The Scottish Government
Riaghaltas na h-Alba

Literature Review on the Impact of Digital Technology on Learning and Teaching

CHILDREN, EDUCATION AND SKILLS

social research

Literature Review on the Impact of Digital Technology on Learning and Teaching

ICF Consulting Services Ltd

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Executive Summary

This literature review was commissioned by the Scottish Government to explore how the use of digital technology for learning and teaching can support teachers, parents, children and young people in improving outcomes and achieving our ambitions for education in Scotland.

Approach

This study is designed to help inform the development of a strategy for digital learning and teaching by providing evidence of how and why digital learning and teaching can benefit learners, teachers and schools. It also aims to identify the conditions that lead to its successful implementation and any differences between primary and secondary settings. In particular it focuses on how digital technologies can support and contribute to five specific educational priorities: raising attainment, tackling inequalities and promoting inclusion, improving transitions into employment, enhancing parental engagement, and improving the efficiency of the education system.

A literature search was undertaken, collecting nearly 1,000 items from academic, governmental and professional sources. These were reviewed to determine their thematic relevance and the strength of the evidence they presented. The most useful were then collated and assessed to:

- Identify evidence of relationships between digital learning and teaching activities and the expected outputs, outcomes and impacts;
- Show the relationships that exist between the digital learning and teaching activities and the outputs, outcomes and impacts for different beneficiaries (learners, parents, teachers, and the school); and
- Identify which outcomes are immediate, medium-term and long-term.

Key findings

The key findings of the research are presented below, separated into the key thematic areas which were examined during the review. In the cases where studies of similar digital equipment, tools and resources have been systematically reviewed or where there is a large body of evidence from different studies which have measured change (from quantitative studies using counterfactuals and testing learners before and after), it is possible to state there is conclusive evidence. In other cases where the evidence base is weaker (mainly qualitative studies drawing on relatively small samples of learners and schools), it is only possible to state that there is indicative evidence or (where few cases) promising evidence.

Raising children and young people's attainment

There is conclusive evidence that digital equipment, tools and resources can, where effectively used, raise the speed and depth of learning in science and mathematics for primary and secondary age learners. There is indicative evidence that the same can be said for some aspects of literacy, especially writing and comprehension. Digital technologies appear to be appropriate means to improve basic literacy and numeracy skills, especially in primary settings.

The level of impact is generally similar to other changes to pedagogies which are effective in raising attainment although the use of digital learning has other benefits. Additionally, the extent of the effect may be influenced by the level of capability of teachers to use digital learning tools and resources effectively to achieve improved learning outcomes.

More effective use of digital teaching to raise attainment happens when teachers are able to identify how digital tools and resources can be used to achieve improved learning outcomes, as well as having knowledge and understanding of the technology. This applies in all schools.

Where learners use digital learning at home as well as school for formal and non-formal learning activities these have positive effects on their attainment. This is due to the extension of their learning time. This is particularly important for secondary age learners.

Reducing inequalities and promoting inclusion

There is indicative evidence that the use of digital tools and resources can help to reduce gaps in subject attainment when they are effectively implemented. There is promising evidence that the use of digital equipment and resources can help learners with additional support needs to improve their skills and competences in literacy and numeracy.

Teachers' skills and competences in recognising how to use digital tools and resources and applying them effectively are critical to achieving positive results for learners with additional support needs or who are disdvantaged in other ways.

Improving transitions into employment

There is promising evidence that digital tools can, where effectively used, build skills in interactivity and collaboration, critical thinking and leadership for secondary age learners. These are considered to be vital skills by employers. There is promising evidence too that for secondary age learners, digital resources coupled with digital tools can increase knowledge and understanding of career pathways, applying for work, and working environments. These resources can make it easier for employers to provide help and support to learners.

In addition to the skills that teachers require to harness digital tools and resources to build learners' employability skills, it is evident that they need to be prepared to develop learner-centred learning approaches. Support for learners to access digital equipment outside the classroom is also important.

Enhancing parental engagement

There is promising evidence that using digital equipment and tools for direct communication with parents can improve learners' and parents' cooperation with requests from teachers about attendance, behaviour and support for learning.

Teachers are more likely to do this once they are more competent in using digital equipment and tools, and once schools use digital tools such as virtual learning environments to facilitate communication with parents.

Improving the efficiency of the education system

There is promising evidence that teachers' efficiency can be increased by using digital equipment and resources to prepare for teaching. There is similarly some qualitative evidence that digital tools and resources enable teachers to do their job better in relation to teaching, assessment and their own on-the-job learning and development.

Primary and secondary settings

While many studies clearly focus on specific learners in terms of age, settings (primary, secondary, special education) and domestic circumstances, none make any comparisons between the impact of digital technologies on educational priorities for different age groups. As a consequence, it has not been possible to identify any differences in the use and impact of digital technology in primary and secondary school settings. However, it is generally the case that the impacts found apply relatively equally to primary and secondary school learners.

Conclusions

Successful utilisation of digital technology depends not just upon sufficient access to equipment, tools and resources, but also on the availability of sufficient training, and knowledge and support networks for teachers. Providing teachers with this support will allow them to understand the benefits and applications of digital technologies and enable them to use digital technologies effectively.

If these needs are met, then the literature provides strong evidence that use of digital technologies can aid learning and teaching, as well as enhance the ability of some children to learn effectively. In particular, there is:

- Conclusive evidence that digital technologies can support educational attainment in general (and in maths and science particularly);

- Indicative evidence that it can support educational attainment in literacy and help close the gap in attainment between groups of learners; and
- Promising evidence that digital technologies can provide assistance to overcoming the challenges faced by some learners; improvements in employability skills and knowledge of career pathways; improved communications with parents; and time efficiencies for teachers.

The literature also identifies the factors that bring about more effective implementation of digital learning and teaching. These include:

- Training and support – not only to use equipment but to exploit digital tools and resources for teaching;
- Overcoming teachers' anxieties about digital teaching, not just about the use of the technology but also the use of different learner-centred pedagogies;
- Allowing teachers to experiment with technology;
- Networking with other teachers and schools;
- Maintaining and upgrading equipment and using tools that are compatible across many systems.

As a consequence, successful implementation of digital learning and teaching requires support to teachers in the form of opportunities to learn (both formally and informally), embedding digital learning in continuing professional development and initial teacher training, direction and leadership within a school, functioning digital equipment and tools, and an environment that gives teachers the flexibility to introduce and use digital learning.

1: Introduction

This study provides an assessment of research literature about digital learning and teaching to inform the Scottish Government's intended strategy.

Context

The Scottish Government has ambitions to raise educational attainment for all learners, and to narrow the gaps in attainment between the most and least disadvantaged children in Scotland. Tackling youth unemployment is also a priority of the Scottish Government. It has set a target to reduce the proportion of young people who are not in education, employment or training by 40% by 2020, and Curriculum for Excellence aims to support all children and young people to develop essential skills they will need to live and work in the twenty-first century.

To help pursue its ambitions, the Scottish Government has developed initiatives to support and encourage the use of digital technology in schools, with the vision that 'Scotland's educators, learners and parents take full advantage of the opportunities offered by digital technology in order to raise attainment, ambition and opportunities for all'. One of the main elements of this work to date has been the delivery of Glow, an online learning environment that provides access to a variety of digital tools and resources, funded by the Scottish Government and made available to all schools across Scotland[1].

Education Scotland recently published a report on the digital technology area of Curriculum for Excellence, which found that ICT is 'used as an enhancement to learning' but is 'on the fringes of the main purpose of tasks or lessons'[2]. In some of the 40 case study schools which provided the findings for the report, inspectors found that ICT can have 'a much more significant influence on learning which motivates learners and encourages career ambitions using technologies' but the extent of change in the use of technologies in schools 'has been modest at best'.

The report concluded that there was more work to be done to place digital technology 'at the heart of learning' in Scotland, and that it had confirmed 'beyond doubt that our children and young people need digital skills and technologies to be given an absolutely central role in the learning process – no longer an enhancement or 'bolt-on', but a foundation and a primary consideration for any planned learning.'

The Scottish Government has commissioned this literature review to explore how the use of digital technology for learning and teaching can support

[1] http://connect.glowscotland.org.uk/start-here/

[2] Education Scotland (2014) Technologies 3-18 curriculum report

teachers, parents, children and young people in improving outcomes and achieving its ambitions for education in Scotland.

Aims and objectives of this study

This study is intended to help inform the development of a strategy for digital learning and teaching. As a consequence its overall aims are to:

- Identify evidence of the ways in which digital learning and teaching supports improved outcomes for learners and teachers/schools;
- Identify the conditions that lead to successful implementation of digital learning and teaching so that the Scottish Government's strategic support is founded on what works and will inform any advice to local authorities and schools.

The specific objectives of the literature review are to:

- Identify the impacts that digital technology has on learning and teaching in both primary and secondary schools; and
- Identify how digital technology can support and contribute to five specific educational priorities:
    1. Raising attainment,
    2. Tackling inequalities and promoting inclusion,
    3. Improving transitions into employment,
    4. Enhancing parental engagement, and
    5. Improving the efficiency of the education system.

For the purposes of the literature review digital technology is defined as any process in which the teacher or learner uses digital equipment such as a computer (or a smart phone, tablet, MP3 player, or console) to access digital tools such as learning platforms and virtual learning environments (VLEs), and/or digital learning resources (such as lessons, tests, learning aids and games) to improve their knowledge and skills. For teachers this can also be to improve their pedagogical approaches and their assessment of learning. The other definitions used in the literature review can be found in Annex 1.

Structure of the report

The report is structured to draw out the evidence of the impact of digital technology on each of the specific educational priorities set out above. The method is described in more detail in the next section, then sections 3-7 present the findings for each of the five educational priorities. This is followed by a consideration of the evidence about successful implementation of digital learning and teaching in section 8 and conclusions about the impacts of digital learning and teaching activities and what this means for the development of a strategy to help to achieve these in section 9.

2: Method

A research protocol was developed, setting out inclusion criteria for a literature search, a search strategy and search terms. This can be found in Annex 1.

Results of the literature search

The initial searches identified over 600 items, along with over 350 additional items from the Scottish Government Library Service's lists and website searches. After a review of abstracts to determine relevance, the list was reduced to 217 items for detailed review. This took account of the subject matter and evidence of empirical research measuring outputs and outcomes of digital technologies in learning and teaching. It did not take account of the methods used in the research. Table 1 below shows the number of items included in the detailed review, by the broad thematic areas of the study.

Table 1 Profile of studies selected for detailed review.

Thematic Area	No of Studies
Raising attainment	100
Reducing inequalities between children	48
Improving transitions into employment	15
Improving the efficiency of the education system	45
Enhancing parental engagement	9
Total	**217**

Even with additional searches to identify more studies on 'improving transitions' and 'enhancing parental engagement', the imbalance between thematic areas could not be reduced. Of the 200 or so studies identified, little more than 60 provide evidence of relevance to this report. A bibliography of these items can be found in Annex 3.

To guide the analysis and assessment of the material, the study took a structured approach to reviewing the quality of evidence in the literature. An assessment framework (in the form of a logic model) was developed to help identify the key evidence of the relationships between digital learning and the outcomes being measured, and of what works to achieve the expected outputs and outcomes being sought from the literature review.

Table 2 below sets out the approach to assessing the quality of empirical evidence found in the literature. Assessment is based on:

- Experience of evaluating policy actions in education and training. Randomised control trials and empirical studies establishing an appropriate comparative situation where a policy measure has not been

implemented are more likely to provide robust assessments of the relationship between any policy measure and the outcomes measured than a small set of qualitative interviews with the delivery agents;

- The criteria used in the What Works evidence reviews[3] and the Scientific Maryland Scale (SMS). These were used as a measure for assessing the quality of research, and to give weight to some research over other research. Because relatively little of the literature about digital technologies in learning and teaching would be scored at level 1 or 2 on the SMS, a less stringent approach is necessary. Consistent results from qualitative and small-scale mixed method studies in different contexts can provide evidence of relationships when better quality research is unavailable.

Table 2 Strength of evidence demonstrating a causal effect

Type of study	Strength of evidence
Studies which have drawn conclusions from meta-reviews of robust evaluations	+++++
Evaluation studies with counterfactual quantitative evidence of a significant effect	++++
Studies which measure change before and after the policy action, controlling for other factors and which have large samples for robust statistical analysis	+++
Research studies which are based on sufficiently in-depth case studies and a sample of qualitative interviews to allow robust qualitative assessments	++
Small scale studies dependent on qualitative data which has not been collected systematically or on a sufficiently large scale	+

The scale in Table 2 is used in this review to suggest that higher level studies (four and five stars) provide conclusive evidence, while middle level studies (three stars) provide indicative evidence and lower levels studies (one and two stars) provide promising evidence. Account also needs to be taken of the contexts, volumes and scales of studies in reaching these conclusions.

Annex 2 sets out the assessment framework devised for this literature review. In the form of a logic model for digital learning and teaching measures, this helps to:

- Clarify the evidence of relationships between the learning and teaching activities and the expected outputs, outcomes and impacts;

[3] Studies where the outcomes for people taking part in the activity are compared with those for people who do not are included in analyses, because they provide credible evidence of effects which can be attributed to the activity. See the What Works Centre for Local Economic Growth's evidence review on Employment Training (2014), for example.

- Show the linkages we might expect to find evidence of, between the digital learning and teaching activities and the outputs, outcomes and impacts for different beneficiaries (learners, parents, teachers, and the school);
- Separate the outcomes which might be considered to be immediate, medium term and longer term.

It is anticipated that digital learning and teaching activities can be more closely related to the immediate and medium term outcomes than the longer term outcomes. Longer term outcomes would be expected to be achieved through a variety of measures, which could include digital learning and teaching activities.

The quality of the literature

The research literature is extensive, even when material about older technologies which are no longer relevant, learners over the age of 18, and largely descriptive (i.e. not empirical or analytical) studies are eliminated. Much of the research, however, is focused on relatively small scale applications of digital technology. Many of these studies use qualitative data from teachers and learners to describe short term outcomes, not testing changes in knowledge or skills over time or comparing subjects to similar groups of learners who have not used digital applications. However, there are studies - particularly on the use of digital learning to increase attainment in specific subject areas - which measure knowledge and skills acquired and compare learners who have used digital applications to learners who have not.

In the main, while a few studies have identified statistical relationships between ICT usage and longer term outcomes - such as attainment in examinations and tests in secondary education - there are no longitudinal studies which show relationships between digital learning and the longer term outcomes set out in Annex 2.

There are a few meta-reviews and meta-analyses of the literature that have examined the conclusions reached by a large body of similar research on digital learning and teaching in specific contexts. There are also some reviews of similar studies/technologies that have examined the methods used to discern the strength of evidence they collectively provide. These together can provide stronger evidence than individual studies of both the outcomes achieved and of how far digital learning and teaching make a difference.

Substantial published meta-analyses for this review are set out in brief in Table 3 below, with further details in Annex 4.

Table 3: Summary of Meta-Analysis Literature Reviews Included in the Review

Authors	Date	Title	Scale covered
Li, Q. and Ma, X.	2010	A Meta-Analysis of the Effects of Computer Technology on School Students' Mathematics Learning	46 primary studies covering 37,000 learners.
Higgins, S., Xiao, Z., and Katsipataki, M.	2012	The Impact of Digital Technology on Learning: A Summary for the Education Endowment Foundation	48 studies synthesizing primary research
Liao, Y-k C., Chang, H-w., and Chen, Y-w.	2008	Effects of Computer Application on Elementary School Students' Achievement: A Meta-Analysis of Students in Taiwan	48 studies covering over 5000 learners
Archer, K., Savage, R., et al.	2014	Examining the effectiveness of technology use in classrooms: A tertiary meta-analysis	38 primary studies
Cheung, A., and Slavin, R.	2012	Effects of Educational Technology Applications on Reading Outcomes for Struggling Readers: A Best Evidence Synthesis	20 studies based covering 7,000 learners

Meta-analyses use a standard measure - effect size - in order to compare studies based on different sample sizes and different measurements of change[4]. Effect sizes in educational experiments which are greater than around 0.4 are considered to be effective, and if achieved over a sustained period should influence learners' longer term attainment (such as grades achieved in examinations).

In using these studies, it is important to be mindful that:

- The outcomes they measure can arise from factors other than the use of digital technology. This can be controlled for where the outcomes can be compared to learners who have not used digital learning;
- The scale of outcome can be influenced by the quality and effectiveness of the implementation of the digital learning by the teacher, and the quality of the teaching;
- The scale of difference can increase with the length of time the digital learning has been used;

[4] Effect size is the quantitative difference between groups (those treated and untreated by the educational intervention). It is the standardised mean difference between the two groups (mean of experimental group minus mean of control group, divided by the standard deviation). An effect size of +0.8 is considered to be high, for example. It means that 79% of those in the control group population would be expected to have done less well than all those in the experimental population. See: Coe, 2002. *It's the effect size, stupid*. Paper presented to the Annual Conference to the British Education Association, http://www.leeds.ac.uk/educol/documents/00002182.htm

- The studies do not focus on how the outcomes are achieved. This is generally more apparent from examining a wide range of smaller scale evaluative studies;
- The studies are most commonly of learners in the US and East Asia. These are all OECD countries with similar ambitions for learners and their progression to higher education and employment, as well as similar curriculums.
- In addition, while many studies clearly focus on specific learners in terms of age, settings (primary, secondary, special education) and domestic circumstances, none make any comparisons between the impact of digital technologies on educational priorities for different age groups. As a consequence, it has not been possible to identify any differences in the use and impact of digital technology in primary and secondary school settings. It has only been possible to identify that the use of digital technologies was beneficial to learners in primary and/or secondary school settings.

3: Digital learning and raising attainment

Key findings

There is conclusive evidence that digital equipment, tools and resources can, where effectively used, raise the speed and depth of learning in science and mathematics for primary and secondary age learners. There is indicative evidence that the same can be said for some aspects of literacy, especially writing and comprehension. Digital technologies appear to be appropriate means to improve basic literacy and numeracy skills, especially in primary settings.

The effect sizes are generally similar to other educational interventions that are effective in raising attainment, though the use of digital learning has other benefits. Also, the extent of the effect may be dampened by the level of capability of teachers to use digital learning tools and resources effectively to achieve learning outcomes. More effective use of digital teaching to raise attainment includes the ability of teachers to identify how digital tools and resources can be used to achieve learning outcomes and adapting their approach, as well as having knowledge and understanding of the technology. This applies in all schools.

Where learners use digital learning at home as well as school for formal and non-formal learning activities these have positive effects on their attainment, because they have extended their learning time. This is particularly important for secondary age learners.

The assessment framework, set out in Annex 2, identifies a number of educational benefits that digital learning and teaching has the potential to help learners aged 5 to 18 to realise, through the opportunity to learn in different ways, access more sources of information, and be tested and get feedback differently. In terms of raising attainment, these benefits include short term outcomes, such as having a greater feeling of control over learning and more confidence to practise a skill, through to medium term outcomes such as faster acquisition of knowledge and skills, and improved impacts in terms of learners achieving higher exam or test results where digital technology has been used.

In this section, the impact of digital technology on children's attainment in a range of areas is discussed, followed by the impact on aspects of numeracy, literacy and science learning.

Raising children's attainment

There is a substantial body of research that has examined the impact of digital tools and resources on children's attainment in a range of areas.

Higgins et al (2012) provide a summary of research findings from studies with experimental and quasi-experimental designs, which have been combined in meta-analyses to assess the impact of digital learning in schools. Their search identified 48 studies which synthesised empirical research of the impact of digital tools and resources on the attainment of school age learners (5-18 year olds).

They found consistent but small positive associations between digital learning and educational outcomes. For example, Harrison et al (2004) identified statistically significant findings, positively associating higher levels of ICT use with school achievement at each Key Stage in England, and in English, maths, science, modern foreign languages and design technology. Somekh et al (2007) identified a link between high levels of ICT use and improved school performance. They found that the rate of improvement in tests in English at the end of primary education was faster in ICT Test Bed education authorities in England than in equivalent comparator areas. However, Higgins et al note that while these associations show, on average, schools with higher than average levels of ICT provision also have learners who perform slightly higher than average, it may be the case that high performing schools are more likely to be better equipped or more prepared to invest in technology or more motivated to bring about improvement.

Higgins et al report that in general analyses of the impact of digital technology on learning, the typical overall effect size is between 0.3 and 0.4 - just slightly below the overall average for researched interventions in education (Sipe & Curlette, 1997; Hattie, 2008) and no greater than other researched changes to teaching to raise attainment, such as peer tutoring or more focused feedback to learners. The range of effect sizes is also very wide (-0.03 to 1.05),which suggests that it is essential to take into account the differences between technologies and how they are used.

Table 4: Summary of meta-analyses published between 2000 and 2012 (in Higgins et al 2012)

Focus	No of studies	Overall Study Effect (ES)	Impact on
General	7	0.24-1.05	Academic success; academic outcomes; learner achievement; school achievement; cognitive outcomes
Mathematics	4	0.33-0.71	Mathematics; mathematics performance.
Mathematics and Science	1	0.01-0.38	Mathematics; computer tutorials in science; science simulations; live 'labs'
Science	3	0.19-0.38	Lower order outcomes; higher order outcomes; retention follow up test; science academic achievements
Literacy	12	-0.03-0.55	Reading skills and comprehension; writing quantity and quality; accelerated reader; standardised reading tests; spelling; word processing on writing; ICT on spelling; computer texts on reading
Other Focus	6	0.07-0.46	Academic achievement; individual achievement; learning outcomes; mathematics achievement; cognitive gains.

In an earlier meta-analysis, Liao et al (2007), considered the effects of digital tools and resources on elementary school learners' achievement in Taiwan. Synthesizing research comparing the effects of digital learning (equipment, tools and resources) with traditional instruction on elementary school learners' achievement, they considered quantitative and qualitative information from 48 studies including over 5,000 learners. Of the 48 studies, 44 (92%) showed positive effects in favour of a computer assisted intervention, while four (8%) were negative and favoured a traditional instruction method. Nearly 60% of the studies examined the effects of computer aided instruction for teaching mathematics or science. Another 11% of the studies concentrated on the teaching of reading and language. They found an overall positive effect size across all the studies of 0.45 (study-weighted grand mean), which is considered to be a moderate effect, with a wide range of effect sizes (from 0.25 to 2.67).

No significant differences were found between subject areas, and the authors suggest that digital learning has the potential to be implemented in many different subject areas. They found that the two subjects that showed the highest effects were reading and languages, which had a high positive effect size of 0.7. Studies using computer simulations also had higher effects. The authors suggest this may be because simulations can provide learners with

the opportunity to engage in a learning activity which could not be replicated in a classroom.

More qualitative studies have identified how improvements in attainment are achieved. From a wide study of primary and secondary schools in England that were early adopters in using digital learning and teaching, Jewitt et al (2011) concluded that:

- Using digital resources provided learners with more time for active learning in the classroom;
- Digital tools and resources provided more opportunity for active learning outside the classroom, as well as providing self-directed spaces, such as blogs and forums, and access to games with a learning benefit;
- Digital resources provided learners with opportunities to choose the learning resources;
- The resources provided safer spaces for formative assessment and feedback.

The sections below focus on specific key areas of attainment: literacy, numeracy, and science learning.

Literacy

There is a large body of research that has examined the impact of digital equipment, tools and resources on children's literacy. The effects are generally positive, though not as large as the effects found where digital learning is used to improve numeracy, and consistent in finding that ICT helps improve reading and writing skills, as well as developing speaking and listening skills.

Effect of context

Archer and Savage (2014) undertook a meta-analysis to reassess the outcomes presented in three previous meta-analyses considering the impact of digital learning on language and literacy learning: Slavin et al (2008 and 2009) and Torgenson and Zhu (2003). Overall they found a relatively small average positive effect size of 0.18, with a few of the studies having a negative effect and three studies showing moderate to large effect sizes. The authors found that programmes with a small number of participants tended to show larger effect sizes than larger programmes but that not all were statistically significant.

Archer and Savage sought to understand whether the context within which the digital tool or resource was used has an impact on outcomes. In particular, they examined whether training and support given to the teachers or other staff delivering the programme had an impact. The authors found that training and support could be identified in around half of the studies and that it did appear to have a positive impact on the effectiveness of the literacy

intervention, with the average effect size rising to 0.57. The authors conclude that this indicates the importance of including implementation factors, such as training and support, when considering the relative effectiveness of digital learning and teaching.

Effect on specific literacy skills

In their meta-analysis, Higgins et al (2012) found that digital learning has a greater impact on writing than on reading or spelling. For example, Torgenson and Zhu (2003) reviewed the impact of using digital technology on the literacy competences of 5-16 year-olds in English and found effect sizes on spelling (0.2) and reading (0.28) much lower than the high effect size for writing (0.89).

In their meta-analysis of studies investigating the effects of digital technology on primary schools in Taiwan, Laio et al (2007) considered studies over a range of curriculum areas; 11 of which addressed the effects of using digital learning in one or more literacy competence. They found no significant differences in effect size between the different subject areas, suggesting the potential for digital technology to raise outcomes is equal across different subjects. However, they did note that the two areas that showed the highest effect sizes (over 0.7) were reading and comprehension.

Effect of specific digital tools and resources

Somekh et al (2007) evaluated the Primary School Whiteboard Expansion (PSWB) project in England. They found that the length of time learners were taught with interactive whiteboards (IWBs) was a major factor in learner attainment at the end of primary schooling, and that there were positive impacts on literacy (and numeracy) once teachers had experienced sustained use and the technology had become embedded in pedagogical practice. This equated to improvements at Key Stage 2 writing (age 11), where boys with low prior attainment made 2.5 months of additional progress.

Hess (2014) investigated the impact of using e-readers and e-books in the classroom, among 9-10 year olds in the USA. The e-books were used in daily teacher-led guided reading groups, replacing traditional print books in these sessions. Teachers also regularly used the e-readers in sessions where the class read aloud, and e-readers were available to learners during the school day for silent reading. The study found a significant difference in reading assessment scores for the group using the e-readers. Scores improved for both male and female learners and the gap between males and females decreased.

The use of digital tools and resources also appears to affect levels of literacy. Lysenko and Abrami (2014) investigated the use of two digital tools on reading comprehension for elementary school children (aged 6-8) in Quebec, Canada. The first was a multimedia tool which linked learning activities to interactive digital stories. The tool included games to engage learners in reading and

writing activities, and instructions were provided orally to promote listening comprehension. The second tool was a web-based electronic portfolio in which learners could create a personalised portfolio of their reading and share work with peers, teachers and parents to get feedback. The authors found that in classes where both tools were used together during the whole school year learners performed significantly better both in vocabulary and reading comprehension (with medium-level effect sizes) than learners in classes where the tools were not part of English language instruction.

Rosen and Beck-Hill (2012) reported on a study programme that incorporated an interactive core curriculum and a digital teaching platform. At the time of their report it was available for 9-11 year old learners in English language, arts and mathematics classes in Dallas, Texas. The online platform contained teaching and learning tools. Learners were assessed using standardised tests administered before the programme and after a year's participation. The results of increased achievement scores demonstrated that in each of the two school year groups covered, the experimental learners significantly outperformed the control learners in reading and maths scores. In observations in classrooms that used the programme, the researchers observed higher teacher-learner interaction, a greater number and type of teaching methods per class, more frequent and complex examples of differentiation processes and skills, more frequent opportunities for learner collaboration, and significantly higher learner engagement. The authors report that the teaching pedagogy observed in the classrooms differed significantly from that observed in more traditional classrooms. The teachers following the programme commented that the digital resources made planning and implementing 'differentiation' more feasible. This is differentiation of teaching in terms of content, process, and product, to reflect learners' readiness, interests, and learning profile, through varied instructional and management strategies.

Effect of the amount and quality of digital technology use

The uses of digital technology and access to it appear to be critical factors. Lee et al (2009) analysed how in the US 15-16 year-old learners' school behaviour and standardised test scores in literacy are related to computer use. Learners were asked how many hours a day they typically used a computer for school work and for other activities. The results indicated that the learners who used the computer for one hour a day for both school work and other activities had significantly better reading test scores and more positive teacher evaluations for their classroom behaviours than any other groups[5]. This was found while controlling for socio-economic status, which has been shown to be a predictor of test scores in other research. The analysis used data from a

[5] Classroom behaviour, as defined in this study, was based on teachers' evaluations of absences from class, timeliness in handing in assignments and arriving to class, and attentiveness and disruptiveness in class.

national 2002 longitudinal study, and it is likely that learners' usage of computers has increased and changed since that time.

Biagi and Loi (2013), using data from the 2009 *Programme for International Student Assessment* (PISA) and information on how learners used digital technology at school and at home (both for school work and for entertainment), assessed the relationship between the intensity with which learners used digital tools and resources and literacy scores. They examined uses for: gaming activities (playing individual or collective online games), collaboration and communication activities (such as linking with others in on-line chat or discussion forums), information management and technical operations (such as searching for and downloading information) and creating content, knowledge and problem solving activities (such as using computers to do homework or running simulations at school). These were then compared to country specific test scores in reading. The authors found a positive and significant relationship between gaming activity and language attainment in 11 of the 23 countries studied. For the other measures, where relationships existed and were significant, they tended to be negative.

The more recent PISA data study (OECD, 2015, using 2012 results) also found a positive relationship between the use of computers and better results in literacy where it is evident that digital technology is being used by learners to increase study time and practice[6]. In addition, it found that the effective use of digital tools is related to proficiency in reading.

Numeracy

There is a large body of research which has examined the impact of digital equipment, tools and resources on children's numeracy skills and mathematical competences throughout schooling. Higgins et al (2012) found from their meta-analysis that effect sizes of tested gains in knowledge and understanding tend to be greater in mathematics and science than in literacy. The key benefits found relate to problem solving skills, practising number skills and exploring patterns and relationships (Condie and Monroe, 2007), in addition to increased learner motivation and interest in mathematics.

Effect on specific numeracy skills

Li and Ma's (2010) meta-analysis of the impact of digital learning on school learners' mathematics learning found a generally positive effect. The authors considered 46 primary studies involving a total of over 36,000 learners in primary and secondary schools. About half of the mathematics achievement outcomes were measured by locally-developed or teacher-made instruments, and the other half by standardized tests. Almost all studies were well

[6] The OECD study found that higher use alone did not improve reading; it is the quality of use which makes a difference

controlled, employing random assignment of learners to experimental or control conditions.

Overall, the authors found that, on average, there was a high, significantly positive effect of digital technology on mathematics achievement (mean effect size of 0.71), indicating that, in general, learners learning mathematics with the use of digital technology had higher mathematics achievement than those learning without digital technology. The authors found that:

- Although the difference was small, younger school learners (under 13 years old) had higher attainment gains than older secondary school learners;
- Gains were more positive where teaching was more learner-centred than teacher-centred. In this regard, the authors differentiate between traditional models, where the teacher tends to teach to the whole class, and a learner-centred teaching model which is discovery-based (inquiry-oriented) or problem-based (application-oriented) learning;
- Shorter interventions (six months or less) were found to be more effective in promoting mathematics achievement than longer interventions (between six and 12 months). It is suggested that such gains in mathematics achievement are a result of the novelty effects of technology, as suggested in other research, and as learners get familiar with the technology the novelty effects tend to decrease;
- The authors found no significant effects from different types of computer technology on mathematics achievement. Whether it was used as communication media, a tutorial device, or exploratory environment, learners displayed similar results in their mathematics achievement;
- Equally, the authors found no significant relationship between the effect of using digital technology and the characteristics of learners included in the samples for studies, such as gender, ethnicity, or socio-economic characteristics.

Effect of the amount and quality of digital technology use

The studies by Lee et al (2009) and Biagi and Loi (2013) found similar results for mathematics as they did for reading and literacy in relation to the use of digital equipment. Learners who used a computer at least one hour a day for both school work and other activities had significantly better mathematics test scores and more positive teacher evaluations for their classroom behaviour in mathematics classes than those who did not use the computer. Biagi and Loi (2013) found a significant positive relationship between intensity of gaming activity and maths test scores in 15 countries out of the 23 studied. As with language, the authors found that learners' total use of digital technologies was positively and significantly associated with PISA test scores for maths in 18 of the 23 countries studied.

Studies have found that using digital equipment for formal learning is also associated with increases in learners' motivation for learning mathematics. House and Telese (2011 and 2012) found that:

- For learners aged 13 and 14 in South Korea, for example, those who expressed high levels of enjoyment at learning mathematics, more frequently used computers in their mathematics homework. However, learners who more frequently played computer games and used the internet outside of school tended to report that they did not enjoy learning mathematics;
- Learners in the USA and Japan aged 13 and 14 who showed higher levels of algebra achievement also used computers more at home and at school for school work. Those who used computers most for other activities had lower test scores. In each of the USA and Japan they found that overall computer usage which included use for school work was significantly related to improvements in test scores.

Effect of specific digital tools and resources

Somekh et al (2007) found that, once the use of IWBs was embedded, in Key Stage 1 mathematics (age 7) in England, high attaining girls made gains of 4.75 months, enabling them to catch up with high attaining boys. In Key Stage 2 mathematics (age 11), average and high attaining boys and girls who had been taught extensively with the IWB made the equivalent of an extra 2.5 to 5 months' progress over the course of two years.

Digital tools and resources can also increase some learners' confidence in mathematics as well as their engagement in new approaches to learning and their mathematical competences. Overcoming learners' anxieties about mathematics and their competence in specific aspects of the subject are common concerns in teaching mathematics which hampers their ability to learn (reported in Huang et al 2014).

Huang et al (2014) researched the outcomes, in Taiwan, from a computer game simulating the purchase of commodities, from which 7 and 8 year-old primary school learners can learn addition and subtraction, and apply mathematical concepts. The model combined games-based learning with a diagnosis system. When the learner made a mistake, the system could detect the type of mistake and present corresponding instructions to help the learner improve their mathematical comprehension and application. The authors compared two learning groups: both used the game-based model but one without the diagnostic, feedback element. They found that the learning achievement post-test showed a significant difference and also that the mathematics anxiety level of the two learner groups was decreased by about 3.5%.

Passey (2011) found that among over 300 schools in England using Espresso digital resources, those that had been using them over a longer period made significantly greater increases in end of primary school numeracy test results than schools which were recent users.

Science learning

Effects on science knowledge and skills

In their meta-analysis, Laio et al (2007) considered 11 studies looking at the impact of digital technology on science learning. These had a moderate average effect size of 0.38 and generally had positive effects. Condie and Monroe (2007) identified that digital learning made science more interesting, authentic and relevant for learners and provided more time for post-experiment analysis and discussion.

In their study of the PISA data, Biagi and Loi (2013) found a significant positive relationship between learners' total use of digital equipment and science test scores in 21 of the 23 countries they studied. They also found evidence of a significant positive relationship between the intensity of using gaming activity and science scores in 13 of the 23 countries they studied. Somekh et al (2007) found that in primary school science all learners, except high attaining girls, made greater progress when given more exposure to IWBs, with low attaining boys making as much as 7.5 months' additional progress.

Effects of specific digital tools and resources

Digital tools and resources generally have a positive effect on learners' science learning. This can be seen from a number of studies assessing outcomes for learners in different stages of education.

Hung et al (2012) explored the effect of using multi-media tools in science learning in an elementary school's science course in Taiwan. Learners were asked to complete a digital storytelling project by taking pictures with digital cameras, developing the story based on the pictures taken, producing a film based on the pictures by adding subtitles and a background, and presenting the story. From the experimental results, the authors found that this approach improved the learners' motivation to learn science, their attitude, problem-solving capability and learning achievements. In addition, interviews found that the learners in the experimental group enjoyed the project-based learning activity and thought it helpful because of the digital storytelling aspect.

Hsu et al (2012) investigated the effects of incorporating self-explanation principles into a digital tool facilitating learners' conceptual learning about light and shadow with 8-9 year old learners in Taiwan. While they found no difference in the overall test scores of the experimental and control groups, they found a statistically significant difference in retention test scores. Those

learners who had paid more attention to the self-explanation prompts tended to outperform those in the control group.

Anderson and Barnett's (2013) study, in the US, examined how a digital game used by learners aged 12-13 increased their understanding of electromagnetic concepts, compared to learners who conducted a more traditional inquiry-based investigation of the same concepts. There was a significant difference between the control and experimental groups in gains in knowledge and understanding of physics concepts. Additionally, learners in the experimental group were able to give more nuanced responses about the descriptions of electric fields and the influence of distance on the forces that change experience because of what they learnt during the game.

Güven and Sülün (2012) considered the effects of computer-enhanced teaching in science and technology courses on the structure and properties of matter, such as the periodical table, chemical bonding, and chemical reactions, for 13-14 year olds in Turkey. Their proposition was that computer-enhanced teaching can instil a greater sense of interest in scientific and technological developments, make abstract concepts concrete through simulation and modelling, and help to carry out some dangerous experiments in the classroom setting. They found a significant difference in achievement tests between the mean scores of the group of learners who were taught with the computer-enhanced teaching method and the control group who were taught with traditional teaching methods.

Belland (2009) investigated the extent to which a digital tool improved US middle school children's ability to form scientific arguments. Taking the premise that being able to construct and test an evidence-based argument is critical to learning science, he studied the impact of using a digital problem based learning tool on 12-14 year olds. Learners worked in small groups and were asked to develop and present proposals for spending a grant to investigate an issue relating to the human genome project. Those in the experimental group used an online system which structured the project into stages of scientific enquiry. The system prompted the learners to structure and organise their thinking in particular ways: by prompting the learners individually, sharing group members' ideas, tasking the group to form a consensus view, and prompting the group to assign specific tasks among themselves.

Using pre- and post- test scores to assess the impact on learners' abilities to evaluate arguments, Belland found a high positive effect size of 0.62 for average-achieving learners compared to their peers in the control group. No significant impacts were found for higher or lower-achieving learners. Belland suggests that for high-achieving learners, this may be because they already have good argument making skills and are already able to successfully structure how they approach an issue and gather evidence. The study also used qualitative information to consider how the learners used the digital tool

and compared this to how learners in the control group worked. The author found that in the experimental group they made more progress and were more able to divide tasks up between them, which saved time. They also used the tool more and the teacher less to provide support.

Kucukozer et al (2009) examined the impact of digital tools on teaching basic concepts of astronomy to 11-13 year old school children in Turkey. Learners were asked to make predictions about an astronomical phenomenon such as what causes the seasons or the phases of the moon. A digital tool was used to model the predictions and display their results. The learners were then asked to explain the differences and the similarities between their predictions and their observations. In the prediction and explanation phase the learners worked in groups to discuss their ideas and come to a conclusion. In the observation phase they watched the 3D models presented by their teacher. Thereafter, they were asked to discuss and make conclusions about what they had watched. The authors found that instruction supported by observations and the computer modelling was significantly effective in bringing about better conceptual understanding and learning on the subject.

Ingredients of success

Where studies examine the process that brings about positive results from digital learning and teaching compared to traditional approaches, it is evident that these are more likely to be achieved where digital equipment, tools and resources are used for specific learning outcomes and built into a teaching model from the outset. This broadly supports Higgins et al's (2012) conclusions that:

- Digital technology is best used as a supplement to normal teaching rather than as a replacement for it;
- It is not whether technology is used (or not) which makes the difference, but how well the technology is applied to support teaching and learning by teachers;
- More effective schools and teachers are more likely to use digital technologies effectively than other schools.

Differences in effect sizes and the extent that learners achieve positive gains in attainment are ascribed by most authors of the studies above to:

- The quality of teaching and the ability of teachers to use the digital equipment and tools effectively for lessons;
- The preparation and training teachers are given to use equipment and tools;
- The opportunities teachers have to see how digital resources can be used and pedagogies adapted (Rosen and Beck-Hill, 2012; Belland, 2009).

Teachers have to adapt to learner-centred approaches to learning if they are to use digital tools and resources (Li and Ma, 2010).

As well as ensuring digital tools and resources are supporting learning goals, success appears to also be linked to some other factors:

- The availability of equipment and tools within schools (and at home);
- How learners use digital equipment. Higgins et al (2012) found that collaborative use of technology (in pairs or small groups) is usually more effective than individual use, though some learners - especially younger children - may need guidance in how to collaborate effectively and responsibly;
- The extent that teaching continues to innovate using digital tools and resources (Higgins et al, 2012).

Fullan (2013) suggested four criteria that schools should meet if their use of digital technology to support increased attainment is to be successful. These were that systems should be engaging for learners and teachers; easy to adapt and use; ubiquitous - with access to the technology 24/7; and steeped in real life problem solving.

Fullan and Donnelly (2013) developed these themes further, proposing an evaluation tool to enable educators to systematically evaluate new companies, products and school models, using the context of what they have seen as necessary for success. Questions focus on the three key criteria of pedagogy (clarity and quality of intended outcome, quality of pedagogy and the relationship between teacher and learner, and quality of assessment platform and functioning); system change (implementation support, value for money, and whole system change potential) and technology (quality of user experience/model design, ease of adaptation, and comprehensiveness and integration).

4: Digital learning, reducing inequalities and promoting inclusion

Key findings

There is indicative evidence that digital tools and resources can help to reduce gaps in subject attainment where they are effectively implemented. There is promising evidence that digital equipment and resources can help learners with additional support needs to improve their skills and competences in literacy and numeracy.

Teachers' skills and competences in recognising how to use digital tools and resources and apply them effectively are critical to achieving positive results for learners with additional support needs or who are disdvantaged in other ways.

Becta reviewed the literature (2007) on the potential for digital learning to overcome disadvantage and disaffection. They found evidence that digital learning increased learners' interest in learning, their confidence in practising a skill and the time they spent on non-formal learning.

There is very little meta-analysis covering this area or examining specific groups of disadvantaged learners. In the main there are small numbers of small scale empirical studies in a variety of contexts for different groups of learners. This makes it difficult to draw conclusions, although Higgins et al (2011) concluded that digital tools and resources can be 'particularly practical for lower ability learners and those with special educational needs where they allow for differentiation and more intensive practice, and provide a greater motivation to learn.

In one controlled study of the use of laptops in classrooms for literacy and numeracy learning which examined differences between girls and boys (Yang et al, 2013), no difference was found in the results.

Reducing inequalities between learners

The groups of learners for whom the literature provides evidence from studies with comparative groups and/or testing learners before and after digital learning can be broadly divided between those where the digital learning provides assistance to close gaps in attainment, and those who have additional support needs where digital learning provides assistance to overcome learning problems.

Closing the gap

Clas et al (2009) found that digital tools could help secondary school learners who had relatively lower literacy, many of whom were learning the language of instruction. Tests of knowledge and understanding (in social studies) before and after the use of an online thesaurus and online dictionary showed that both improved their subject knowledge and their understanding, and that the online dictionary made a bigger difference, most probably because it was easier to use.

Reed et al (2013) found that digital resources could help learners over the age of 8 who were 6-12 months behind their age group in their reading age to catch up. The phonics programme which was followed in class helped most learners to improve both their reading and spelling in standard tests. Murphy and Graham (2012) found from a wider review of studies that word processing generally had a positive impact on the writing skills of weaker writers. This was related to help with revision and spelling before assessment.

Zheng et al (2014) found that providing a laptop to access digital resources, in order to improve disadvantaged lower secondary learners' science learning, was effective in reducing the gap in knowledge and understanding, as well as increasing their interest in science subjects. They attributed this to the more individualised learning that was possible. Jewitt and Parashar (2011) found that providing a laptop and internet connection to low income families in two local authority areas in England increased the completion/quality of homework, the time spent on it and the extent of independent learning.

Providing assistance to overcome learning challenges

There is promising evidence that digital equipment can support learners with learning disabilities. O'Malley et al (2013) found that among a small number of learners the majority benefited from using an iPad to increase numeracy. While Gonzalez-Ledo et al (2015) found that literacy among a group of learners with learning difficulties increased when they were provided with a computer graphics organiser (they wrote more words and included more story elements in their composition). Seo and Bryant's (2009) review of 11 studies of using digital tools with learners with learning disabilities for maths found no conclusive evidence, though most of the studies had a positive effect on addition skills.

Having digital resources can improve numeracy skills such as subtraction. Peltenberg et al (2009) found that, among 8-12 year-old learners in some special schools in the Netherlands, the approach to learning and practising subtraction in the e-learning resources had a positive effect on their competence (measured by comparing their scores on online tests using the tool and using pen and paper). They argued that the learners were better able to see their mistakes and to better understand what went wrong.

Devlin et al (2013) demonstrated how virtual interactive worlds can be used to enable a small group of secondary age looked after children to develop their team work and negotiation skills.

Ingredients for success

Many of the studies point not just to the importance of teachers' ability to use the equipment and tools but also to their understanding of how they can be used to respond to learners' needs in both guided learning, homework and non-formal learning - i.e. successful pedagogical use has to be a feature of training. Mouza et al's (2008) study of a smallscale laptop initiative for secondary age learners from low income families in the US found that much of the difference in learners' improvements in competences related to their teachers' skills in redesigning learning. D'Arcy (2012) attributed the progress in engaging travellers' children in learning with a laptop and digital resources after they had dropped out of secondary education to the tutors' ability to guide and interest them.

Several studies suggest that improvements could have been greater if teachers had received effective training beforehand (O'Malley et al, 2013; Clas et al, 2009). This also applies to parents and volunteers where digital resources were being used for learners with disabilities. Cavanaugh et al (2013) attributed the scale of improvement to the time that parents were able to help and their ability to do so. Celedon-Pattichis et al (2013) identified that undergraduate volunteers were critical to an out of school learning project using digital resources for learners with learning needs.

5: Digital learning and improving transitions into employment

Key findings

There is promising evidence for secondary age learners that digital tools can, where effectively used, build skills valued by employers: interactivity, collaboration, critical thinking and leadership. There is promising evidence too that for secondary age learners, digital resources coupled with digital tools can increase knowledge and understanding of career pathways, applying for work and working environments. These can make it easier for employers to provide help and support to learners.

In addition to the skills that teachers require to harness digital tools and resources to building learners' employability skills, it is evident that they need to be prepared to develop learner-centred learning approaches while schools need to enable learners to have access to digital equipment beyond the classroom.

Alongside literacy, numeracy and wellbeing, Curriculum for Excellence emphasizes the development of skills for 'learning, life and work'. These include thinking skills, skills for enterprise and employability, and skills for health and wellbeing (which include personal learning, planning and career management, working with others, and leadership). These are broadly transversal skills which underpin learners' work readiness and contribute to successful transitions to employment. A survey conducted by Eurydice (2010) found that ICT can be, but is less often, used to teach skills of leadership and responsibility, as well as critical thinking through active and experiential learning with digital tools and resources.

There is not a great deal of research literature which has measured how digital learning and teaching has made a difference to acquiring these skills. There are a few small scale studies which show promising evidence that digital teaching approaches may be more effective than other teaching approaches in building these skills in secondary aged learners.

Improving children's transition between education and work

Digital learning can be an effective means of developing learners' cooperative learning and working skills. Higgins et al's (2012) meta-analysis of impact studies shows that collaborative use of technology (in pairs or small groups) is usually more effective than individual use in developing skills around interaction and learning through their peers. This draws on the conclusions of Lou et al's meta-analysis (2001) which found that the majority of studies of

group work using digital tools and resources had a greater effect size than individual use.

Digital tools on VLEs have enabled learners aged 14-18 to develop skills in research and enquiry, independent learning, collaboration and interactivity which mimic a work environment.

Jahnke (2010) reported that an on-line discussion forum created for International Baccalaureate learners preparing their extended essays increased their understanding of the requirement and extended the help which could be provided from their peers. This resulted in the learners being better able to undertake the research to complete the essay, and the teachers finding it easier to respond to needs, 'build a group understanding of the requirement' and engage a larger number of learners.

Jun and Pow (2011) reported that a group web log provided small teams of learners with the means to undertake a collaborative inquiry task which required group working and critical thinking. The feedback from the learners who took part in the task and the teachers' observations from the results identified that the learners improved their research skills and gained experience of working in team under a leader.

Digital resources, such as games and virtual worlds, can also enable learners to achieve these skills. Di Blas and Paolini (2014) found consistent positive results from four similar projects in different countries where computer games had been used to improve learners 'capacity to work in groups'. These all used teacher and learner surveys and before-and-after tests of learners to assess skills gained. Biagi's (2013) finding of a consistently positive association between intensive use of ICT for gaming and PISA test scores suggests that gaming might indeed stimulate desired skills, competences and abilities - such as problem solving, strategic thinking, memory, fantasy, interaction, adaptation, etc.'

Digital resources have also enabled learners aged 14-18 to gain knowledge and understanding of work and employability skills where there are limited opportunities for gaining these from work experience in a sector in which they are interested. Fowkes and McWhirter (2007) reported that computer assisted careers guidance is widely used, though they need active learning strategies to increase learners' knowledge and understanding.

ICF (2014) reported positive benefits for learners in Scotland who participated in a pilot of the Get In Get On (GIGO) on-line course on the financial services sector. This covered pathways to work in the sector and employability skills needed, with access to an on-line mentor to respond to questions and provide feedback. The positive benefits included:

- Understanding the pathways to jobs in the sector (24 out of 25 survey respondents) and courses required (22 out of 25 agreed);
- Focus group participants largely recognising the course was relevant to their needs to understand more about employability skills they needed, and that they have gained these (making an impression, meeting deadlines, presentation);
- Schools recognising that it was as effective if not more so than providing and supporting a work placement for a week.

Digital resources can also foster independent learning. Barker and Gossman (2013) found that among around 250 17 year-olds in upper secondary education in England, over half reported that the use of Moodle had helped to develop these skills. This was related to having control over the time and pace of learning.

Ingredients for success

Teachers' knowledge and understanding of how digital tools can work to provide employability skills inside and outside the classroom, to groups of learners and to individual learners, appears to be essential to exploiting their use.

Infrastructure was found to be crucial (e.g. VLEs, access to resources, broadband width, access to laptops/tablets). Where schools do not have access to this infrastructure it is important that they can identify ways in which digital resources can be used safely when supplied by third parties.

With employability skills, access to employers and their employees can be facilitated by digital tools and resources since it makes it easier for them to volunteer time and resources to providing help and support to learners.

6: Digital learning and enhancing parental engagement

Key findings

There is promising evidence that direct communication with parents can improve learners' and parents' compliance with requests from teachers about attendance, behaviour and support for learning.

Teachers are more likely to do this once they are more competent in using digital equipment and tools, and their schools use digital tools such as VLEs to facilitate parental communications.

There is a substantial research literature which shows that where parents are actively engaged in their children's education through their involvement in the school, their support for reading and homework, and their provision of resources which can be used for learning, that this can make a difference to their children's attainment and attitude towards learning[7].

Schools have begun to recognise that digital tools can be used to communicate more effectively with parents and that parents can enable, if not encourage, their children to use digital equipment, tools and resources for educational purposes. As Formby (2014) found, children learning to read in lower socio-economic groups were more likely to have access to touch screens than books, and this could be exploited to increase their literacy levels.

There is not a great deal of research literature which has measured how schools' use of digital tools and resources has made a difference to their communications, which has in turn changed parents' behaviours, such as their support for learning. The literature which exists shows promising evidence that using digital tools for communication with parents can provide benefits to parents and school management that can enhance learners' attention to learning.

Improving engagement

Selwyn et al assessed improvements to parental communications in a small sample of primary and secondary schools in England that had made good progress in using digital tools within the school for learning and teaching. They found that:

[7] For example, Jeynes 2005, 2007; Fan and Chen, 2001; Desforges and Abouchaar, 2003; Schofield, 2006

- Direct communications increased the probability that parents had a better understanding of information and had received it. This was reflected in teachers' perceptions of greater compliance with requests for learners to change their behaviour and complete work and a better response from parents for information which indicated that more parents had acted on the communication;
- Feedback could reach parents who were not normally seen for face to face feedback about their children. Teachers were able to customise feedback and showcase good work and progress. This was reflected in teachers' perception that they were able to establish some relationship with parents they did not see.

Parents in these schools felt that they were better informed, while teachers felt that they had easier and more effective means to provide information which was beneficial to parents and children's behavior and willingness to learn. The authors concluded that digital tools were 'a technical fix to some of the problems of communication with parents rather than reconfiguring relationships'.

Condie and Monroe (2007) found that reporting to parents is enabled by digital tools. To teachers it meant that the same information could be provided to all parents and customized for parents and learners.

Johannesen (2013) found that in several secondary schools in Norway where teachers had adopted online assessment which was made available to parents and learners (as opposed to oral reporting at a parents evening) the teachers felt that this encouraged better reflection (self-assessment) by the learners and improved their communication to parents. Grant (2011) studied several secondary schools where digital tools were being introduced for direct, more customised communication with parents. He found that teachers believed that they could speed up communication, do it more easily/regularly and avoid the problems of using learners (i.e. that messages were not always conveyed or conveyed accurately).

Jewitt et al (2010) found that digital tools enabled teachers to post homework and message parents about relevant tasks which they could use to assist with homework completion. Some parents appreciated being able to access this information, although only a few parents took up the opportunity to do so.

Jewitt and Parashar (2011) found that providing low income families with a laptop and internet connection appeared, from learners' feedback, to 'help to make visible what they are learning' and 'to create and support opportunities for parents and learners to talk about what they were learning' in households where this was not usual. Several studies which have examined parental involvement in digital learning (coaching) found that it made no difference to learner outcomes (Black, 2009, Cavanaugh et al, 2014).

Ingredients for success

Successful implementation depends not just on teachers' proficiency in using digital tools for communication but the proficiency of school managers and school administrators. Blau and Hameiri (2010) found a relationship (in 10 secondary schools in Israel) between teachers' understanding and frequency of use of a digital learning management system in the school and their use of it for parent and learner communications. Those who were the lowest users of the system were least likely to use it for communication with learners or parents.

Infrastructure and school systems to collect information for parental communications are prerequisites.

7: Digital learning and improving the efficiency of the education system

Key findings

There is promising evidence that teachers' efficiency can be increased by using digital equipment and digital resources to prepare for teaching. There is similarly promising evidence that digital tools and resources enable teachers to do their job better in relation to teaching, assessment and their own on the job learning and development.

This section provides a review of the studies which include evidence of how digital learning and teaching can improve the efficiency of the education system, focusing on teachers and schools.

Teachers expect digital teaching to enable them to source materials for lessons and provide formative assessment more efficiently, as well as meeting a wider range of learner needs more effectively. As a consequence, within a school, preparation and assessment might be less time consuming and teaching time more productive through digital learning and teaching.

Improving teacher and school efficiency

A review of the literature indicates there is little empirical evidence explicitly showing a relationship between the increased uptake of digital learning and teaching and an improvement in the efficiency of teachers or of schools. Studies have mostly focused on increased effectiveness (better results) rather than efficiency (cost benefits/value for money of the investment and use), although two studies provide some estimate of cost saving.

The evidence (including small scale anecdotal evidence, as well as larger scale self-reported survey results and comparative studies) is provided below in relation to aspects of digital learning and teaching for which there are reported efficiencies.

Digital equipment

Blackwell (2013) found, from a small-scale qualitative survey and observation of schools in the US, some evidence of increased teacher efficiency in early childhood education as a result of using tablet computers and associated software and applications. These came from:

- Using video, camera and audio recorders to document learning and provide longitudinal assessment (e.g. of speech and cognitive development);

- Automatic gathering of tests and quiz results, writing examples etc, to support quicker and more accurate assessments;
- Using touch screens and having faster booting up and logging-in compared to computers.

Blackwell concludes: 'While little evidence exists on how tablet computers are being integrated into the classroom and how this integration is changing or reinforcing current teaching practices, these unique features provide evidence that tablet computers *could* enact such changes in the education environment.'

Similarly, a small scale qualitative evaluation of iPad Scotland (Burden 2012) found that the use of iPads encouraged teachers to explore alternative activities and forms of assessments for learning. Teachers generally reported that iPads required virtually no training for them to be used effectively, allowed them to develop and extend homework activities, and enabled them to provide better feedback to learners about their learning. The initiative was described by stakeholders as 'the most easily accepted, successful and problem-free [digital] initiative they had ever witnessed' because of the low levels of resistance to their use.

PBS and Grunwald Associates LLC (2010), using a survey of 1,400 classroom teachers in the US, also report that teachers (pre-school to secondary school) believe that a variety of technology devices and web-based systems 'help them do their jobs better' and 'help them to engage students in learning'. For instance, 68% of teachers surveyed reported that they value interactive whiteboards as a means to supplement and support teaching. Similarly, Peterson and McClay (2012) in a mixed-methods study with over 300 teachers in Canada found that teachers saved time in classroom teaching by using smart-boards – examples were easier to demonstrate and could be saved for future use.

Digital tools and resources

Teachers' have increasingly found online learning and knowledge exchange platforms to be useful (PBS and Grunwald Associates, 2010) and this may be enabling teachers to prepare for lessons more efficiently and tailor lessons to learning outcomes. The study reports that 97% of teachers surveyed used digital media for searching for, and managing, interactive games, activities, lesson plans and simulations.

Increasingly, digital media is reported by teachers as a means to support content management (rather than paper files and reports). Teachers report using data management systems to track assessment scores (76 per cent), refine the curriculum (71 per cent), develop individual education plans (62 per cent), or get professional development or feedback (54 per cent).

There is indicative evidence that learning assistance tools (which provide useful hints or feedback to learners to 'reinforce learning') can free up teacher

time in classrooms. For instance, Huang et al (2010) reported that '*teaching loads were significantly reduced* [by the learning assistance tool] *because appropriate hints or feedback were automatically provided to learners without teacher involvement'*. Cook et al's (2010) meta review of efficiencies concluded that digital teaching does not guarantee greater efficiency in teaching, but in some instances can *facilitate* efficiency by enabling learners with varying aptitudes to work more effectively. This allows teachers to spend more time with those who need it.

In relation to preparation, Passey (2011) found that Espresso digital resources, which are widely used in primary schools in the UK, were quicker and easier to use than other digital resources. While the time savings estimated were not large (about seven hours a year per teacher), the study found that these would be greater for higher users of the resources. For the GIGO digital resources for learning about work reported in the previous chapter (ICF, 2014), participants using the digital resources had a unit cost of about £175, which compares to an estimated unit cost for a work placement of about £1,300.

Hargis and Wilcox (2008) discussed some of the free and ubiquitous resources that can be used to support teacher efficiency, including online collaboration tools (e.g. Skype, Google documents, Second Life). Some promising evidence is provided of how these tools have improved teacher efficiency (albeit in a university setting):

- Presenting a lesson to a wider audience such as in another school or another class within a school simultaneously; and
- Helping learners who are off site.

The Blackwell study (2013) indicated that there was limited evidence that teachers used technology to share learning about the most effective teaching practices.

8: Conditions to bring about effective use and integration of digital technologies

Key findings

The literature identifies factors that bring about successful implementation of digital learning and teaching; these factors are:

- **Training and support not only to use equipment but to exploit digital tools and resources for teaching;**
- **Overcoming teachers anxieties about digital teaching, not just about the use of the technology but also the use of different learner-centred pedagogies;**
- **Allowing teachers to experiment with technology;**
- **Networking with other teachers and schools; and**
- **Maintaining and upgrading equipment and using tools that are compatible across many systems.**

If these were adopted, more effective implementation of digital technologies should be expected to increase efficiency.

This section focuses on the conditions (not specifically related to the key educational priorities discussed in the previous sections) that can bring about effective use and integration of digital technologies in learning and teaching. The main conditions identified to support this (training and support; overcoming resistance to changes in teaching approaches; and, networking/ team working) are discussed below.

Training and support

Studies show how training and support for teachers to use digital tools and resources can improve their confidence and capabilties, their effective use and understanding of their benefits.

According to a recent Teaching and Learning International Survey (TALIS) (OECD 2015), approximately 60% of teachers report moderate or high development needs in ICT for teaching. A lack of initial teacher training on how to use technology can lead to teachers feeling unprepared in how to use it effectively in their teaching practices (Blackwall, 2013).

There is promising evidence that the use of blended learning (online and face to face) in initial teacher training can lead to increased use of technology in the classroom (Foster 2012). Equally, Masters et al (2012) found in a controlled study that online training for teachers compared to other approaches brought about better outcomes in the classroom for the learners they subsequently taught. Urban-Woldron (2013) also found that long-term blended learning for teachers is more effective than one-off face to face teaching sessions at fostering teachers' abilities to integrate technology into the classroom.

Abar and Barbesa (2001) found in a study which examined maths teachers' engagement with online learning in Brazil that the effective integration of technology in education involves issues beyond teachers' control such as school organisation and support material, which are essential first steps for the usage of new technologies.

Harris (2006) suggests that time efficiencies for teachers do not seem to become significant until at least the second year of course delivery, when developing blended learning (e-learning plus classroom delivery). As such, it is very important to facilitate frequent dialogue about teacher workload and to find ways to provide short term additional preparation time and support.

Overcoming resistance to changes in teaching approaches

In their meta-analysis, Cheok and Wong (2015) found that characteristics of teachers (attitude, anxiety and self-efficacy) are closely linked to teachers' satisfaction and engagement with technology. They conclude that: "Organisation support in terms of; training, technical and management, are all important factors necessary in initiating teachers into adopting new innovation." Reimann et al's (2009) study of rural teachers in Australia suggests that in order to bring about effective and efficient use of digital tools and resources (including sharing knowledge across educational institutions), teachers need to 'adapt their professional identity (or attitude) to include the role of innovator' and that to do so, they need space and time to adapt to new methods.

Petko (2012) indicated that computer and Internet applications are more often used by teachers in the classroom when:

- Teachers consider themselves to be more competent in using ICT for teaching;
- More computers are readily available;
- The teacher is more convinced that computers improve learner learning; and
- The teacher more often employs learner centred forms of teaching and learning.

This was corroborated by Goodwyn (2009) who states that 'digi-teachers (teachers who have a capacity to integrate ICT into everyday learning), have strong motivation to connect with their learners' lives and have normalised digital technology in the classroom – however, for the most part they are self-taught'. He suggests that they provide excellent role models for colleagues and should be given time off to improve their practice and support others.

Parette et al (2009) in a US study concluded that schools need to provide more support by showing teachers how they can integrate technology into their curriculum if it is to be used effectively. Fredricksson (2008) found that allowing teachers to take risks and trial small scale innovations as well as sharing practices of what works and does increases their motivation to implement innovative uses which may reduce teachers' resistance under time pressures.

Blackwall (2013) found that even over extended time periods with technology, there are limited changes in teachers' approaches to teaching and learning as a result of having technology in the classroom (Lindahl and Folkesson, 2012; Tondeur et al., 2008). He concluded that technology itself may not necessarily shift early childhood educators' internalised teaching practices and philosophies. Many of the studies examined (e.g. OECD 2015; Younie and Leask 2013) conclude that teachers who hold constructivist beliefs about their job (i.e. those who see themselves as facilitators of learners' own inquiry, or see thinking and reasoning as more important than specific curriculum content) are more likely to understand the pedagogical benefits of using digital learning and teaching (and other active teaching techniques) and will use it in the classroom.

According to Plomp et al (2009), three different stages have been identified in the effective development of the use of ICT in schools:

1. Teachers use digital tools and resources to support traditional methods of teaching, such as drill-and-practice, text orientation, whole group lectures and desk work;

2. Teachers gain confidence and use technology as part of more innovative instruction, including, team teaching, inter-disciplinary project based instruction, and individually pace instruction; and

3. Teachers enter an inventive stage in which they experiment and change the use of technology to support active, creative and collaborative learning.

Networking/team working

Studies indicate there is little in the way of online collaboration (between teachers in a school, betweeen schools, between countries), even though examples of this (e.g. Fredricksson, Reimann et al and various EU projects)

indicate these can be useful for teachers/schools to increase the effectiveness of their use of digital teaching.

Younie and Leask (2013) predict challenges in collaboration, knowledge-sharing and transferability of teachers' skills where schools implement different learning platforms which may not 'talk to each other'. Informal peer support for teachers through communities of practice are considered the most effective model for networking and collaboration outside the practitioners' settings based on their success in the higher education sector which provide examples of good practice (Dawes, 2001; Leask and Younie, 2001; Younie, 2007).

Provision and maintenance of equipment

Financial resources are cited in many studies as a barrier to effective implementation and maintenance of ICT infrastructure to support teaching and learning. Fredricksson (2009) and Goodwyn (2011) concluded that as far as sustainability is concerned the budgetary consequences of introducing computers into schools, the maintenance of the existing infrastructure, and upgrading both hardware and software have to be absorbed.

9: Conclusions

This section sets out a summary of the available evidence of the impacts that the use of digital technologies in schools has on learning and teaching, followed by a consideration of the factors which are essential for implementing successful use of digital technologies for learning and teaching in schools.

Impacts on learning and teaching

It is important to note that the research literature has some shortcomings for a study of this kind. Much of it describes uses of digital tools and resources without any assessment of the outcomes or how and why they were achieved or not achieved. Most studies that attempt to measure any outcomes focus on short and medium term outcomes, small numbers of learners or teachers or schools, and commonly measure these qualitatively. The studies that do measure change, and measure change quantitatively against a comparative group or other ways to attribute the change to the digital tools or resources being applied, tend to do this over short periods (four weeks to six months).

As a consequence, this led Higgins et al (2012) to conclude that 'taking the body of research as a whole, there is not a conclusive case for the impact of digital technology on longer term educational attainment outcomes', but there is compelling evidence that digital technology provides teachers with tools and resources that can aid learning and teaching and enhance the ability of some children to learn effectively. The meta-analyses discussed provide some strong evidence of impact, while the qualitative studies provide evidence about how the these impacts are achieved.

All this is reflected in the conclusions which can be reached. In the cases where studies of similar digital tools and resources have been systematically reviewed or where there is a large body of evidence from different studies which have measured change (three stars and better in Table 2), it is possible to state there is conclusive evidence. In other cases where the evidence base is weaker (mainly studies with one or two stars in Table 2, it is only possible to state that there is indicative evidence or promising evidence.

Based on this, this review provides:

- Conclusive evidence that digital technologies can support educational attainment in general and improvements in numeracy/mathematics and science learning;
- Indicative evidence that digital technologies can support educational attainment in literacy and closing the gap in attainment between groups of learners;

- Promising evidence that digital technologies can provide assistance to overcoming the challenges faced by some learners; improvements in employability skills and knowledge of career pathways; improved communications with parents; and time efficiencies for teachers.

Table 5 Summary of quality of evidence for each thematic area

Thematic Area	Strength of evidence
Raising attainment	
General	Conclusive
Numeracy/mathematics	Conclusive
Literacy	Indicative
Science learning	Conclusive
Tackling inequalities and promoting inclusion	
Closing the gap in attainment between groups of learners	Indicative
Provide assistance to overcoming the challenges faced by some learners	Promising
Improving transitions into employment	
Improvements in employability skills and knowledge of career pathways	Promising
Enhancing parental engagement	
Improvements in communications with parents	Promising
Improving the efficiency of the education system	
Improvements in time efficiencies for teachers	Promising

While many studies clearly focus on specific learners in terms of age, settings (primary, secondary, special education) and domestic circumstances, none make any comparisons between the impact of digital technologies on educational priorities for different age groups. As a consequence, it has not been possible to identify any differences in the use and impact of digital technology in primary and secondary school settings. However, it is generally the case that the impacts found apply relatively equally to primary and secondary school learners.

The literature review identifies areas where more research evidence is required in order to draw stronger conclusions. These are around comparing the impacts of digital learning in primary and secondary settings and evidencing impacts on improving transitions into employment, enhancing parental engagement and improving school efficiency

Successful implementation

Studies which have assessed what has worked to bring about positive outcomes from using digital tools and resources for learning and teaching show that it is teachers that make the changes to exploit and harness digital technology. As the OECD (2015) study concluded: 'technology can amplify great teaching but great technology cannot replace poor teaching'. Teachers achieve this through having digital proficiencies with equipment and tools; being able to identify suitable applications for teaching and assessment and integrating them into specific lessons and curriculums; and being able to adapt their pedagogical approaches for classroom teaching, guided learning (homework), and formative assessment.

To do this they require the following support. These are little different to the ingredients required for any significant shift in pedagogy.

Organisational leadership

Professional development of school staff

It is crucial that teachers have opportunities to learn how to use all applications and get support in using them initially if they are to enhance their pedagogies and increase their confidence and capabilities. Where they do, they are better able to identify knowledge and skills which can be acquired through digital tools and resources, the learning styles which can be better suited to these, and opportunities for children to learn outside the learning in class. This can be from blended learning and communities of practice as much as off site training courses, since teachers need support while they put what they have learnt into practice and become comfortable with tools and equipment. Schools need to support the development of networks as well as participation in training since informal peer support and collaboration are effective means of knolwedge sharing and learning.

School leaders as agents of change

It is important that if schools wish to obtain greater benefits from digital technologies they must move usage towards Plomp et al's third stage of development: "teachers enter an inventive stage in which they experiment and change the use of technology to support active, creative and collaborative learning." If this is achieved, learners are more likely to exploit digital technologies and increase the time they spend on active learning. School leaders need to direct the development of digital technologies and ensure that teachers have time to undertake training and, when adopting digital teaching, have additional preparation time and opportunities to take risks.

Knowledge exchange and support for teachers

Continuing professional development

Teachers benefit from opportunities to use, observe and practice changes to teaching. This is particularly important with digital technologies where it is clear

that changing practices towards learner centred approaches appear to bring greater benefits to learner attainment. This can be achieved through supported learning in small groups and online commuities of practice.

Initial teacher training
New entrants to teaching need to be equipped to use digital technologies and understand their benefits and applications. Teachers are more likely to adopt digtial technolgies for teaching when they are competent themselves.

Understanding the benefits
While many teachers can be resistant to using digital technologies because of their confidence and competence in using them, once the benefits of digital learning are better understood they are more convinced of the value of using them in their teaching.

Infrastructure including access

Access to equipment, tools and resources
It is crucial that if digital technologies are to be used in learning and teaching that schools have equipment and tools that can be used by learners as well as teachers. Tools and resources require sufficient bandwidths. Digital technologies also need to be kept up to date. Schools need to budget for maintenance of the existing infrastructure as well as its upgrading.

Support to use
Where digital equipment is provided, training is needed to support appropriate and effective use in the classroom.

Flexibility in learning and teaching

It is crucial that teachers have discretion in how lessons and homework ensure educational outcomes are achieved. Allowing teachers flexibility will give them opportunities to ensure digital technology can be fully utilised.

In summary, successful implementation requires support to teachers in the form of opportunities to learn (both formally and informally), embedding digital learning in continuing professional development and initial teacher training, direction and leadership within a school, functioning digital equipment and tools, and an environment that gives teachers the flexibility to introduce and use digital learning.

Annex 1: Research protocol

The inclusion criteria

The table below sets out the criteria by which literature was selected.

Table A1.1: The criteria for study inclusion

Characteristics of the literature	Inclusions
Time period	Post 2005
Language and geography	No exclusions
Type of publication	Peer reviewed journal articles Un-peer reviewed academic research outputs (reports; working papers; discussion papers; conference papers) Government/EC and government/EC commissioned research outputs Publications of other research organisations/think tanks/advocacy bodies Evidence provided by practitioners in conference/workshop settings
Population groups	5-18 years olds
Settings	ISCED 1, 2 and 3 Formal teaching in school setting (compulsory and non-compulsory) Out of school and non-formal learning directed by teachers Lesson preparation, delivery and assessment
Type of policies/ interventions in scope	Use of digital teaching and learning tools and materials (i.e. digital media and online environments) Out-of-school learning Pedagogical developments using ICT Teacher training and support for ICT Digital capacity and resources
Types of outcome within scope (see also section 2.1.3 below)	Raising attainment (especially in literacy, numeracy, science learning and ICT skills) Tackling inequalities/promoting inclusion for 'protected' groups and low-socio-economic status families/areas (e.g. impacts on attainment (as above), progression, health and wellbeing) Improving transversal employability skills (e.g. 'skills for learning, life and work' as outlined in the Curriculum for Excellence Senior Phase) Improving efficiency for teachers (especially reducing their time spent on developing teaching resources and improving the quality of assessment) Enhancing parental engagement (especially greater satisfaction with school communications and the ability to engage more parents in their children's education)
Study designs	No exclusions on design

Search strategy

The search included the sources below.

Table A1.2: Sources of material

Type of source	Sources to be consulted
Journal databases	EBSCO databases (includes the Education Resources Information Centre); Scopus
Specific journals	Educational Evaluation and Policy Analysis Educational Review European Journal of Education British Journal of Educational Technology International Journal of Learning International Review of Education Journal of Digital Learning in Teacher Education The International Journal of E-Learning and Educational Technologies in the Digital Media Journal of Interactive Media in Education International Journal of Mobile and Blended Learning International Journal of Virtual and Personal Learning Environments Research in Learning Technology International Journal of E-Assessment
Research institutions and agencies	Professional Education and Leadership research cluster, University of Stirling Moray House School of Education, University of Edinburgh Learning Sciences Research Institute, University of Nottingham; Institute of Educational Technology, Open University The London Knowledge Lab, University College London Centre for Technology Enhanced Learning, Lancaster University Faculty of Education University of Hull Technology Enhanced Learning Group, Durham University Digital Learning Research Cluster, University of Wolverhampton Technology, Innovation and Play for Learning Research Group, Manchester Metropolitan University Education Endowment Foundation Teaching and Learning Toolkit NESTA Eurydice Open Education Europa Portal OECD
Government and government agencies	Scottish Government Library Services Education Scotland Scottish Qualifications Authority UK Department for Education Education Ministries and educational/curriculum agencies in other countries European Commission including Eurydice
Website searches	Google Scholar

The draft terms in Table A1.3 below were used to search for journal articles held on databases hosted on Ebsco (http://www.ebscohost.com/). Terms were also translated so that searches could be undertaken in French and German to widen the material collected. Selected search results were exported to reference management software (Zotero) to compile a bibliography.

Table A1.3: Initial database search terms

Primary	AND	AND
Online	Teach*	Impact
ICT	Educat*	Effect
Web	Learn*	Outcome
Internet	Instruct*	Achieve*
Digital	Class*	Progress*
Computer	Pedagog*	Academic
CAL	Support	Participat*
'Open educational resources'	Assess*	Skill*
'Digital resources'	Instruct*	Confidence
Media	Tuition	Attain*
Tech*	School	Competenc*
Virtual	Student	Disadvantage*
VLE	Pupil	'Low-socioeconomic'
'Learning platforms'		Inclu*
		Equal*
		Qual*
		Higher*
		Perform*
		Motivat*
		Efficien*
		'Basic skills'
		'Skills for Life'
		Literacy
		Numeracy
		Science
		'ICT skills'
		Employability
		Transversal
		'Parent engagement'
		Communicat*

Scope of the literature review: definitions

- Learners are those in education in primary and secondary schools between the ages of five and 18; school staff include classroom teachers, school senior managers, school administrators, and newly qualified teachers.
- Attainment can be measured by progress against tested standards and the achievement of qualifications. The focus is on four key areas of the curriculum: literacy, numeracy, science learning, and ICT skills.
- Inclusion and equalities can be measured by positive impacts for the protected groups defined in the Equalities (Scotland) legislation and for those from low socio-economic status families/areas or who may not be able to attend school (due to exclusion or illness). Positive impacts could include attainment, progression, health and wellbeing, and in the short term increased access to and/or engagement with learning.
- Improved transitions can be measured by the attainment of employability skills, such as collaboration and team working, following instructions/planning tasks, knowledge and understanding of pathways to employment, and the use of digital tools to demonstrate skills and competences reflecting the emphasis on ‘skills for learning, life and work’ in the senior phase of Curriculum for Excellence.
- Efficiency can be measured by reducing the time teachers spend on developing resources for teaching from the collaboration and sharing/reuse of resources for teaching and assessment, and improving the quality of teaching and assessment.
- Parental engagement can be measured by parents’ greater satisfaction with school communications and the ability to engage more parents.

Annex 2: Assessment framework

Any literature review needs a framework to draw out the key findings of the relationships we are looking for evidence of and to provide a narrative structure for the summary and analysis. We generally use a theory of change or logic model to provide such a framework because it:

- Clarifies the relationships we are looking for evidence of between the learning and teaching activities and the expected outputs, outcomes and impacts;
- Shows the linkages we might expect to find evidence of between the activities and the outputs, outcomes and impacts for different beneficiaries of the digital learning and teaching (learners, parents, teachers, the school);
- Separates the outcomes which might be considered to be immediate, medium-term and longer term.

The assessment framework is presented below:

Table A2.1: Assessment framework

		Inputs: Learning/Training Activities	Outputs: New knowledge, skills and competencies and positive attitudes	Short term outcomes: knowledge, skills & competencies	Medium term outcomes: knowledge, skills and useful competencies	Impacts: Knowledge, skills and competencies applied with economic and social effects
Theory of change: gain from formal and non-formal education and training	Learners	Digital learning resources available for formal and non-formal learning School platform/VLE available for learner/teacher communication	More opportunity to be active in learning and test knowledge/skills Access to more sources of learning (more varied, wider coverage) Gain transversal employability skills, such as collaboration and team work, following instructions/planning tasks, knowledge and understanding of pathways to employment Gain skills in key areas of curriculum	Greater feeling of personal control over learning More motivation and interest in learning More confidence to practise and use a skill Greater completion of homework to quality required	Increased time spent on non-formal learning Improved competences (sustained learning gains) in basic skills - key areas of literacy, numeracy, science skills and ICT – and transversal skills for life and work Faster learning Clearer understanding of how to achieve learning and work ambitions	More learners achieve higher levels of attainment in literacy, numeracy, science skills and ICT skills throughout schooling More learners achieve better results in other subjects where digital learning has been used Gaps in attainment are reduced for protected groups/children from low income backgrounds Fewer learners fail to make an effective transition to higher or further education, training or employment between ages of 16 and 24
	Teachers	School platform/VLE available for learner/teacher	Better able to use digital technologies for teaching and assessment	Better able to meet needs of learners with different learning	Increased capability to teach all learners effectively without	

		Inputs: Learning/Training Activities	Outputs: New knowledge, skills and competencies and positive attitudes	Short term outcomes: knowledge, skills & competencies	Medium term outcomes: knowledge, skills and useful competencies	Impacts: Knowledge, skills and competencies applied with economic and social effects
		communication Teacher training in use of VLE etc. Teacher training in use of digital resources and their pedagogical use	Better able to engage some learners in learning Reduced time spent on lesson preparation of materials	styles/ special educational needs More frequent use of digital technologies for teaching Better able to provide individual feedback	decrease in class size Increase capability to narrow gaps in learning because of learner's background and learning styles/needs	
	Schools	Provision of teacher training and support to use digital resources etc. Provision of sufficient bandwidth etc. to use digital teaching resources etc.	Better able to provide resources for teaching and learning and communication with parents Teachers encouraged to collaborate within the school and with teachers in other schools to use digital resources	More frequent communication with parents Better targeted and customised communication with learners, teachers and parents Teachers sharing and reusing resources	More parents actively engaged with their children's education More parents feel school keeps them informed Teachers spending more time on assessment and feedback	Schools achieve more without increased resources Parents more satisfied with outcomes their children achieved at school Schools offset some costs of ICT with savings in running costs

Annex 3: Bibliography

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Annex 4: Meta-analysis literature reviews included in the review

Review publication	Scope of review	Criteria and quality assessment	Sources included
Li, Q and Ma, X. (2010)	This study examines the impact of digital technology on mathematics education in kindergarten to pre-college classrooms through a systematic review of existing literature.	Almost all studies were controlled, employing either random assignment of learners to experimental/ control conditions or using statistical control for quasi-experimental designs. Nearly two thirds of the studies were published journal articles, and the rest were doctoral dissertations or unpublished reports.	85 independent effect sizes extracted from 46 primary studies involving a total of almost 37,000 learners. Studies are international.
Higgins, S, Xiao, Z, and Katsipataki, M. (2012)	The aim of this review is to present a synthesis of the evidence from meta-analysis about the impact of the use of digital technology in schools on children's attainment, or more widely the impact of digital technology on academic achievement.	The research considered published reports from 1990 to 2012, separating the analysis (1990-1999 and 2000-2012) to check that the findings and implications from earlier and possibly obsolete technologies were not influencing the overall findings.	48 studies which synthesised primary research studies on the impact of technology and the attainment of school age learners (5-18 year olds). Studies are international.
Liao, Y-k C, Chang, H-w, and Chen, Y-w (2008)	To synthesize existing research comparing the effects of digital technologies versus traditional instruction on elementary school learners' achievement in Taiwan.	To be included studies had to report sufficient quantitative data on both digital technology teaching and traditional teaching methods so that effects could be compared, and be available through university or similar libraries. Studies were from 1995-2003.	48 studies were located from four sources. Statistical and reference information on the studies is included in the report. Studies were international.
Archer, K, Savage, R et al. (2014)	To reevaluate previous digital technology based studies by examining the reported quality of the training and support teachers received and the reported quality of implementation fidelity.	Used information from 3 previous meta-analyses, selected because they reviewed comparable criteria with control groups, adequate study duration and valid achievement measures and reported robust statistical information. Studies ranged from 1970-2007.	38 studies from 3 previous systematic reviews that examined the impact of ICT on literacy learning for learners aged 5-16 years of age. Studies were international.

Cheung, A, and Savage, R. (2012)	Examines the effectiveness of digital technology tools and resources in improving the reading achievement of struggling readers in elementary schools.	To be included studies had to cover children with reading disabilities, learners in at least the lowest 1/3 of their classes, or any learner receiving additional tutoring, or having special educational needs; use a control group, use standardised tests and last a minimum of 12 weeks. Studies were from 1980 with most (14) being from 2000.	A total of 20 studies covering 7,000 learners aged 5-11 were included in the final analysis. Studies were international.

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The views expressed in this report are those of the researcher and do not necessarily represent those of the Scottish Government or Scottish Ministers.

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