECD, 2015). Although this study is now quite dated and adopts a relatively broad brush to many of the questions central to this report, PISA data indicates that despite the pervasiveness of ICT in our daily lives, digital technology has not yet been as widely adopted in formal education. In addition, where they are used in the classroom, their impact on student performance is mixed, at best. Of course, this not a new finding and parallels the situation in higher education, as Twigg (2003, p.2) reports:

> ... comparative research studies show that rather than improving quality, most technology-based courses produce learning outcomes that are simply 'as good as' their traditional counterparts—in what is often referred to as the 'no significant difference' phenomenon.

While this is a potentially telling conclusion, the present report aims to go beyond the 'no significant difference' phenomenon (Ferster, 2017) by inviting deeper and more contextually rich analyses of the literature. However, the starting point is that PISA data already indicates the following in relation to use of digital technology for learning in schools. First, that the foundation skills required in a digital environment can and should be taught. Second, more needs to be done to improve equity in the ways in which the use of digital technology is implemented and supported. Third, teachers, parents and students need to be aware of the potential dangers of the use of digital technology. Finally, in terms of the effectiveness of the use of digital technology it is important to learn from what is already known about how they are being used.

Building on these findings and previous major meta-analyses of the literature (Means et al., 2010), the report supports the OECD's assertion that connections between students, computers and learning are neither simple nor hard-wired; and the real contributions digital technology can make to teaching and learning have yet to be fully realised and exploited. As long as computers and the Internet continue to have a central role in our personal and professional lives, students who have not acquired basic digital competences will find themselves unable to participate fully in the social, cultural and economic life around them – let alone play an active role in shaping better futures.

4. Theoretical lens

This section describes the explicit theoretical lens adopted to guide, organise and interpret different insights on the impact that the use of digital technologies have (or not) on educational outcomes. The following six strands when woven together help explain the conceptual underpinnings used in exploring the questions outlined in the introduction, which are the primary focus of the report (see Figure 1).

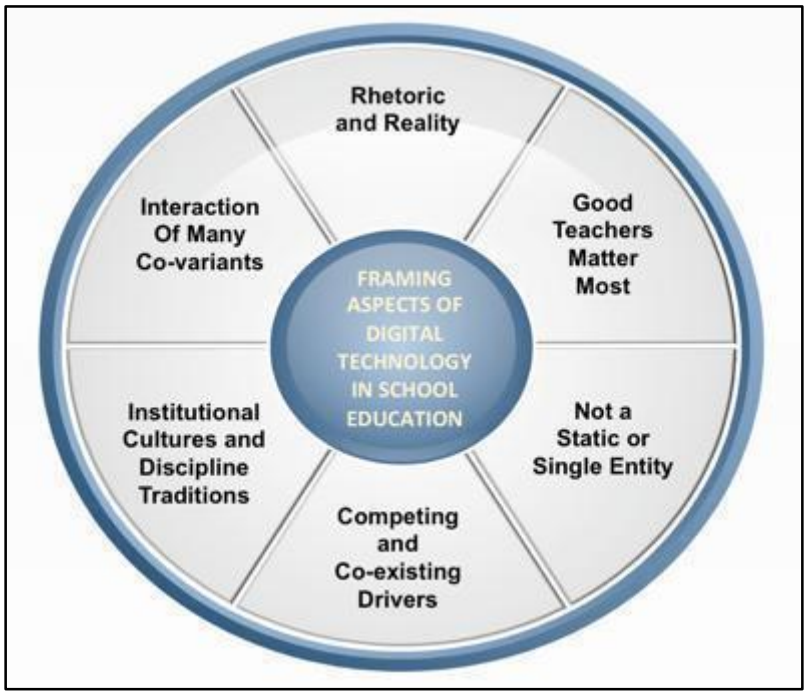

Figure 1: The theoretical lens

First, it is evident from the literature that digital technologies have the potential to enhance and, in theory, transform traditional ways of teaching, learning and assessment. However, despite a variety of new hardware devices and software solutions, traditional forms of pedagogy remain resistant to change (Cuban, 2018). While digital technology affects almost every aspect of our everyday lives, learning in classrooms is still the norm for the majority of school organisation (Ravitz, Becker & Wong, 2000). As Marcus-Quinn and Hourigan (2017) argue, schools still lag significantly behind the transformative promise of digital technologies. Hence there is a tension between the rhetoric and reality of using technologies for teaching, learning and assessment – that is, the actual experience in the classroom and the real world in which many children live in their homes and local communities.

Second, whilst digital technologies have significant promise in terms of facilitating innovative teaching and learning, well-prepared and effective teachers matter most. The quality and effectiveness of pedagogy and related educational outcomes is heavily dependent on the way teachers use and mediate the technology in their classrooms. It follows that innovative and impactful professional learning for teachers has never been more important in order to help schools respond to these developments and harness the educational potential of digital technologies.

Third, new digital technologies are arising all the time, such as Augmented Reality (AR) and Artificial Intelligence (AI), and these clearly have significant implications for teaching and learning. Put another way, the field is particularly dynamic, which poses a number of challenges for educators, researchers and policy-makers, as, by analogy, keeping up with new developments is a bit like running to catch a moving train (Becker, 1998). The key point is that digital technology is not static or a single entity, which makes sweeping generalisations about their impact on learning somewhat problematic.

Fourth, digitally-enhanced learning offers a variety of opportunities to improve educational outcomes (Scott, 2015a, 2015b, 2015c). Despite these opportunities, OECD (2015) findings suggest the majority of schools in Europe have made limited progress in adapting their curriculum and delivery models accordingly, although there are indications this is beginning to change (Licht, Tasiopoulou & Wastiau, 2017). The reasons for limited progress are complex and there are many competing and co-existing

drivers for the adoption of digital technologies in schools ranging from serving narrow vocational ends, promoting better educational outcomes for students, and to more broadly preparing children for a rapidly changing future. Thus digital technologies can be used in school education for different purposes and efforts at evaluating their impact and effectiveness need to be cognisant of the main underlying drivers and intended outcomes.

Fifth, despite the multi-dimensional promise of digital technologies, traditional models of instruction still dominate the sector and serve as a significant barrier to wider conceptions of educational outcomes. For example, while Learning Management Systems (LMS) have become common in secondary schools, evidence suggests they are mainly used as content repositories (Farrelly, Raferty, & Harding, 2018; De Smet, 2015) and, at this level, Massive Open Online Courses (MOOCs) largely remain a peripheral innovation with few school-level students participating in free online courses (Glass, Shiokawa-Baklan & Saltarelli, 2016). Traditional school subjects and institutional cultures also serve as barriers, which is particularly apparent in terms of assessment practices (Department of Education and Skills, 2004). It would appear, for example, that the status of the traditional 'pen and paper' exam has not yet been seriously challenged in most European countries (Morton, 2017).

Sixth, it is particularly difficult to establish direct causal relationships between pedagogy and technology interventions. Therefore, the report is cognisant of the many situational factors mediating success and the risks of drawing causal inferences. As Solomon (1990) once wrote, the music we enjoy does not just come from the sound of a single flute, but is produced by many instruments in a whole orchestra working in harmony together. The relationship between pedagogy and technology interventions is both contextual and dynamic, and as mentioned earlier, the teacher's role is crucial in determining how digital technology is used in school education.

5. Changing nature of the digital society

This section reflects on today's educational landscape in the context of a changing, dynamic digital society. It considers the evidence underlying some of the claims about future societies and the challenges that arise as a result and the impact on traditional models of teaching, learning and assessment.

The so-called fourth industrial revolution (Schwab, 2017) has implications for the nature of schooling and the roles of both teachers and learners. The fourth industrial revolution describes the exponential changes to the way we live, work and relate to one another due to the adoption of cyber-physical systems, the Internet of Things (IoT, 2018) and the Internet of Systems (Caprel, 2015). The World Economic Forum (2016) claims that developments in genetics, Artificial Intelligence, robotics, nanotechnology, 3D printing and biotechnology, to name just a few, are laying the foundation for a revolution more comprehensive and all-encompassing than anything we have ever seen.

A number of important macro-level drivers are associated with the pressure on schools to respond to the digital-era. First, the changing nature of work; we have been told for over a decade that today's schools and universities are at risk of preparing a generation of students for jobs that do not yet exist using out-of-date teaching methods and old learning technologies (Brown, 2017a). In a similar vein, several respected international agencies and generally trusted academic sources often cite the claim that 65% of jobs of the future have yet to be invented (Davidson, 2011).

However, a recent BBC (2017) podcast helps to expose some of the flimsy evidence underlying such popular assertions (Brown, 2017a). In attempting to trace the original source of the future of jobs claim,

the investigation found little or no solid evidence backing up the empirical basis of this statement. Doxtdator (2017) provides a more scholarly critique of the factual evidence behind the '65% of future jobs have yet to be invented' claim. He begins by citing the viral Shift Happens (2007) video that builds a strong and compelling narrative, which has subsequently been cited as an authoritative source by several high-profile reports published by the OECD (n.d.) and World Economic Forum (2016). Doxtdator was surprised to find after further investigation that versions of the jobs claim date from at least the 1950s and in the 1970s similar statements typified the discourse about how the nature of work was supposed to change. He provides a useful synthesis of several counterarguments provided by other scholars working in the area, which serve to solidly de-bunk such unsubstantiated predictions of the future. While we are teaching students for an unknown future, this is not an entirely new issue, as the future is different for every new generation, although perhaps the important distinction is the growing pace of change (Scott, 2017).

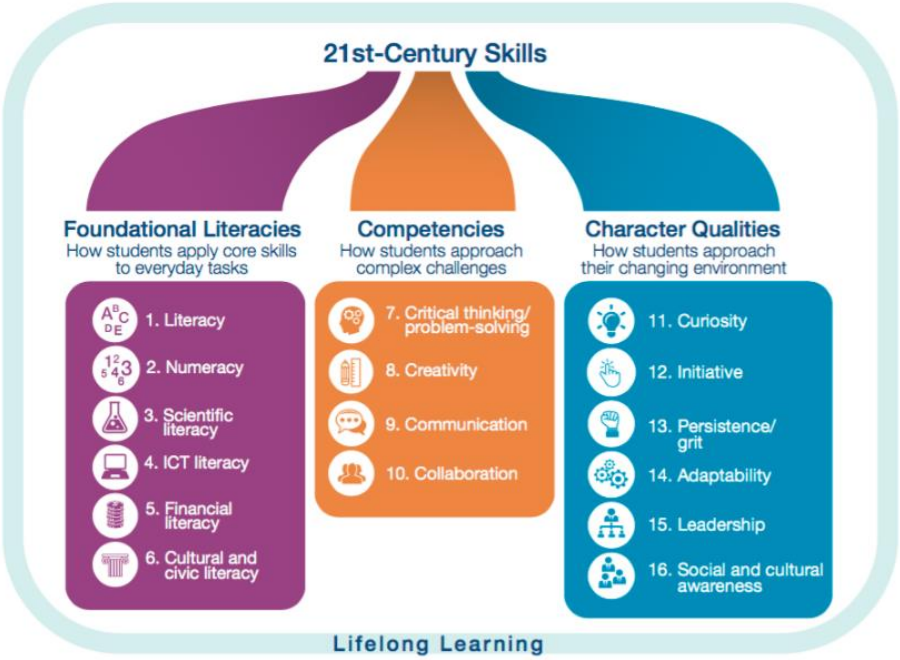

Figure 2: 21st-Century Skills (World Economic Forum, 2015)

Second, there is widespread acceptance that the so-called 'millennial generation' has different needs and expectations as a result of growing up in the digital-era. Many argue that as today's learners are immersed in a world of technology they are by nature digitally savvy; however, the popular distinction between 'digital natives' and 'digital immigrants' has been widely discredited (Judd, 2018). As the OECD (2015) report suggests, it is more likely that a wide spectrum of learners exists with differing levels of access, expertise and experience in their use of digital technology. Hence a more nuanced or sophisticated perspective of generational differences is required in making the case for schools to embrace the potential of new digital technologies (Pollak, 2018). Nevertheless, in light of the pace of change, we need to move beyond basic knowledge recall to developing 21st Century skills where students become more adaptive, lifelong and life-wide learners, as illustrated in Figure 2.

Having said that, there is an important tension between the development of new 21st Century skills and latent concerns around the disruptive presence of new digital technology in schools. These concerns are apparent in popular literature, which raises questions about the amount of screen time, the distraction of technology in schools and its negative impact on learning (see for example, O'Brian, 2017). Of course, such concerns are not new, as 20-years ago Armstrong and Casement (1998; cited in Brown 2017b)

claimed that it was scandalous that so much money had been allocated for computers and Internet access with so little serious evaluation. In their view:

> A generation of children have become the unwitting participants in what can only be described a huge social experiment (Armstrong & Casement, 1998, p.2; cited in Brown, 2017b, vi).

While such blanket statements and headline grabbing reports ignore the importance of the educational context and typically assign too much attention to the technology itself, they remind us of the long history of hyperbole and moral panics surrounding the perceived impact of technology on schools. The key point is that in light of this tension we need to be explicit about what is it that we want students to learn with new digital technologies and why they should have an important role in classrooms.

Third, there is now a wider spectrum of learning activities and resources from the traditional one-to-one Oxbridge tutorial model to learning through free OERs and MOOCs (Jemni & Kinsuk, 2017). MOOCs are challenging existing educational delivery models, although some argue the hype associated with MOOCs is waning (Qayyum, 2017), and that new forms of recognition of learning are arising, such as certificates of achievement, digital badges, micro-credentials (Ifenthaler, Bellin-Mularski & Mah, 2016; Liyanagunawardena, Scalzavara & Williams, 2017; Roy & Clark, 2018) and application of blockchain technologies (Witthaus et al., 2016; Grech & Camilleri, 2017, OUA, 2018). Although micro-credentials are not currently prominent in the schooling sector, they are likely to be in the future, as illustrated by the concept of 'EduBlocks' and 'The Ledger' in a futuristic video looking at education in 2026 (Institute for the Future, 2016).

So how do these powerful forces of change impact on the role of teachers and learners? In the case of learners, most people would agree that modern schools should prepare students to be adept at using digital technologies in almost every aspect of their lives. In the United States, The Office of Educational Technology (2017) states that:

> [In the future we need] learners who master agency [which] lays the foundation for self-directed lifelong learning, a critical skill for thriving in a rapidly changing world and for our nation to remain globally competitive.

Of course, preparing adept learners for the future also needs to incorporate a critical understanding of when and when not to use technology. This point underscores the need for teachers to also have critical digital literacies that go beyond narrow skills and competencies as no digital technology is benign (Brown, 2017c). While widespread agreement exists that digital literacies are crucial for living, working and learning in the 21st Century, the literature is littered with a plethora of models and frameworks (see for example, Alexander et. al., 2016; Beetham, 2017; Belshaw, 2015; Jenkins et al., 2006; Lankshear, & Knobel, 2008). Importantly, the European Commission has added to this literature with its own digital competence framework for both citizens (Carretero, Vuorikari & Punie, 2017) and educators (Redecker & Punie, 2017). However, according to Brown (2017c) most of these frameworks share a common flaw as they fail to go beyond the goal of merely preparing people to participate in the digital society. Arguably in this respect, the outcomes of formal education through new digital technologies need to develop critical citizenry, and individual and collective agency to help reshape better futures for all (Brown, 2018a).

By 2030, automation (driven by robotics and AI), globalisation and flexibility are predicted to change what we do in almost every job (FYA, 2017). Despite the need to be wary of such sweeping predictions, there is widespread belief that technology will reduce the need for individuals to complete routine tasks,

enabling them to focus on solving strategic problems and thinking creatively (Forbes Agency Council, 2017). We are also being told that traditional, linear career trajectories are rapidly becoming outdated, which is why schools need to prepare more adaptive lifelong learners. Moreover, the crucial role of digital technologies in almost every area of work is creating skills gaps and new career opportunities (Rainie & Anderson, 2017). While this claim has a solid factual basis, we are also being told at the same time that we need to prepare learners for jobs that do not even exist today. Importantly, the different change narratives often lack critical analysis and are couched in the language of technological determinism (Adler, 2006) – that is, a perspective which attributes far too much significance to the impact of technology itself rather than the role of people and culture (Selwyn, 2016). That said, social determinism, which is usually associated with the claim that 'technology is just a tool' and it is how people use the tool that is most important in determining related educational outcomes, is equally problematic; no tool is neutral (Brown, 2016a).

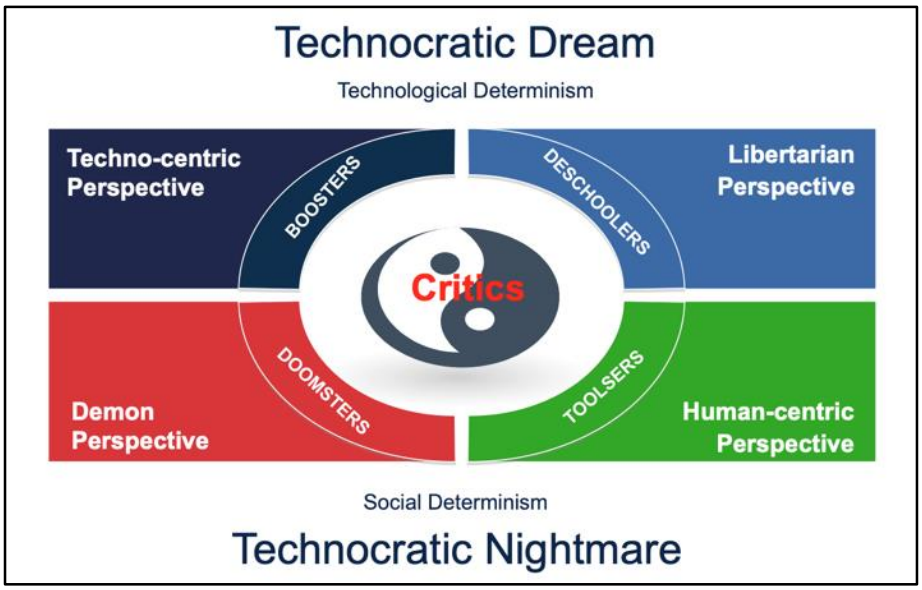

Figure 3: Teachers' competing mindsets (Brown, 2016a)

The key point is that a number of competing mindsets or perspectives influence the use of new digital technologies in schools (Brown, 2016b). Over the years, several taxonomies of the different perspectives adopted towards technology in schools have appeared in the literature. For example, Cuban (1993) identified 'the technophiles', 'the preservationists', and 'the cautious optimists'. The technophiles who chase the technological dream are shown in Figure 3 to include both the 'Boosters' and 'Deschoolers' who share a sense of inevitability that new digital technology is a driving force of society. The distinction is that the Deschooler views digital technology as a means of fundamentally disrupting an out-of-date education system. In contrast, the 'Doomsters' reflect those people opposed to the growing role of digital technology in schools and like the 'Toolsters' are guilty of adopting a socially or culturally deterministic view of the relationship between society and technology. The problem is they potentially misread the wider significance of the technology itself.

While this visual representation of the competing mindsets is overly simplistic, the central position of 'the Critic' is intended to illustrate that new digital technology can be both good and bad simultaneously, depending on the context. The Critic does not view technology as demon or panacea, nor do they imagine that new digital technologies are just another tool. Instead, they view the rapid growth of digital technologies in schools as a type of Chinese crisis. As Oppenheimer (2003) wrote:

> In Chinese script, crisis consists of two opposing characters, one symbolizing danger, the other opportunity. The tension of this duality exemplifies what has been happening lately in schools as politicians and education leaders in nearly every community in the world have been making their largest investment ever in state-of-the-art technology (p.xiii).

In summary, the lesson from reflecting on the changing nature of the digital society is that we should not uncritically accept the competing and co-existing change forces promoting greater use of new digital technology in schools. The underlying social, economic and vocational drivers are not new and require closer scrutiny, as does the pedagogical rationale.

6. The affordances of digital technologies

This section discusses the concept of affordances and then draws on recent future-focussed reports speculating on the future of digital technologies in school education. Gibson (1977) defines the term affordance as:

> All "action possibilities" latent in the environment, objectively measurable and independent of the individual's ability to recognize them, but always in relation to the actor and therefore dependent on their capabilities (Gibson, 1977, pg. 67-82).

For example, a tall tree has the affordance of food for a giraffe because it has a long neck, but not for a sheep, or a set of stairs has an affordance of climbing for a walking adult, but not for a crawling infant. Therefore, affordances are always in relation to individuals and their capabilities; this includes the individual's past experience, values, beliefs, skills and perceptions. Gibson also argued that:

> The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill (Gibson, 1979, p. 127).

Application of the concept of affordances to digital technologies is useful in a number of respects (Conole & Dyke, 2004). First, establishing a clearer understanding of the affordances should help to inform teachers in their use of technologies to achieve particular goals. Second, it can help to identify potential limitations and inappropriate uses of the technologies. Third, by making the inherent affordances of technologies explicit, this can act as a discussion point for critique and further refinement. Fourth, it can provide a checklist to help teachers understand the advantages and disadvantages of different technologies. Fifth, it can be used as a mechanism for supporting teachers' professional learning and improving practice – for example, by providing a checklist of potential benefits and drawbacks of different technologies, which can be used to inform choice and the ways that practitioners might choose to use them. Ng (2015) argues that students are more critical users of technologies. They are wary about engaging with digital technology if they are unable to see the purpose or value of using the technology. Educators need to be aware of the types of technology that are available for teaching and learning and their enabling capabilities.

Affordances differ according to the technology and the educational contexts in which they are used for teaching and learning. Moreover, descriptions of the affordances of digital technologies and related claims about improvements to educational outcomes, are still not adequately backed up by in depth trustworthy research evidence (Selwyn, 2014). This is an observation reinforced by Cuban's (2018) research and our analysis of both the grey and academic literature. Hence, there are still many more questions than definitive answers concerning the true extent of the impact of digital technologies on school education. The affordances of digital technologies (Ng, 2015; Selwyn, 2013, Trust, 2017) can

influence the ways in which technologies enable learners to interact with multimedia resources, to communicate and collaborate.

Aagaard (2018) argues that our current understanding of affordances does not adequately address the use of educational technology. He goes on to state that affordances do not just offer a range of action possibilities, but they actively invite certain actions. Extending the above example, they invite the giraffe to eat the leaves in the tree.

While digital technologies have many different affordances and can be applied in many different ways in schools, the Internet is arguably the single most disruptive innovation to have impacted on teaching and learning over the past 50 years (Quora, 2017). At the end of 2016, about 3.5 billion individuals – nearly one-half of the world's population – were using the Internet, a threefold increase in 10 years (Broadband Commission, 2017). What this means is that much reading is now done online, making digital reading a critical skill (OECD iLibrary, 2015). Furthermore, the more that accessing information over the Internet through computers becomes standard, the more important digital reading skills become a crucial educational outcome (Ramalingam, 2018). Although the terms are often used interchangeably, innovation is distinct from reform and change. Innovation is the implementation not just of new ideas, knowledge and practices, but also of improved ideas, knowledge and practices, whereas reform or change do not necessarily mean the application of something new, nor do they imply the application of improved ideas or knowledge (OECD, 2016).

However, the number of people worldwide without Internet access remains a concern with the UNESCO Broadband Commission (2017) estimating that by the end of 2017, some 3.58 billion people were predicted to be online, equivalent to 48.0% of the global population. According to Meeker (2018), the number of people with Internet access by 2017 had risen to nearly 4 billion, with better, faster and cheaper devices. In 2017, 85% of European households had an Internet connection, approximately double the share recorded in 2007 (EuroStats Statistics Explained, 2018). Nevertheless, a study published in 2017 estimated that 18% of primary and secondary schools in Europe were not connected to broadband (Forzati, et al., 2017) and a recent report found that European targets set for 2020 will not be achieved, with rural areas remaining less well connected than cities (European Court of Auditors, 2018). These reports illustrate how consideration of technology affordances is somewhat academic when a sizeable number of teachers and students do not have adequate access to the Internet.

Even when access is widely available, many claims about the value of digital technologies are often presented descriptively, without any critical analysis. For example,

Jandhyala (2018) cites a number of reasons for using online educational tools in the classroom. First, technology-driven education increases the learning and retention rates of today's learners, who have grown up with digital technologies. Second, digital technologies enable more interaction, participation, and engagement with rich multimedia content and a variety of ways to communicate and collaborate with peers, teachers and the broader community. Therefore, technology allows global learning, beyond the classroom. Third, digital technologies mean that students can engage with content outside of the classroom, for example by enabling them to watch and re-watch lectures. In addition, increasingly podcasts and classroom gaming are part of the learning process. Fourth, there is an abundance of free digital technologies, which can be used to personalise the learning experience.

Jandhyla's blog post, is typical of many of the unsubstantiated claims available in the grey literature, however it does go on to list a number of important examples. First, use of online quizzes, to test students understanding and provide formative feedback. They also allow students to pose questions and raise

doubts, which can be particularly valuable for shy students. Educational podcasts and videos provide a valuable alternative to just reading content. These can be listened or watched in advance of a class, so that the classroom time is freed up for more student-centred interaction. Video conferencing enables students in geographically different locations to co-attend a lecture. Students can use the backchannel to discuss the content and raise questions. Sessions can be recorded so that students can re-watch. Online gaming is increasingly recognised as an engaging way for students to learn (Teachthought, 2017). When used well they enable students to apply and test whatever they have learned on a daily basis. They are also claimed to motivate students to challenge each other and to continue learning outside the classroom (Paristiowati et al., 2017).

Finally, Jandhyala (2018) cites educational whiteboards for group interactions and presentations. Edsys (2018) also points to interactive whiteboards as being important, arguing that their affordances are changing the way in which subjects are covered in class. They are visually appealing for students, and teachers can easily handle multimedia presentations. Teachers and students can draw or write on them or take notes. Hence, the affordances of interactive whiteboards invite specific types of actions, but these are only realised in relation to how they are applied. Therefore, a key message is that the design of technologies and how they are used matters; not all tools have the same affordances or predispositions for particular actions. It follows that, for this reason, no single all-encompassing answer is possible to the question of impact on educational outcomes.

7. Ecology of digital technologies in schools

This section builds on the point that the use of digital technologies in schools is not a single entity and argues that today's educational context is complex and dynamic and digital technologies add to this complexity. The ten trends for transforming education that the European Political Strategy Centre lists (n.d.) indicate how complex the educational landscape is, with a range of interrelated and sometime competing facets. Supercomplexity (Barnett, 2000; Barnett, 2014) can be defined as structures that are comprised of multiple complex systems, which interact and operate at various scales; as a consequence, our very frameworks for understanding and engaging in the world are in dispute such that we, personally and in our institutions, no longer have a clear sense of identity or our responsibilities. It is a state of challengeability and contestation.

The notion of the modern classroom has both expanded and evolved as the virtual space has increasingly taken its place alongside the physical space. Importantly, when thinking about when and where learning can occur, students can now learn 'in-school in class' at scheduled times, 'in-school out of class' at unscheduled times, 'out of school in class' at scheduled times, and 'out of school out of class' at unscheduled times (Brown, 2015), as illustrated in Figure 4. Increasingly, some of the affordances of digital technologies are contributing to a type of digital leakage across these four key spaces or quadrants of the learning ecology.

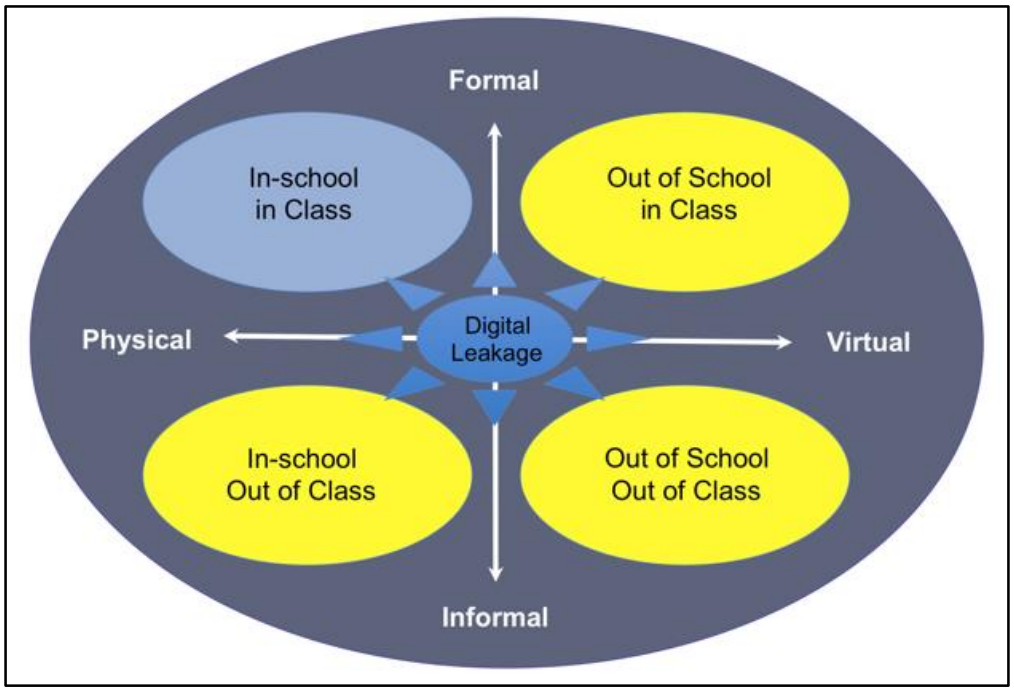

Figure 4: The new digital learning ecology (Brown, 2015)

The above depiction of the digital learning ecology illustrates that teaching and learning are now set in a wider and constantly changing techno-ecosystem with which individuals interact and co-evolve. Pea (2008) describes a series of phases of technology interaction (cited in Borgeman et al., 2008). The first phase being essentially 'cultural mediated' (face-to-face), the second being 'symbol mediated' (letters and numbers), the third being 'communication mediated' (TV, radio, phone), the fourth being 'network mediated' (wireless, database, Internet) and the fifth being 'cyber infrastructure mediated' (cloud computing, intelligence of crowds, constant contact, sensors networks). Pea's phases map nicely to our complex ecology metaphor as they demonstrate an evolving, increasingly complex and nuanced digital landscape, which relates back to affordances as well as the co-evolution of technologies and people. Put another way, this ecological perspective recognises that as technology shapes society so does society shape technology (Drinkwater, 2018) and is more complex and nuanced than the conception of technology as progress.

Nevertheless, many educators believe that technology is a powerful tool for transforming learning (Office of Educational Technology, 2017). They uncritically accept claims that technology can enable quality enhanced, personalised learning and experiences that are more engaging and relevant to students' individual needs. While many of these claims remain unsubstantiated, there is no doubt that the educational landscape is changing as a result of digital technologies, enabling students to have better access to information and ways of creating and sharing knowledge with their peers. For example, digital technology can enable students to engage more seamlessly with inquiry-based learning and real-world challenges. Increasingly, schools have access to the Internet in the classroom and use of a range of technologies, including a Learning Management System (Collins & Halverson, 2018,), which is particularly the case in secondary schools. As the quadrants in the above figure illustrate, technology can also provide students with virtual access to learning experiences beyond the classroom – that might be physically unavailable to them – such as museums, libraries and other out-of-school locations.

Some would have us believe that learners are increasingly demanding and want more personalised and flexible learning opportunities, which have been referred to as the "I Want What I Want When I Want It" (IWWIWWIWI) generation (OUA, 2018). Although we have shown the danger of uncritically

accepting such generalisations, with the significant integration of smartphone technology and the influence of social media, students have arguably become accustomed to gathering and consuming information in bursts and increasingly want bite size chunks of learning (Trowbridge et al., 2017). In addition, there is anecdotal evidence that school students are increasingly mixing formal educational offerings with free materials and courses, available through OER and MOOCs (Cavanagh, 2017; Cairneagle Associates, 2014). As a result, new forms of recognition of learning and accreditation are emerging, such as digital badges, certificates of participation/achievement. Of course, different learners will have different needs and will therefore choose different experiences, but the increasing leakage across the different places, spaces and modes require teachers to design for educational outcomes with this wider digital learning ecology in mind.

The increasing potential for connectivity beyond the classroom in this wider learning ecology means that it is important to teach students to become responsible digital citizens (EdTech, 2018). The importance of digital citizenship and data security more generally is increasingly being recognised, which aim to enable students to become competent users of technologies, aware of the benefits and potential dangers (Alexander et al., 2016; Beetham, 2017; Office of Educational Technology, 2017). In addition, most models of 21st Century skills, such as the one proposed by the World Economic Forum (2016), recognise the importance of how students approach complex challenges and their changing environment. They encourage students to take control of their learning, to meta-reflect (i.e., to reflect on their learning) in order to become more adaptive lifelong and life-wide learners.

This raises the question of how teachers can ensure that they are fostering 21st Century skills. One mechanism to achieve this is through e-portfolios (electronic journals for students to evidence their achievement of educational outcomes), which can help encourage critical self-reflection and self-assessment (Becker, Dolmans & Merriënboer, 2016). E-portfolios are suited to supporting the process of learning, development and assessment of integrated, cross-curricular knowledge and generic skills (e.g., creativity, critical thinking, employability, active citizenship and social participation in the digital world), as opposed to focusing solely on assessment of learning and disciplinary knowledge in individual subject areas (Kunnari & Laurikainen, 2017). Although Scully, O'Leary and Brown (2018) demonstrate the research literature in this area is relatively immature and suffers from positive reporting bias, the concept of the e-portfolio offers a potentially valuable digital platform for promoting self-directed lifelong learning. However, in order to develop self-directed learning skills, they need to be integrated throughout:

> ... the educational routine, when teachers coach students regularly, when scaffolding is applied to increase motivation, and when the portfolio is designed to facilitate at least goal-setting, task-analysis, plan implementation, and self-evaluation' (Becker, Dolmans & Merriënboer, 2016, p.32).

In other words, successful practice with e-portfolios to advance the goals of promoting lifelong learning and 21st Century skills requires the technology to be fully embedded in the learning process (Kunnari & Laurikainen, 2017). Redefinition or transformation of the whole learning ecology is required, as opposed to incremental curriculum enhancements through digital technologies.

8. Effective pedagogy for innovation

Digital technologies can be used to implement a range of innovative pedagogies. This section will critique some of the claims about the need for new models of 21st Century pedagogy and reiterates the

point that the role of the teacher is still crucial.It is common to hear that school education needs to shift from being teacher-centred to learner-centred (Varatta, 2017). Other distinctions between these two contrasting paradigms or pedagogical approaches talk about the need to move away from teacher-centred to more learning-centred classrooms. Churchill (2017) provides an indication of the ways in which learning is (or needs to) shift from a focus on teacher-centred to learning-centred practice (**Error! R eference source not found.**). Of course, such binary conceptions of the need for new learning-centred models of practice are not new, with Perkins (1992) over 20-years ago making a case for a shift from training memories to educating minds – that is, from knowledge recall to teaching students higher-order thinking and problem-solving skills.

Table 1: Teacher-centred and learning-centred approaches (Churchill, 2017)

Teacher-centred	**Learning-centred**
- Learning of facts and declarative knowledge - Memorising information - Teacher is central to learning - Passing text/ exam and achieving the grade - Drilling of right questions and routine - Learning to pass exams - Focus on information presentation to passive learning - Technology as a media channel - Learning from resources and technology	- Learning of conceptual knowledge - Working with information - Activity is central to learning - Applying knowledge, theoretical thinking and demonstrating generic skills - Problem-solving, design, project work and inquiries - Learning how to learn - Focus on how learning occurs within an activity - Technology as intellectual partner in learning - Learning with resources and technology

However, Sfard (1998) argues in a seminal publication on learning theory that acquisition (teacher-centred) and participation (learner-centred) metaphors of learning are not mutually exclusive; this is a false dichotomy. Arguably, these two root metaphors of learning and the dangers of picking just one provide a much stronger theoretical framework for analysis of the pedagogical affordances of new digital technologies rather than simplistic binaries proposed by Churchill and others. In particular, Sfard's work underscores the tendency for the uncritical adoption of popular teaching and learning 'catchisms' in the context of new digital technologies, which Selwyn (2016) eloquently articulates in his critique of the literature. While so-called constructivist, inquiry-based approaches have become fashionable they have been shown to have serious shortcomings (Kirschner, Sweller & Clark, 2006), and, arguably, the fundamentals of good pedagogy have not really changed over the past 50-years. For example, a recent meta-analysis of the effectiveness of direct instruction over a half-century of research shows that it continues to be a valuable method for inclusion in any teacher's pedagogical toolbox (Stockard et al., 2018).

Therefore, this report contends that efforts to harness the potential of new digital technology in school education should be framed in the language of promoting learning-driven approaches, which recognise the value and need for a wide range of both traditional and contemporary teaching methods.

Put another way, fostering learning-driven approaches that support a variety of teaching methods should be one of the outcomes we seek rather than theoretical exclusivity towards a specific pedagogy. In this respect, the HoTEL (n.d.) project provides a useful visualisation of the wide range of learning theories and pedagogies, mapping these back to cognate disciplines, key theorists and the central tenets of each

theoretical perspective. The key point is that there is no one single pedagogical model for the use of digital technologies as the most appropriate designs for learning (both with and without technology) should be informed by the nature of the students, intended educational outcomes, specific discipline cultures, and so on. As a recent US report on how people learn concludes:

> Effective instruction depends on understanding of the complex interplay among learners' prior knowledge, experiences, motivations, interests, and language and cognitive skills; educators' own experiences and cultural influences; and the cultural, social, cognitive, and emotional characteristics of the learning environment (National Academy of Sciences, 2018, pp. 6-7).

While effective pedagogy involves many different factors, Paniagua and Istance (2018) draw on the OECD's (2010) seven principles of learning to promote the importance of pedagogical combinations. More specifically, they propose six clusters of innovative pedagogies from different theoretical perspectives to support different approaches and different purposes: blended learning, gamification, computational thinking, experiential learning, embodied learning, and multi-literacies and discussion-based teaching. The value of Paniagua and Istance's (2018) work is that they provide an inclusive and integrative framework for thinking about the conditions for successful teaching and learning innovations, especially in terms of how different pedagogical combinations or constellations can be used to harness the potential of digital technologies in schools.

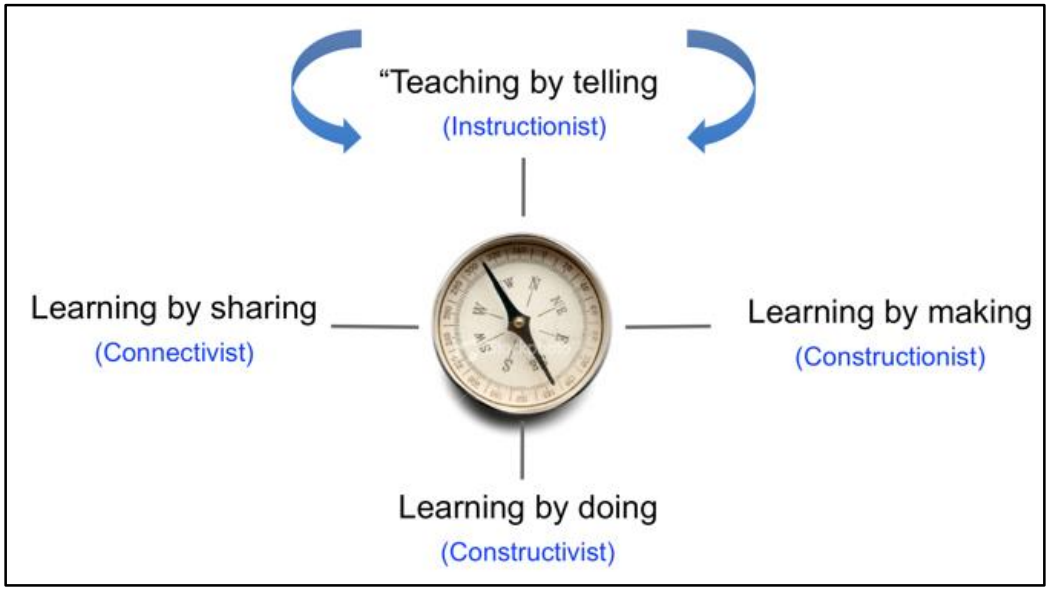

Figure 5: Pedagogical compass (adapted from Brown 2008)

Put more simply, Brown (2016a) argues that effective pedagogy requires a teacher's pedagogical compass to swing between learning by listening, learning by doing, learning by making and learning by sharing depending on the context, nature of the students and learning intentions (Figure 5). Metaphorically speaking we need to ensure the needle is not always pointing towards more traditional 'learning by listening' methods but equally the compass should not be stuck in any particular direction, as effective pedagogy requires a variety or combination of approaches.

At an even deeper level, Scott (2015b) anchors the question of a guiding pedagogy or an overarching framework for the transformative use of new digital technologies in the original UNESCO Pillars of Learning: learning to be, learning to do, learning to know, and learning to live together. In many respects this enduring framework for learning still has relevance in the 21st Century in helping to define or reimagine the types of educational outcomes we might want to achieve through new digital technologies in schools.

9. Learning and future classrooms

In looking at the future of learning, this report describes a number of new and emergent developments in digital technologies. In particular, it considers the future classroom and how new and emerging developments in digital technology might be able to help reimagine the curriculum, support intentional pedagogical combinations and promote more 21st Century learning-driven approaches. It begins by introducing a number of future-focussed reports on new and emergent technologies.

The annual New Media Consortium (NMC) Horizon Report indicates which technologies are likely to have the most impact in one, three and five years' time.1 The K-12 report for 2017 indicates the following technologies (NMC, 2017).

In the one-year timeframe, mobile learning via tablets and smartphones will be increasingly important in the classroom. On a related note, Sung at al. (2016) undertook a meta-analysis of the effects of integrating mobile devices in teaching and learning. They found only a moderate effect size for the application of mobile devices to education, which suggests they have yet to have a truly transformative impact on educational outcomes. As mobile devices facilitate multitasking, there may result in fragmentation, which could have a negative impact on learning. According to the Horizon Report, cloud computing will also be increasingly important; teachers will be able to share learning materials and experiences with each other, their students and parents. Kates et al. (2018) examined the relationship between mobile phone use and educational achievement. Of the 39 studies they investigated, 36 reported a negative relationship and 3 reported a positive relationship.

In two to three years, the application of big data through learning analytics will enable teachers to see students' progress more accurately and show students how they are learning and what they are achieving, along with matching their progress against the progress of their peers. Edsys (2018) argues that data generation in the classroom is on the rise, including assignments, attendance, projects and weekly tests. Monitoring these can enable a teacher to get an assessment of students' performance.

In the five-year timeframe, 3D printing is likely to be widespread to enable students to make tangible models for their ideas. Virtual laboratories will give students the chance to perform physical experiments repeatedly, providing them with extra practice and guidance. This it is claimed will encourage productive failure and enable students to make and learn from their mistakes.

The OU UK's Innovating Pedagogy report (2017) lists ten changes to higher education, which in the future will also have relevance to schools. The future of education is likely to continue to change and co-evolve with technologies and needs to meet the challenges of a complex future. Some have argued that the role of teachers will diminish as the use of technologies becomes more prevalent (Hanson, 2009) and as we see the impact of AI (Torque, 2018). This is unlikely to be the case. In fact the role of the teacher will be increasingly important to help learners navigate their learning and make effective use of technologies (Microsoft, 2018; Office of Educational Technology, 2017).

In the future, it is likely that students will learn across a range of formal, non-formal and informal contexts (i.e., within and beyond the traditional classroom as illustrated in Figure 4). Therefore they can evidence their achievement of educational outcomes through e-portfolios or through the use of

[1] This no longer exists and the reports have been taken over by EDUCAUSE

blockchain technologies (see UniversaBlockchain, 2018 for an outline of how blockchain technologies will impact education).

Murray (n.d.) argues that education is changing as a result of the increasing use of digital devices, arguing that students will each have digital devices and will use social media to communicate with peers. Homework will be submitted online and grades will be posted immediately. Classes will have an associated website and calendar and students will be able to share their screens with each other and their teacher and there is some indication that this is already starting to happen. Edsys (2018) argues that a personalised class website will help students, teachers and parents to keep in touch. Information about upcoming assignments and syllabus can also be posted on a class website.

Bernard (2017) argues that technologies can help accommodate the variety of ways in which learners learn, so that the learning experience is personalised. In this respect, the use of adaptive technologies will be of particular note in relation to future classrooms . With information only an Internet search away, students need to move beyond information recall to develop the skills needed to be part of a technology-saturated environment and to enable them to learn on their own. Bernard (2017) also argues that the teacher's role will be more important than ever in technology-enriched classrooms. Teachers will be able to use the data available via a LMS to track students' progress, and identify and support students who are struggling. Rogers (2018) argues that in the near future students will expect seamless technology in school and use of 1:1 devices will be standard. Critical data will be stored in the cloud. He also suggests that collaborative tools and video communication tools will become more widespread.

Nanton (2018) lists three examples of ways in which technologies might transform the classroom. First, technologies can enable students to connect with experts in their field beyond the classroom, via remote teaching. Second, collaborative tools can allow teachers to manage their classrooms, enabling them to create classes, distribute assignments, set quizzes and provide feedback. Third, the flipped classroom will become increasingly important, whereby students engage with 'passive' content in advance of the classroom. The classroom context can then be used to expand on and master the material through classroom exercises and discussions. The teacher no longer lectures the students but becomes more of a facilitator of learning. While on the surface the theory of the flipped classroom supports more contemporary models of pedagogy, what does the research literature actually say? Does the flipped classroom lead to improved educational outcomes? Chuang et al. (2018) explored individual learner characteristics, such as learner motivation, self-efficacy and epistemology beliefs and their impact on educational outcomes. Learners with high beliefs exhibited improvement in the post-tests without doing well in quizzes. However, not all researchers support such positivist discourse (Schmidt & Ralph, 2006; sushislifeblog, 2016).

Po (n.d.) lists eight technologies that will arguably shape future classrooms:

1. Augmented Reality (AR)allows users to see additional information layered over what they see through the lens. One application of AR is virtual field trips. Edsys (2018) argues that engaging students in the classroom is the key to gain their interest in learning and that this is possible to a greater extent with AR.

2. 3D printersenable students to print out 3D models. Teachers can use these to reconstruct complex concept models to teach theoretical concepts. An example is using a 3D printer to teach the concept of molecular structures and configurations. Edsys (2018) suggest that these enable students to have access to 3D models of the different elements covered in their subjects. A 3D view is claimed to help students develop a deeper level of understanding. However, once again we found that such claims about the

potential of digital technologies in school education are not always well supported with credible or trustworthy research evidence(Niederhauser et al. 2018).

3. The use of cloud computing to store students' work, which means they have access to their work and resources from anywhere, enabling more flexible, learning across formal, informal and non-formal learning contexts.

4.The use of online networking to connect beyond the classroom and to enable more many-to-many interactive learning where ideas are allowed to flow freely. Edsys (2018) argues that online social networking enables students to socialise with their classmates and teacher. Teachers can act as moderators and students can share their ideas with their peers.

5. Social networking can play a crucial role in improving engagement, interaction and team building activities in the classroom. This may be the case but once again our review found very little evidence in the research literature on school education published since 2017 to substantiate such claims. Indeed, a number of authors argue there are significant disadvantages to using social media, such as issues around addiction, social isolation and distraction (Dabaroz, 2018; Ahmad, 2016). Of course it needs to be noted that this gap in the research literature may reflect the time lag between innovations in practice and the publication of research findings.

6. Flexible OLED-based displays (organic light-emitting diode),which are lightweight, flexible and thin. Biometric tracking uses an individual's unique assets (such as fingerprints, facial recognition, iris patterns and voice) to authenticate identity. Eye tracking can be used by a teacher to understand what a student absorbs and understands in a particular learning context. The data can be integrated with interactive adaptive systems to adjust the content to best meet a particular student's learning approach. However, it is worth noting that there may be ethical issues associated with this type of technology.

7. Multi-touch LCD (Liquid Crystal Display) screens, which allow greater interactivity. Students can sit around the table, swipe on the tablet to manipulate and drag images around the screen or type notes with their onscreen keyboards. Such screens are useful for collaborative learning activities.

8. Game-based learning can enable students to learn in fun and engaging ways through interactive games. Po speculates that in the future education will no longer be restricted to formal educational contexts; use of digital technologies mean that learning can take place across a range of contexts. Once again we found that such speculative predictions on the future of school education appear to be common in the grey literature, but there is a distinct lack of supporting research evidence in peer-reviewed academic literature published in the last few years to support many of these claims. Also, Dawson and Dawson (2016) identify the problem of significant positive reporting bias in the literature on innovations in teaching and learning, as failed initiatives or implementation projects where the results are insignificant are less likely to be published.

Singh (2018) suggests that chatbots or Artificially Intelligent conversational tools, built to improve student interaction and collaboration, will be a game changer in education in the near future. He cites intelligent tutoring systems that can provide a personalised learning environment to the students by analysing their responses and how they go through the learning content. Similarly, chatbots with AI technology can be used by turning a lecture into a series of messages to make it look like a standardised chat conversation. The bot may repeatedly assess the level of understanding of the student and present the next part of the lecture accordingly. He goes on to suggest that virtual assistants can enhance student

engagement. Bots could also provide feedback, information about a course and associated assignment deadlines or to ask students what they like or would like changed with their course.

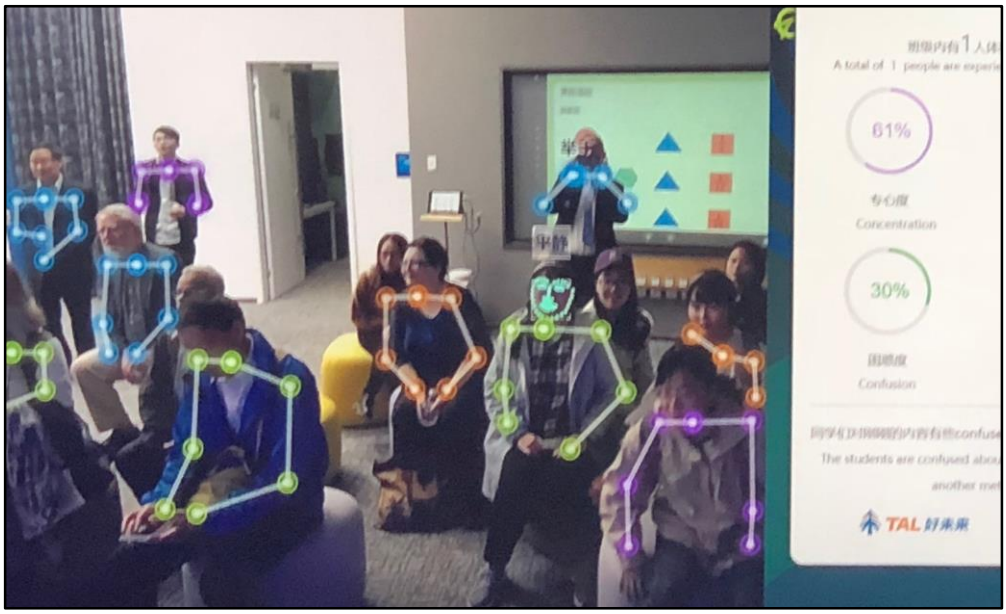

Figure 6: Example of new analytics on learner emotion

The importance of emotion in relation to learning is well known. At a recent first-hand experience in Beijing at the TAL Education Group (Figure 6), the use of learning analytics is quickly evolving to use facial recognition software to provide data on student engagement and affective and emotional responses to learning experiences. This line of research includes efforts to share a personal dashboard of key indicators with learners, although questions remains over the validity of this information. Despite the claim that the analytics can predict emotions, there are flaws in that the learners can easily subvert this. D'Mello (2017) argues for the need to couple the discovery-oriented, data-driven, analytic methods of learning analytics and educational data mining with theoretical advances and methodologies from the affective and learning sciences.

Another area of research generating a lot of excitement is that of teaching robots. Greene (2018) indicates that researchers around the world are closing in on the development of a truly autonomous robot. However, in a recent study Belpaeme et al. (2018) argue that although robots can play an important role in the education of young people they will never fully replace teachers. They suggest that due to current technical limitations – particularly around speech recognition and the ability for social interaction – the role of teaching robots will largely be confined to that of teaching assistants or tutors, at least for the foreseeable future.

However, as stated throughout this report, we need to be cautious about the hyped and technologically deterministic discourse around the potential of digital technologies to transform education in the future. As Weller (2018) shows in a 20-year review of educational technology, there is a long history of educators chasing the next big thing. The reality of learning in the future classroom is likely to be more nuanced, dependent on a complex range of inter-related factors, such as the affordance of technologies, teacher beliefs, and institutional contexts and cultures.

In terms of looking to the future of classrooms, it is useful to articulate some future scenarios. Watanabe-Crockett (2018) outlines six future learning scenarios for envisioning schools of tomorrow:

- The first focuses on a classroom without walls, learning across a range of contexts and through a variety of resources.

- The second is about customised learning, where resources are matched to student preferences and skills levels.

- The third is about real-world connection: students need to weed out misleading and incorrect information to make the best decisions for themselves and their environment.

- The fourth is about enhanced assessment and feedback, critical, as mentioned elsewhere in this report, because we know assessment is a key driver.

- The fifth is about enabling a flatter classroom, moving beyond exams to more of a focus on field experience and classrooms without walls.

- Finally, teachers' roles will shift from delivery to facilitation, where they help students to navigate their own learning, fostering habits of lifelong learning in the process.

Delgao (2018) describes the classroom of the future focusing on promoting collaborative and flexible learning spaces with new educational methodologies. Delgao explores creative spaces where students can record, produce and edit as a team, where they can present their projects, enabling them to be active learners, developing solutions to communication problems, and providing them with opportunities to promote self-reflection and informal learning.

Katz (2017) provides a vignette of a student Anaya in 2035. Features include a MindClock, a blending of online and on-the-ground classes, group and solitary work, maker, doer and thinker classes. Anaya also has Mr. Yip, her Holographic Advisor Bot (HAB), who helps her understand the critical thinking and design/engineering thinking learning goals and helps her navigate the thousands of courses that would satisfy her plan. Finally, she has implants that enable her to participate in numerous languages.

In summary, this section has provided examples of how digital technologies might be used to facilitate different pedagogical approaches and enable students to communicate and collaborate, to reflect on their learning, and receive timely, appropriate and personalised forms of teaching, learning and assessment. The focus has been on exploration of the potential impact of digital technologies on future classrooms.

It concluded with some scenarios for the future. The section demonstrates the potential opportunities digital technologies offer in the future. Nonetheless, to date the field has been dominated by hype, hope and disappointment and therefore past experience suggests we need to be cautious.

10. Importance of teacher's professional learning

A significant theme throughout this report is the central role of the teacher in the design, delivery and support of learning interventions. Key to this is the need for and importance of Teacher Professional Learning (TPL). The term TPL is chosen deliberately in this report as opposed to the more traditional term Continuing Professional Development (CPD) as the former conveys a less deficit-oriented model that appreciates how valuable professional learning can occur in formal, non-formal and informal contexts (WGU, 2017). This conception of TPL also recognises that supply-driven one-off approaches or the traditional one-day workshop model does not work (Lashwood, 2018).

Professional learning

> ...is more effective if it communicates the pedagogical value of technology, coupled with practical examples of technology-enhanced teaching strategies, and preferably linked to subject-specific and curriculum-relevant learning outcomes (Conrads et al., 2017, p.16).

According to Brown (2018b), it is generally accepted that the design of effective and impactful TPL in the context of new digital technologies needs to:

- Recognise teachers as learners
- Contextualise learning activities
- Value teachers' existing knowledge
- Engage teachers in critical self-reflection
- Challenge pre-existing pedagogical beliefs
- Recognise important discipline differences
- Foster strong professional communities of practice
- Support multi-faceted approaches to meet differing needs
- Embed new digital technologies in authentic and meaningful contexts
- Promote deep and sustainable changes to educational practices which enhance outcomes for learners

More generally, Darling-Hammond et al. (2017) make the point that effective professional learning results in changes to teacher knowledge and practices and leads to improvements in student learning outcomes. They define professional learning as a combination of both externally provided and job-embedded activities that increase teachers' knowledge and help them change their instructional practices in ways that support student learning. Therefore, the measure of the success of any TPL initiative is the extent to which it promotes enhanced educational outcomes for students.

New digital technologies can easily be used to reinforce or perpetuate traditional teaching methods (Butler, 2017; Tondeur et al., 2016). Put another way, there is a tendency for teachers to merely tame new digital technologies based on traditional practices rather than embrace transformative models which more fully exploit their pedagogical affordances (Brown, 2015).

There is a crucial link between teachers' pedagogical beliefs and their educational use of technology (Tondeur et al., 2016), which must be taken into account if TPL is to be effective and impactful. Arguably, teachers' pedagogical mindsets rather than their technical skill-sets matter most in shaping innovative practices. While a large number of teachers in increasingly technologically-rich classrooms reportedly lack the skills and confidence to employ new digital technologies for educational purposes (Conrads et al., 2017), it is debatable whether improved attitudes and competencies alone will result in more transformative pedagogical mindsets leading to better educational outcomes. Indeed, merely increasing teachers' confidence and basic digital skills without challenging traditional pedagogical beliefs may simply lead to new technology being a poor substitute for more pedagogically-rich learning activities with no fundamental change.

This point reiterates the core principle of 'pedagogy first' in the design of any transformative model of professional learning aimed at harnessing the potential of new digital technology in schools. This principle is implicit in both the well-known Technology Pedagogy Content and Knowledge (TPACK) framework (Harris, Phillips, Koehler & Rosenberg, 2017) and the recently developed Digital

Competence Framework for Educators: DigCompEdu (Redecker & Punie, 2017) as Figure 7 illustrates. In DigCompEd, educators' professional and pedagogical competences serve as overarching pillars across the six areas of the framework which also encapsulates the call to action with the development of learners' transversal skills (i.e. skills that are typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge and that can be used in a wide variety of situations and work settings), subject-specific competences and digital competence. Notably, this call to action is a crucial element missing from TPACK. While some European countries, such as Ireland (Department of Education and Skills, 2017) and Croatia (Balaban, Begicevic Redjep & Klacme Calopa, 2018), have developed their own maturity models for TPL in the context of digital technologies, the most effective and impactful interventions supporting enhanced educational outcomes for students are less well known (Conrads et al., 2017).

There remains a significant gap or disconnection between the goals for 21st Century teaching and learning and well-designed TPL programmes to develop these skills (Butler et. al., 2017). Faced with this uncomfortable reality, Butler et al. (2017) argue that the challenge is to design professional learning experiences for teachers that enable them, in turn, to design learning activities that enable their students to develop the competencies required to live and thrive in the digital-era. What is clear from the literature is that there is no 'one size fits all' supply-driven or demand-led model of professional learning.

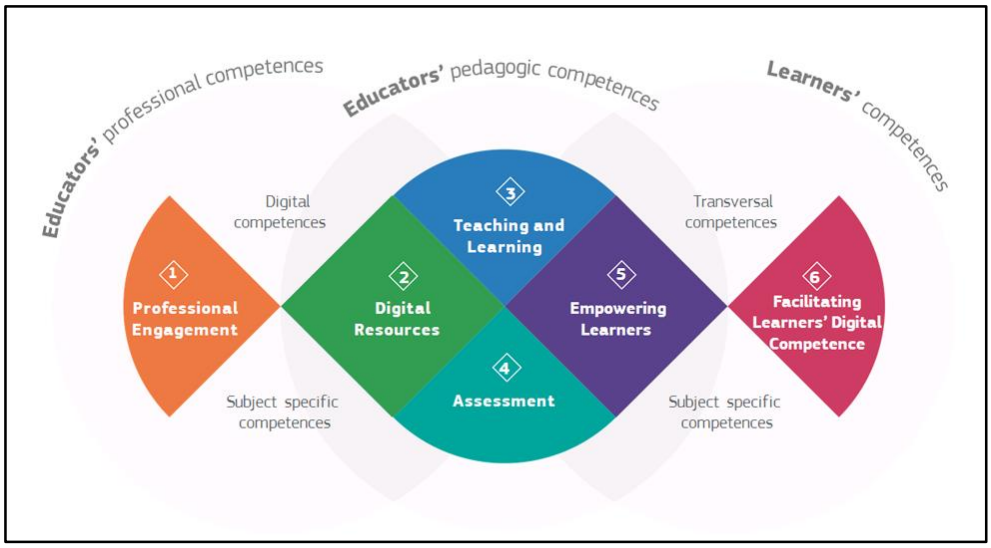

Figure 7: DigCompEd Framework (Redecker & Punie, 2017)

TPL can take a range of formats: formal courses and masters programmes, specialised and tailored workshops, peer support and mentoring, examples of good practice in innovative learning interventions and use of digital technologies, portfolios of professional practice, teaching and learning conferences, and opportunities for teachers to share and discuss their practice. One of the most valuable means is learning from colleagues by engaging in informal conversations (Thomson & Trigwell, 2016). Conversation can be used for a variety of purposes: to help teachers manage their teaching context, improve their teaching and student learning, reassure themselves about their teaching practice, discuss teaching-related issues and problems and provide them with opportunities to connect with like-minded peers to exchange ideas, and to enable them to develop an educational language. Coupled to this, team-based professional learning and the development of communities of practice are increasingly being seen as important (Butler et al., 2017; Conrads et al., 2017; Gast et al., 2017). In addition, it is recognised

that supporting professional learning with development grants and establishing schools clusters for innovative teaching initiatives can also make a significant difference (Selver & Ham, 2010).

There is also evidence that online communities present an effective professional learning opportunity for teachers (Conrads et al., 2017) and recent research suggests that many teachers voluntarily engage in communities, such as e-twinning, to enhance their digital pedagogical skills (Castaño-Muñoz et al., 2018; Koutsodimou & Jimoyiannis, 2015). An innovative approach through the design and delivery of a MOOC for teacher professional development is described by Butler et. al. (2017). They conclude that one of the key challenges is to design the social networking within the MOOC structure to sustain the collaboration, dialogue and ongoing reflection that is necessary for changes in pedagogical orientation and classroom practices. The challenge is to develop ways that a school-embedded, job-focused model of TPL can be scaled effectively so that rich learning experiences are contextualised and rooted in classroom practice (Butler et al., 2017). Possible ways of doing this according to Butler et. al. (2017) involve a blended model with

> The identification of cohorts of teachers at local and regional levels that would be capable of supporting others, recreating the collaborative nature of peer coaching and developing communities of practices that would sustain a culture of self-evaluation (p.241).

The importance of self-evaluation is recognised in a new tool recently launched by the European Commission (2018) known as SELFIE (Self-reflection on Effective Learning by Fostering Innovation through Educational Technology). This tool is designed to help schools and teachers assess their use of technology to support students' learning. SELFIE asks questions to school leaders, teachers and students and based on this feedback it provides a picture, that is a SELFIE: a snapshot of school's strengths and weaknesses in their use of digital technologies for learning. Importantly, SELFIE represents a significant shift away from traditional supply driven models of CPD by promoting teachers' reflection, self-reliance, adaptability and the development of local solutions for local problems.

In summary, supporting TPL and strengthening educators' capacity and capability to meaningfully integrate digital technologies into the curriculum is a key priority (Conrads et. al., 2017). However, effective TPL is complex and depends on a range of factors; it remains unclear what models, approaches and interventions are most effective and scalable in developing the types of pedagogical mindsets and specialised technology pedagogical knowledge that help embed new digital technologies throughout the curriculum for enhanced educational outcomes.

11. Major barriers and enablers

While the literature is dominated by examples of positive ways in which digital technology can improve educational outcomes, Himmelsbach (2017) lists six advantages and disadvantages of using technology in the classroom.

On the one hand, technology allows teachers to experiment with pedagogy, democratise the classroom and better engage students. On the other hand, technology in the classroom can be distracting and even foster cheating. He quotes Goodrum, Director of Academic Technology and Information Service, from Oregon State University:

> Digital education is generating new learning opportunities as students engage in online, digital environments and as faculty change educational practices through the use of hybrid courses,

> personalised instruction, new collaboration models and a wide array of innovative, engaging learning strategies.
>
> Furthermore, a 21st century view of learner success requires students to not only be thoughtful consumers of digital content, but effective and collaborative creators of digital media, demonstrating competencies and communicating ideas through dynamic storytelling, data visualisation and content curation.

While the list of advantages and disadvantages cited in the introduction needs to be understood in terms of specific educational contexts, Himmelsbach (2017) concludes by stating that the key to technology use in the classroom must be the teacher-student relationship and interaction. Technology is not meant to replace the teacher, but rather to help create a flexible and engaging learning environment. A number of models, such as the Community of Inquiry framework (Garrison and Anderson, 2003), recognise the importance of the teacher's presence and the teacher-student, student-student and student-content interactions. However, these have not been well researched in school education as of yet. Allen et al. (2013) did a meta-analysis exploring future student achievement from observed teacher interaction with students in the classroom. They found that classrooms characterised by a positive emotional climate, with sensitivity to adolescent needs and perspectives, use of diverse and engaging instructional learning formats, and a focus on analysis and problem solving, were associated with higher levels of student achievement.

In a detailed OECD report, Paniagua and Istance (2018), list a number of pedagogical implications of technology use. In terms of advantages, technology can improve educational outcomes and improve learning engagement and motivation. Technologies can be a complement to teaching and not a substitute, and give learners an active role and promote collaboration. Challenges include the fact that young learners may not be technologically savvy and technologies may reproduce traditional pedagogies.

Cambridge Assessment (2017) define digital technologies as

> Digital processing systems that encourage active learning, knowledge construction, inquiry, and exploration on the part of the learners, and which allow for remote communication as well as data sharing to take place between teachers and/or learners in different physical classroom locations". The site lists the following examples: Bring Your Own Device (BYOD) – where students can bring their own technology into the classroom, e-portfolios, flipped classroom, Personal Learning Networks (PLNs) and Virtual Learning Environments (VLEs).

Mobile phones or tablets can be used to search the Internet as part of a research activity. BYOD is now possible more than ever given the decreasing cost of such devices. The risks are that they may be difficult to control and monitor usage, not all learners will have good devices and teachers may not understand how best to use such devices in the classroom.

With e-portfolios, students and teachers create an electronic catalogue of their work that tracks their learning journey. This might be, for example, a portfolio of artwork, along with a written reflection. It provides a way of quickly and seamlessly presenting a wide variety of material in different formats and a way of logging learning progress. However, there may be data security and confidentiality issues and teachers may not know how to use them. TeachThought (2018) lists the following five reasons for using e-portfolios in the classroom: they expand the repertoire available to students and teachers, they can support students who are struggling, they increase accessibility, they develop 21st Century skills and they enable students to track and demonstrate progress.

Cambridge Assessment (2017) argue that a digital technology classroom can foster dialogic and emancipatory practice. Dialogic practice is where students are actively, engaged and empowered participants in a conversation from which learning emerges. Emancipatory practice is where an individual student's ideas go beyond the learning prescribed by the teacher/syllabus as they draw on knowledge gained from outside the formal educational context.

A number of frameworks for systematic integration of digital technologies have been developed. For example, the SAMR framework shows how technologies can progressively enhance learning from Substitutions, Augmentation, Modification and Redefinition (Puentedura, 2013). However, the value of these frameworks for technology integration depends on how they are used; some have criticised the SAMR framework for being too linear (Love, 2015), whereas it is known that design should be creative, iterative and reflective of the context (Conole, 2013). The key point about SAMR is it moves from enhancement to transformation. The central question is whether future classrooms will be focussed on true transformation or on incremental change.

This section returns to the question of the major success factors in terms of effective use of digital technologies in schools. Examples of barriers and enablers to the effective use of digital technologies in schools have already been peppered throughout this report. Therefore, the discussion primarily seeks to identify and reflect on the main barriers and enablers according to a distinction between first and second order factors (Ertmer et aI., 1999) that influence the impact of digital technologies on teaching and learning.

First-order barriers are defined as constraints and limitations that are external to teachers (Ertmer et aI., 1999). They can be classified as being extrinsic factors that prevent attempts to adjust or tinker with the current system to make it more effective. Typically, such barriers include: lack of access, lack of funding, lack of vision, lack of leadership, lack of planning, lack of resources, and inadequate infrastructure (Ertmer et aI., 1999). Second-order barriers are defined as conflicts and tensions that are internal to teachers and the places they work (Ertmer et al., 1999). These barriers include intrinsic factors that prevent the adoption of new teaching methods and technologies in ways that might help reimagine basic conceptions of school education and the nature of teachers' work. Typically, such barriers refer to teachers' educational mindsets, beliefs about teaching and learning, beliefs about technology and its educational value, established classroom practices, institutionalised routines, social and interpersonal relationships, and ability and willingness to change. While second-order barriers and enablers play a key role at the local level in influencing classroom practice, a scalable and sustainable culture of innovation depends on a range of factors across the macro, meso and micro-levels of the education system.

We know from past experience that funding, infrastructure and lack of explicit policies or strategies are key first-order barriers. In terms of the latter, it remains unclear from the literature whether the development of a dedicated digital learning strategy at both the national and school level is more effective than infusing the use of new digital technologies for teaching, learning and assessment throughout existing policy initiatives. Of course, the two options are not mutually exclusive and perhaps the key lesson is the importance of policy alignment. If a dedicated strategy is developed then the goals, aspirations and desired outcomes need to be reflected within and woven throughout other educational policy initiatives. This lesson applies across all three levels of the sector and therefore requires an aligned dialogical approach involving a combination of top-down, middle-out and bottom- up policy-making processes.

Another important first-order factor is the need for a coherent strategy to help build teachers' capacity and capability to effectively use digital technologies (Scottish Government, 2016). However, this

enabler raises the question as to whether targeted efforts to upskill teachers in the use of digital technologies are more effective than infusing or embedding these skills in a wider programme of professional learning. This question concerns the issue of transfer and what is likely to have the greatest impact on educational outcomes. The literature on professional learning suggests that greater success is likely to arise when efforts to challenge teachers' mindsets and build their digital capacity and capability are embedded in authentic and meaningful contexts. The key point is that based on past experience merely teaching digital skills to teachers in the hope this will increase their confidence to make effective use of new technology in the classroom is unlikely to have a transformative impact on traditional practice.

Lawrence and Tar (2018) illustrate this point in a useful summary of many of the factors that influence teachers' adoption of digital technologies. They claim that technologies provide opportunities for greater flexibility, interactivity and accessibility for engaging teaching and learning at the individual, group and societal levels. However, they argue teachers' attitudes towards digital technology play an important role in influencing adoption and integration in the classroom; for example, if teachers have negative attitudes towards technology, providing them with excellent access and infrastructure may not influence them to use it in their teaching. They also show that the adoption and integration of digital technology is strongly governed by teachers' characteristics such as age, gender, educational experience, and knowledge of technology. Other teacher-level barriers include teachers' lack of time, resistance or disposition to change, and the complexity of integrating technology in an already busy classroom. Barriers to adoption identified by Lawrence and Tar (2018) also include a number of institutional-level factors already noted such as limitation of infrastructure, lack of access, lack of professional development, and lack of technical support.

A number of other factors also need to be noted as important first-order barriers and enablers in supporting teachers' work. For example, Chen (2017) lists ten major challenges facing public schools, which play a role at both the micro and meso-levels: funding, class sizes, poverty, family factors, technology, bullying, student attitudes and behaviours, parental involvement (or lack of), and student health. In terms of student-focussed factors, Couros (2017) lists a number of issues related to learner success, including the need to provide students with choice in terms of how and what they are learning along with enough time to enable them to reflect and build on what they have learnt. Importantly, assessment is also identified as a key barrier and enabler in helping students to be more mindful of their learning (Couros, 2017). The way students respond to different types and purposes of assessment, coupled with the variety of ways digital technologies can be used in the classroom, raises the importance of new approaches to designing for learning and the potential of learning analytics. New digital technology has been shown in higher education to provide a means of capturing and reporting back data that was not previously possible (see for example, Dalziel et al., 2016; Rientes & Toetenel, 2016). Therefore, we need to harness the potential of learning analytics so that teachers can identify and help learners who are struggling, and those who would value more advanced or personalised instruction. As the recent report from the National Academy of Sciences (2018) concludes:

> Effective use of technologies in formal education… requires careful planning for implementation that addresses factors known to affect learning. These factors include alignment of the technology with learning goals, provision of professional development and other supports for instructors and learners, and equitable access to the technology. Ongoing assessment of student learning and evaluation of implementation are critical to ensuring that a particular use of technology is optimal and to identifying needed improvements (p.8).

In line with these findings, the OECD Schools for 21st-Century Learners study (Schleicher, 2015) identifies three key facets needed to ensure that technological innovations are used effectively to support 21st century learners, namely; confidence, willingness to innovate, and strong leadership. Schleicher also argues that teachers are central to achieving this. Their confidence in using digital

technologies in pedagogically meaningful ways and their willingness to innovate through these technologies are two of three key ingredients the above discussion helps us to better appreciate and understand there is more to these particular enablers than the report suggests. The third ingredient is strong school leaders, who are assumed to establish the school-level conditions that enable the first two ingredients to flourish (EC, 2017). While there is consensus throughout the literature that strong leadership is needed, an important question remains: to what extent does digital transformation for enhanced educational outcomes depend on fundamentally new forms of leadership (Siemens et al, 2018).

What the discussion of barriers and enablers illustrates is that there is no simple answer to overcoming the reasons why schools and teachers do not fully embrace the educational opportunities made possible by digital technologies; however, the counter argument is also true in terms of to what extent technologies should be embraced or not. Arguably, the important lesson is that in the future policy-makers and educational leaders would benefit from more explicitly framing discussions about the potential of digital technology in the real or actual problems teachers perceive they face, rather than inadvertently falling into the trap of promoting new digital solutions in search of problems. With this point in mind, building on Cuban's butterfly metaphor referenced in the introduction, Doe Zantamata (The HIYLIFE, 2014) serves to remind us that change is both incremental and unpredictable and we need to be careful that we do not expect too much from schools, teachers and students, too quickly:

> Change isn't just one thing, just one time, just one big revelation. Change occurs in stages, and phases, which each add depth, color, character, and create a multidimensional, multifaceted you.

12. Summary

This section summarises the main findings of the report in relation to the research questions outlined in the introduction. It reflects on some of the major lessons emerging from the literature and then proposes six guiding principles and recommendations.

In terms of the question of how digital technology can be used to enhance teaching and learning, the possibilities are almost endless, as illustrated by the many examples and affordances described in this report. It is problematic therefore to treat digital technology as a single entity. Accordingly, aggregated generalisations of the impact digital technologies have on educational outcomes tend to underestimate the importance of context and tell us little about the pedagogical approaches and conditions of implementation. Better understanding the conditions that contribute to effective practice and learning driven pedagogy remains an important area for future research. Moreover, there is a risk that in searching for evidence of improvements to educational outcomes through new digital technologies we may be using traditional or out-of-date proxies or key indicators when the changes taking place to the complex ecology of learning are more subtle, qualitative and/or incremental.

The impact of digital technologies on educational outcomes on a system level remains suboptimal for a number of reasons. Of particular note is how digital technologies are often being used to reinforce relatively traditional classroom practices and whether (or not) current approaches to professional

learning enable teachers to develop the necessary mindsets, pedagogical combinations and related 21st Century skill sets to reimagine the curriculum. While teachers' reluctance (Hashim, 2017) to embrace innovation is often cited as one of the main reasons for limited evidence of transformative change, this report shows that a complex mix of both first-order and second-order factors is important for effective digital technology use in school education.

Therefore, in terms of the question about enablers, it is worth reiterating the point that the connections between students, learning and technology are neither simple nor hard-wired (OECD, 2015). Sufficient funding, adequate infrastructure and policy alignment are crucial along with leadership and effective models of professional learning. These need to support deep critical reflections that challenge traditional pedagogical beliefs. While the role of teachers' beliefs has not always been fully appreciated, we cannot underestimate the influence of traditional school cultures and wider system-level barriers. Of particular note is the influence of assessment as a key driver for learning. The reality is that traditional models of assessment of learning, still largely anchored in conventional print-based approaches, remain a key barrier to innovation. While digital technology cannot compensate for poor teaching (OECD, 2015), the issue of assessment illustrates how, through no fault of their own, schools and teachers are part of much wider competing and co-existing values, influences and change forces within the new digital society. The implication is that policy-makers and those wishing to promote curriculum transformation through digital technology must adopt a wider understanding of how schools cannot be expected to fix the problems of an ever-changing society. Therefore, we concur with the conclusion of Conrads et al. (2017) that:

> There is no single off-the-shelf solution to transforming education through digital technologies (p.7).

13. Key Principles and Recommendations

13.1 The digital learning ecology is complex

Digital technologies have associated affordances. They may be predisposed to enable teacher-centred practice or facilitate more learning-driven approaches. These affordances may or may not be realised depending on how the technologies are used and are influenced both by the way in which teachers plan to use them in their design of learning interventions and how the students respond to them. It is problematic to aggregate the multi-faceted affordances of digital technologies into a single generalised statement divorced from context or institutional culture to evaluate their impact on educational outcomes. Digital technologies are not a single entity which confer the same teaching and learning benefits irrespective of type and educational context.

Recommendation: Research on digital technologies in schools must take greater account of the complexity of the learning ecology and there is a need for a deeper and more nuanced understanding of how different affordances of technology support pedagogical combinations known to enhance educational outcomes.

13.2 There is no single metaphor of 21st Century models of learning

Learning occurs through a variety of mechanisms. This includes enabling learners to apply what they have learnt to real-world contexts, to reflect on their learning and to engage in dialogue with their peers

to co-construct knowledge. However, there is no single all-encompassing theory that explains the complexity of embedding digital technologies in 21st Century learning ecologies.

Recommendation: Designs for effective learning with digital technologies should promote a variety of intentional pedagogical approaches that most appropriately support learners' needs, intended educational outcomes, subject discipline requirements, and instructional and institutional contexts.

13.3 Teachers mediate technology implementation

Digital technologies offer many opportunities for teachers to create innovative learning interventions that provide engaging opportunities for their students. However, helping teachers fully embed digital technologies in the curriculum requires a combination of professional learning opportunities that support critical reflection and action rooted in classroom practice.

Recommendation: Professional learning opportunities must encourage teachers to critically reflect on their pre-existing mindsets and pedagogical beliefs in the context of their practice.

13.4 Assessment needs to support deep learning

Assessment is a key driver for improving educational outcomes. It can be used for diagnostic purposes, to provide formative feedback, feed-forward for learning, or for summative assessment. It is important that the assessment elements are constructively aligned to educational outcomes (Biggs, 1999a; Biggs, 1999b), which includes how digital technology is embedded in the process. Furthermore, there is a deeper question related to assessment about whether *how* we assess students and *what* we assess is still relevant to performance in today's 'real world' settings.

Recommendation: Where appropriate, new digital technologies should be woven throughout formative and summative assessment, including final examinations, to support active, authentic and meaningful learning.

13.5 The impact of leadership and institutional cultures

While responsibility for leadership needs to be widely distributed, senior educational leaders need to understand how digital technologies can be used to augment a future-focussed vision for school education in the 21st Century. More specifically, innovation in education through digital technologies is tough work and requires senior leaders to build institutional cultures that empower teachers to re-imagine the curriculum and challenge traditional models of assessment.

Recommendation: Institutional factors known to influence successful implementation of digital technologies should be the focus of targeted professional learning for educational leaders and shared widely within their existing communities of practice.

13.6 Refocusing on education for the future

It is impossible to predict the future of education, but we know that digital technologies will continue to evolve and will have an increasing impact on schools and society. The question is how do we want digital technology to serve society and the education system *for* the future? The answer to this question strikes at the fundamental purpose of schools in the digital society and requires us to (re)envision the way in which public education can contribute to better futures for all.

Recommendation: Future policies designed to enable the effective use of digital technologies in school education need to shift the current discourse away from the language of education *in* change to focussing on education *for* change with a longer-term horizon.

14. Final Reflections

This report has considered many of the factors that influence effective practice in the innovative use of digital technologies for teaching, learning and assessment. It illustrates how digital technologies have considerable potential for supporting a purposeful variety or combination of pedagogies and more learning-driven approaches. However, the report is not the first attempt to explore some of the overarching questions framing this study and we already know from a long history of research on technology in schools that there is no magic bullet to transforming traditional educational practices. The field is characterised by a cycle of hype, hope and disappointment concerning the impact of technology on educational outcomes; a point reinforced throughout this report.

Another important takeaway from this report is that many questions remain unanswered, which concurs with the OECD's (2015) conclusion to their seminal report. While this finding is not new, it reminds us that the digital society invites future-focussed debates about the purpose of school education in the 21st Century. As part of this debate, we need to consider the question: what are the real problems that schools, teachers and learners are facing and that technology could help to solve? If you ask teachers, then you are likely to hear 'reduce my workload', 'overcome the burden of too much administrative work', 'give us more choice over what we teach and how we assess students', and so on. Although speculative, the answer to this question reminds us that policy-makers and educational leaders need to forge close dialogical partnerships with teachers and local stakeholders to better understand the problems schools are facing. National policies and European-wide plans are valuable but more middle-out and bottom-up approaches will be needed to support local change and foster an innovation culture.

Downes (2017) argues that education is change, and change is at once our greatest strength and our greatest challenge. He goes on to state that change is not just the new, it is invariably a combination of the old and new. Change does not simply arrive from nowhere; it emerges as a result of a growing unease with existing practice. Ultimately the lesson is that any successful educational change must win the 'hearts and minds' of those who have to implement the innovation in their own local settings. In this respect, extending the butterfly metaphor, this final quote encapsulates the importance of fostering transformative mindsets where educators have the courage, freedom and innovative spirit to become digital teaching and learning pioneers in their own schools:

> "How does one become a butterfly" She asked… "You must want to fly so much that you are willing to give up being a caterpillar" (Trina Paulus, adapted from A. A. Milne, 1922).

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