The Impact of Digital Technology on Learning: A Summary for the Education Endowment Foundation

Full Report

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Interpreting the evidence from meta-analysis for the impact of digital technology on learning

Overview

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. It is divided up into three main sections. The first sets out an overview of the wider research into the impact of technology on learning to set the context and the rationale for the value of this information. The next section reviews the evidence from meta-analysis and other quantitative syntheses of research into the impact of digital technology. A further section looks at trends in the use of digital technology and learning in the UK and internationally, to provide further context for the recommendations which follow.

The purpose of this review is to identify implications for future investment in the use of digital technology for learning in schools. Digital technologies are now embedded in our society. Focus has shifted from whether or not to use them in teaching and learning, to understanding which technologies can be used for what specific educational purposes and then to investigate how best they can be used and embedded across the range of educational contexts in schools.

Summary of key points

Overall, the research evidence over the last forty years about the impact of digital technologies on learning consistently identifies positive benefits. The increasing variety of digital technologies and the diversity of contexts and settings in which the research has been conducted, combined with the challenges in synthesising evidence from different methodologies, makes it difficult to identify clear and specific implications for educational practice in schools.

Studies linking the provision and use of technology with attainment tend to find consistent but small positive associations with educational outcomes. However a causal link cannot be inferred from this kind of research. It seems probable that more effective schools and teachers are more likely to use digital technologies more effectively than other schools. We need to know more about where and how it is used to greatest effect, then investigate to see if this information can be used to help improve learning in other contexts. We do not know if it is the use of technology that is making the difference.

Research findings from experimental and quasi-experimental designs – which have been combined in meta-analyses – indicate that technology-based interventions tend to produce just slightly lower levels of improvement when compared with other researched interventions and approaches (such as peer tutoring or those which provide effect feedback to learners). The range of impact identified in these studies suggests that it is not whether technology is used (or not) which makes the difference, but how well the technology is used to support teaching and learning. There is no doubt that technology engages and motivates young people. However this benefit is only an advantage for learning if the activity is effectively aligned with what is to be learned. It is therefore the pedagogy of the application of technology in the classroom which is important: the *how* rather than the *what*. This is the crucial lesson emerging from the research.

Taken together, the correlational and experimental evidence does not offer a convincing case for the general impact of digital technology on learning outcomes. This is not to say that it is not worth investing in using technology to improve learning. But it should encourage us to be cautious in the face of technological solutions to educational challenges. Careful thought is needed to use technology to best effect.

There is a recurrent and specific challenge in understanding and applying research evidence as it takes time for robust evidence to emerge in education, and the rapid pace of change of technology makes this difficult to achieve.

The challenge is to ensure that technology is used to enable, or make more efficient, effective teaching and learning practices. With this in mind the findings from the synthesis of the meta-analyses indicate the following overall trends:

- Collaborative use of technology (in pairs or small groups) is usually more effective than individual use, though some pupils, especially younger children, may need guidance in how to collaborate effectively and responsibly.

- Technology can be as powerful as a short but focused intervention to improve learning, particularly when there is regular and frequent use (about three times a week) over the course of about a term (5 - 10 weeks). Sustained use over a longer period is usually less effective at improving this kind of boost to attainment.

- Remedial and tutorial use of technology can be particularly practical for lower attaining pupils, those with special educational needs or those from disadvantaged backgrounds in providing intensive support to enable them to catch up with their peers.

- In researched interventions, technology is best used as a supplement to normal teaching rather than as a replacement for it. This suggests some caution in the way in which technology is adopted or embedded in schools.

- Tested gains in attainment tend to be greater in mathematics and science (compared with literacy for example) though this is also a more general finding in meta-analysis and may be at least partly an artefact of the measurement process. In literacy the impact tends to be greater in writing interventions compared with reading or spelling.

- At least a full day's training or on-going professional inquiry-based approaches to support the introduction of new technology appear the most successful. The implication is that such support should go beyond the teaching of skills in technology and focus on the successful pedagogical use of technology to support teaching and learning aims.

Overall, the over-arching implication is that the technology is solely a catalyst for change. The question is how can technology can bring about improvement and make teaching and learning practices more efficient or effective. Focusing on the change (and the process of change), in terms of learning is essential in supporting effective use.

Recommendations

1. The rationale for the impact of digital technology on teaching and learning needs to be clear:
    - Will learners work more efficiently, more effectively, more intensively? Will the technology help them to learn for longer, in more depth, more productively? Or will the teacher be able to support learners more efficiently or more effectively?

2. The role of technology in learning should be identified:
    - Will it help learners gain access to learning content, to teachers or to peers? Will the technology itself provide feedback or will it support more effective feedback from others, or better self-management by learners themselves?

3. Technology should support collaboration and effective interaction for learning:
    - The use of computer and digital technologies is usually more productive when it supports collaboration and interaction, particularly collaborative use by learners or when teachers use it to support discussion, interaction and feedback.

4. Teachers and/or learners should be supported in developing their use of digital technology to ensure it improves learning.

- Training for teachers (and for learners), when it is offered, usually focuses on technology skills in using the equipment. This is not usually sufficient to support teachers and pupils in getting the best from technology in terms of their learning. On-going professional development and support to evaluate the impact on learning is likely to be required.

5. Identify what learners and teachers will *stop* doing:
    - The use of digital technology is usually more successful as a supplement rather than as a replacement for usual teaching. Technology is not introduced into a vacuum. It is therefore important to identify carefully what it will replace or how the technology activities will be additional to what learners would normally experience.

Approach and methods

This review summarises the research evidence contained in meta-analyses to identify patterns of impact in the accumulating research about the effects of technology on learning, and to identify the extent of the possible impact of technology on learning. A systematic search revealed 48 studies which synthesised primary research studies of the impact of technology on the attainment of school age learners (5-18 year olds). Whilst this presents only a partial and retrospective view of such impact, it is the only approach to allow a systematic comparison of a large number of studies with an estimate of the extent of the effects on learning.

Background

The role of technology in education has been an important question since the potential of computer technology to transform Skinner's teaching machines was recognised in the 1960s. It remains an important issue today with debates about the impact of technology on our society, the implications of quick and easy online access to information for knowledge and learning and the effect of technology on young people's social, emotional and physical development frequently in the news. It is therefore important to take stock of what we know about the impact of digital technology on education from what we have learned over the last fifty years. Appendix 1 sets out a number of these issues in terms of some contemporary myths about the effects of technology.

The main approach used to evaluate the impact of technology on teaching and learning in schools has been where pupils' attainment across a range of tested curriculum outcomes has been correlated with the quantity or quality of technology which was available or which they experienced in their institutions (see, for example, Watson, 1993; Wenglinsky, 1998; Weaver, 2000; BECTA 2003). In the USA, only a small relationship between computer use in the school curriculum and improvement in pupils' test scores was found in a longitudinal study (Weaver, 2000). At this very general level, computer use makes very little difference to pupils' achievement. In the UK, the Impact 2 study (Harrison *et al*. 2004) identified statistically significant findings positively associating higher levels of ICT use with school achievement at each Key Stage, and in English, Maths, Science, Modern Foreign Languages and Design Technology. An association between high ICT use and higher pupil attainment in primary schools was also reported in an earlier Teacher Training Agency study (Moseley *et al.* 1999, p 82) though the interpretation by the research team was that more effective teachers (and more effective schools) tended to use more innovative approaches, or chose to use the ICT resources that they had more appropriately, rather than that the technology itself was the cause of the differences in pupil performance.

This connection between technology and learning is found fairly consistently however, and other studies have indicated a stronger association. The ICT Test Bed evaluation identified a link between high levels of ICT use and improved school performance. The rate of improvement was faster in ICT Test Bed Local Authorities (LAs) than in equivalent comparator LAs in KS2 English (Somekh *et al*. 2007). However, what this association shows is that, on average, schools with higher than average levels of ICT provision also have pupils who perform slightly higher than average. The causal link could be quite the reverse, with high performing schools more likely to be better equipped or more prepared to invest in technology or more motivated to bring about improvement. Fuchs and Woessmann's (2004) analysis of this link between provision and performance based on the Programme for International Student Assessment (PISA) data supports this interpretation:

> "the initial positive pattern on computer availability at school simply reflects that schools with better computer availability also feature other positive school characteristics. Once these are controlled for, computer availability at school is not related to pupil performance in math and reading." (p. 13)

The Organisation for Economic Co-operation and Development's (OECD) more detailed analysis of Programme for International Student Assessment (PISA) data indicates a complex picture of association between pupil performance, their access to computers at home and at school together with frequency of use which varies from country to country (OECD 2006, p 51-66). Though as a note of caution the research found that pupils who used computers most widely tended to perform slightly *worse* on average than those with moderate usage. Overall the analysis suggests that the linkage may not be a simple causal one, nor necessarily a simple linear association. There may be a limit to the amount of technology which is beneficial.

In findings from experimental and quasi-experimental research studies, where gains in knowledge or understanding for groups of pupils using ICT has been compared with gains for groups learning the same content without technology, results again tend to show positive benefits for ICT. These have been reviewed using a narrative approach with consistently positive conclusions (e.g. Parr & Fung, 2000; Andrews *et al*. 2002; Cox *et al*. 2004; Hartley, 2007) as well as through quantitative synthesis using meta-analysis (see Appendix 2 (2000-2012) and 3 (1990-1999) for more details about these studies, with a full bibliographical list of meta-analyses of the impact of digital technologies on learning in Appendix 4). Again these reviews typically conclude that technology has a positive and measurable effect on learning. Most of these reviews of the efficacy of ICT or digital technologies do not, however, consider the effects *comparatively*. A large majority of researched educational interventions have a positive impact but the relative impact is not usually considered (see, for example, Hattie, Biggs & Purdie, 1996; Sipe & Curlette, 1997; Marzano, 1998; Hattie, 2008). When a comparative view is taken technology interventions appear to be less beneficial, as Sipe and Curlette (1997) originally observed:

> "when compared to 'no computers', 'computers' produces a nice effect size. However, when compared with typical effect of innovation on educational achievement, computer innovations are not that different from the average innovation." (p 608)

Taken together, the correlational and experimental evidence does not offer a convincing case for the *general* impact of digital technologies on learning outcomes. Serious questions can be raised about the nature of the evidence base (Hrastinski & Keller, 2007). It may be the case, of course, that ICT and digital technologies do have an impact on learning, but that this is not apparent when looking at attainment (as measured by performance tests), or that it is particularly beneficial for certain groups or learners. It is therefore important to identify more precisely and articulate more clearly where and the use of digital technologies is beneficial (Schacter & Fagano, 1999). As the OECD study concludes:

> "More micro-studies are needed within countries to explore the extent to which for individual pupils, certain kinds of computer usage raise performance, and which kinds are most effective. At the same time, in countries where basic computer access is approaching universal, policy needs to turn its attention from providing the technology to ensuring that its usage is effective."
>
> (OECD, 2006, p 69)

The proliferation of technologies also makes this question hard to answer at a general level. One of the criticisms of the meta-analytic studies listed in Appendix 4, is that they tend to put all of the different kinds of technologies into a single category of 'technology' or 'ICT' begging the question of what the range of impact is, and whether some technologies or some educational approaches using technology are more effective than others. Similarly with correlational studies, it may be that some schools are using (some) technologies to beneficial effect, but that when the data is aggregated, this is impossible to identify.

A further, more speculative point relates to the phases of implementation or adoption of digital technologies. The evidence for this is more tentative and is based on a personal interpretation of trends over time. There appears to be a pattern of impact of ICT or digital technologies where in the early stages there is a high level of enthusiasm, supported by either anecdotal or qualitative accounts of the benefits of the introduction of a new or emerging technology in an educational setting, such as with integrated learning systems or interactive whiteboards. At the next stage, as the technology and teaching approaches develop and evolve, these effects are investigated more rigorously. At this stage a more mixed message tends to appear with different studies finding different effects or levels of effect (see for example, Parr and Fung's (2000) retrospective analysis of Integrated Learning Systems or Higgins, Beauchamp and Miller's (2007) review of interactive whiteboards). It is rare for further studies to be conducted once a technology has become fully embedded in educational settings as interest tends to focus on the new and emerging, so the question of overall impact remains elusive.

If this is the situation, there may, of course, be different explanations. We know, for example, that it is difficult to scale-up innovation without a dilution of effect with expansion (Cronbach *et al.* 1980; Raudenbush, 2003; 2008). It may also be that early adopters (Rogers, 2003; Chan *et al.* 2006) tend to be tackling particular pedagogical issues in the early stages, but for later adopters (Rogers's 'early' and 'late majority') then the focus may shift to the adoption of the particular technology itself, without it being chosen as a solution to a specific teaching and learning issue. At this point the technology may be the same, but the pedagogical aims and intentions are different, and this may explain a reduction in efficacy.

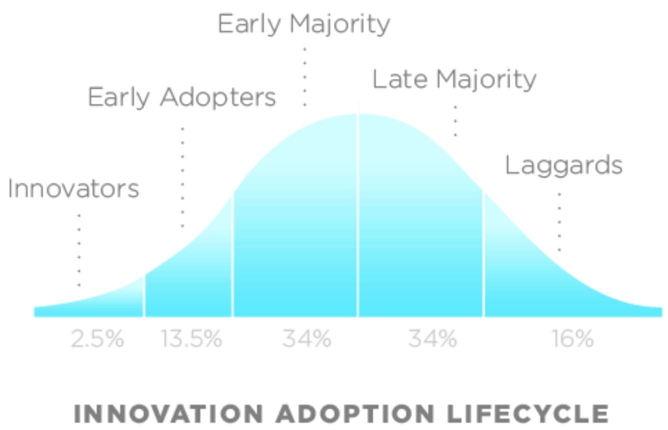

Figure 1: Rogers's adoption of innovation lifecycle[1]

Where this makes a further difference may also be in what the technology *replaces*. Technology is not introduced into a vacuum. As schools and teachers introduce technology they stop doing something else. When teachers choose to adopt technology themselves they often do it as part of a process of inquiry (Somekh, 2007) and it replaces or displaces some problematic practice; when it is adopted for its own sake, its displaces or replaces other teaching and learning activities which may have been as (or more) effective. Hence an ecological view of adoption is needed, where the justification of technology adoption is a relative one (Zhao & Frank, 2003). It should replace less effective practices, and be effectively integrated into the resources available to a learner to support their learning (Luckin, 2008), as part of a more effective or more efficient learning context. As yet we do not have the tools to enable us to support these decisions (Underwood and Dillon, 2004).

Overall, the challenge of assessing the impact is more acute than ever. The rise in technologies and the range of ways that they can be used in diverse educational settings across the spectrum of learners, coupled with the pace of change of technology make the task ever more demanding. The focus must shift from the technologies to the pedagogies of use, and the analysis of general impact to the specific differences that digital technologies make to teaching and learning contexts and interactions with regard to different learners. The quantity of technology use is not the key factor to student learning. "How much" matters only when "what and how" are identified (Lei & Zhao, 2007).

Global trends: a move towards increasing scepticism?

The UK is pioneering in terms of the use of ICT and digital technologies in many areas of education, and in the schools sector in particular. Important contributions to the literature include reviews on: effective pedagogy in primary schools (Moseley *et al.* 1999), evidence about the impact of Integrated Learning Systems (see Parr & Fung, 2000), the effects of interactive whiteboards, (e.g. Higgins, Beauchamp & Miller, 2007), the use of mobile and handheld technologies (Cheung & Hew, 2006) and virtual learning environments (Passey & Higgins, 2011). It is therefore not surprising that current international research reiterates the broad messages outlined above, such as about the small overall association between technology and attainment (Wainer *et al*. 2008) and positive findings for smaller and more intensive interventions (Liao & Hao, 2008).

[1] Image from http://en.wikipedia.org/wiki/File:DiffusionOfInnovation.png

One feature of the international research which is not reflected in the studies discussed above is the role of ICT and digital technologies in assessment. A considerable proportion of the published research in the field looks at computer-based testing (including the assessment of higher order thinking and assessment of extended writing) and computer-adaptive testing. Pedagogy, curriculum and assessment are inextricably linked (Mabry & Snow, 2006). The current situation in the UK perhaps indicates that this is an area for further research and development. The challenge will be to link work on pupils' involvement in formative assessment, with effective diagnostic feedback for teachers, as well as the summative purposes and accountability issues (Harlen, 2007) involved in schools.

There are some global trends identifiable which reflect enthusiasm for new and emerging technologies accompanied by more varied evidence as these technologies are adopted more widely (for an overview of evidence relating to schools see Voogt & Knezek, 2008):

- Continuing enthusiasm for new and emerging technologies is unlikely to diminish as innovative technologies offer new teaching and learning opportunities (Web 2.0, mobile and ubiquitous technologies, multi-touch surfaces, learning analytics, cloud computing: e.g. Chan *et al.* 2006)
- Identifying the impact of one-to-one provision of technology is challenging. This is both for laptops (Dunleavy *et al.* 2007; Silvernail & Gritter, 2007) and mobile technologies (Naismith *et al.* 2004). Similarly, there is a challenge for one-to-one provision in terms of pedagogy, such as developing effective interaction and collaboration (Liu & Kao, 2007) or in addressing teachers' concerns effectively (Donovan *et al.* 2007): for a review see Penuel (2006). This may be particularly pertinent to the current enthusiastic introduction of tablet computers and iPads.
- The internet has had a relatively disappointing impact as an educational resource (e.g. Cole & Hilliard, 2006), especially considering concerns about its use (e.g. Richards *et al.* 2008). The 'world-wide web' is an amazing resource which has developed in the space of just over twenty years. The facility to search and find information in different forms about almost any subject matter you can think of is a fantastic educational resource, which would have been literally incredible 30 years ago. However letting learners loose on the internet is a little like sending teenagers into the British Library and expecting them to make successful forays to support their learning.
- There is a lack of evidence of the beneficial impact of e-learning on pupils' achievement. Much of the research published relates particularly to the Higher Education sector (e.g. Davis & Graf, 2005; Kanuka & Keland, 2008; Passey and Higgins, 2011), with very little evidence of impact on students' learning. It is certainly the case that well motivated and experienced learners can learn very effectively through e-learning. It is also clear, however, that without such motivation, skills and experience e-learning may well not be so successful.
- Enthusiasm for gaming and games-based approaches may be misplaced, as there is a lack of evidence of impact in terms of attainment (Vogel et al. 2006). Children and young people are often highly motivated by computer games and simulations. The challenge is to ensure that the learning can be applied outside of the game environment.
- There are some concerns about the detrimental impact on health and well-being of sustained used of computer technology, particularly for younger learners (e.g. Straker *et al.* 2005). These concerns relate to physical issues (such as posture and eyesight); health concerns (such as physical fitness and obesity) and social issues (social isolation or addiction). We can't "uninvent" new technologies, but we can think about using them in ways which promote physical and mental well-being.
- There is an increasing acknowledgement of the tension between technological and pedagogical change (e.g. Steffens, 2008), and the influence of other aspects of the educational system (such as assessment in particular, e.g. Mabry & Snow, 2006). The pace of technological change in society has been very rapid over the last 50 years or so, and appears to show no sign of slowing down. Aspects of schooling, such as teaching and learning, the curriculum and, perhaps most importantly, assessment and accountability have changed rather more slowly. The curriculum and

its assessment in turn shape the way technology is (and can be) used in schools, arguably limiting the potential of new and emerging technologies for learning.

One interpretation of the trends in the wider literature is a recognition of the seriousness of the challenge from enthusiasts (e.g. Underwood, 2004) to a growing critical voice from the skeptics (e.g. Oppenheimer, 2003; Wainer *et al.* 2008; Slay, 2008) with an increased interest in the cost-effectiveness or value for money of technology in education (e.g. Margolisa *et al.* 2007) and the issue of sustainability (Mee, 2007), which can only be exacerbated in times of economic difficulty. This is a battle new and emerging technologies are likely to find hard to win, as early iterations of technologies tend to be more expensive than mass-produced models. If our speculation is correct that innovators and early adopters tend to get the best from such technologies, this sharpens the challenge. The majority who jump on the bandwagon of the technology (and get it cheaper), don't necessarily know what to do with the equipment it to get the best from it educationally. If Rogers' (2003) theory is correct, effect will diminish over time as the 'late majority' may also be more reluctant converts. On the other hand, it is impossible to imagine that digital technologies will not be used in educational settings as they are now so embedded in wider society. At this point the question of cost-effectiveness and relative benefit becomes increasingly urgent. Will schools be able to sustain the investment in interactive whiteboards, one-to-one provision of laptops, PDAs or iPads or the next generation of multi-touch desks *and* sustain the legacy equipment they already have? Do we have sufficient evidence to argue which older technologies should be retained and which might be replaced with more effective or more efficient approaches for teaching and learning with newer technologies? These challenges frame the context in which we currently find ourselves.

Why meta-analysis?

This review intentionally summarises the evidence contained in meta-analyses and other quantitative syntheses of research to identify patterns of impact in the accumulating research about the effects of technology on learning so as to draw possible implications for the future. Meta-analysis also allows an estimate to be made of the extent of the possible impact of technology on learning in terms of the effect sizes calculated. This helps to put the impact of technology in perspective, both in terms of its relative benefit, but also to identify how much more effective teaching and learning might be when supported with digital technologies. A systematic search of education databases and journals revealed 48 studies which synthesised primary research studies of the impact of technology on the attainment of school age learners (5-18 year olds). Whilst we accept this presents only a partial and retrospective view of such impact, we suggest it is the only review approach to allow a systematic comparison of a large number of studies together with an estimate of the extent of the effects on learning.

Meta-analysis is a method of combining the findings of similar studies to provide an overall quantitative synthesis or 'pooled estimate of effect'. The results of separate interventions using technology can be combined so as to identify clearer conclusions about which interventions are effective and which factors are associated with more effective approaches. The advantages of meta-analysis over other approaches to reviewing are that it combines or 'pools' estimates from a range of studies and can therefore aggregate results to identify patterns or trends in findings over time.

It can also show whether the findings from similar studies vary more that would be predicted from their samples so that the causes of this variation can be investigated ("moderator analysis"). This is particularly valuable as the results from a range of smaller studies can be combined to provide answers to questions without relying on the statistical significance of each of the individual studies as this relates closely to sample size. Many small studies with moderate or low effects may not reach statistical significance and if you review the field by simply counting how may were statistically significant, you may be misled into thinking that the evidence is less conclusive than if you combine these studies into one study or meta-analysis. The statistical techniques to undertake meta-analysis form a set of transparent and replicable rules which are open to scrutiny.

Another key advantage of meta-analysis is that it helps to deal with the quantity of information in research which can overwhelm other approaches. This is particularly important when trying to draw relative inferences across different areas of education research. The number of studies available to review in any area of technology and education is extensive, so techniques to aggregate and build up knowledge to propose further research and test theories and ideas are invaluable.

We have identified that 45 meta-analyses of the effects of technology on learning in schools have been published between 1990 and 2012 (see Appendix 2 and Appendix 3). The most recent of these, 30 published since 1999 are summarised in Table 1 below[2]. We separated 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. Meta-analysis is a retrospective approach, and the earliest meta-analyses in the 1980s reviewed the computer technology used in education from the 1960s to the 1980s. The kinds of technology and software have changed beyond recognition, though some of the approaches (such as ‘drill and practice’) are still recognisable. Overall it is questionable what can be inferred about digital technology use for current practice from the earliest experiments. One noticeable finding is that the typical overall effect size in the general analyses of the impact of technology on learning is that it is between 0.3 and 0.4, just slightly below the overall average for researched interventions in education (Sipe & Curlette, 1997; Hattie, 2008). However the range of effects is also very wide (-0.03 to +1.05) suggesting that it is essential that the differences between technologies and how they are used should be taken into account. Interestingly, there is no real change in this difference over time, suggesting that when technology is used to improve current practice, similar gains are achieved.

Meta-analysis also lets us identify patterns in these findings to investigate whether larger effects are found with some kinds of technology, different approaches to using technology or their impact on different learners and in different contexts, rather than just identifying whether technology has a positive effect on average (Tamim et al., 2011). Looking for patterns or themes in this way may help identify where the use of new and emerging technologies are likely to be beneficial in the future. It may help us identify ‘best bets’ for learning (Higgins, Koktsaki & Coe, 2012).

[2] Summary tables of meta-analyses published between 2000 and 2012 and between 1990 and 1999 can also be found in the appendices.

Table 1: Summary of meta-analyses published between 2000 and 2012

Focus	Reference	Overall ES	Impact on	Notes
General	Camnalbur & Erdogan, 2010	1.05	Academic success	In Turkey
General	Christmann & Badgett, 2003	0.34	Academic outcomes	Elementary students
General	Liao, 2005	0.55	Student achievement	In Taiwan
General	Tamim, 2009	0.35	Student achievement/ performance	Second order meta-analysis (same data as Tamim et al. 2011)
General	Sandy-Hanson, 2006	0.24	School achievement	Kindergarten to Grade 12
General	Waxman et al., 2002	0.39	Cognitive outcomes	
General	Waxman et al., 2003	0.44	Cognitive outcomes	Update/extension of Waxman et al. 2002
Mathematics	Cheung & Slavin, 2011	0.15	On mathematics	Kindergarten to Grade 12
Mathematics	Li & Ma, 2010	0.71	On mathematics	School students' mathematics learning
Mathematics	Seo & Bryant, 2009	NSPE[3] 0.33 (median)	Mathematics performance	Students with learning disabilities
Mathematics	Tokpah, 2008	0.38	On mathematics	Computer Algebra Systems
Maths and Science	Kulik, 2003	0.38 (median) 0.59 (median) 0.32 (median) 0.01 (median)	ILS on maths Computer tutorials in science Simulations in science Live 'labs'	Instructional Technology in Elementary and Secondary Schools
Science	Bayraktar, 2001	0.27	Science achievement	
Science	LeJeune, 2002	0.34 0.38 0.19	Lower order outcomes Higher order outcomes Retention follow up test	Simulated experiments in science education
Science	Onuoha, 2007	0.26	Science academic achievements	Computer-Based Laboratory on College And Pre-College Science
Literacy	Blok et al., 2002	0.25	Reading skills and/or	Beginning reading

[3] No single pooled effect

			comprehension	
Literacy	Goldberg et al., 2003	0.50 0.41	Writing quantity Writing quality	Computers on student writing
Literacy	Graham & Perrin, 2007	0.55	Writing quality	Word processing on writing
Literacy	Kulik, 2003	0.30 0.43 0.06	Writing quality Accelerated Reader Reading/ILS	Elementary and secondary Schools
Literacy	Moran et al., 2008	0.49	Reading	Middle school grades
Literacy	Morphy & Graham, 2012	NSPE 0.52 0.48	 Writing quality Writing length	Word-processing programs and weaker writers/ readers
Literacy	Pearson et al.	0.49	Reading	Middle school grades: same study as Moran et al., 2008
Literacy	Sisson, 2008	0.35 (mean) 0.22 (mean)	Academic performance Standardised reading tests	Fast ForWord
Literacy	Soe et al., 2000	0.26	Reading achievement	
Literacy	Strong et al., 2011	NSPE 0.08 -0.03	 Vs untreated controls Vs treated controls	Fast ForWord
Literacy	Torgerson & Elbourne, 2002	0.37	Spelling	
Literacy	Torgerson & Zhu, 2003	NSPE 0.89 0.20 0.28	 Word processing on writing ICT on spelling Computer texts on reading	ICT on literacy learning in English, 5-16
Other focus	Cassil, 2005	0.43	Academic achievement	Mobile and hand held technologies
Other focus	Lou et al., 2001	0.16	Individual achievement	Small group vs individual learning with tech
Other focus	Means et al., 2009	0.24	Learning outcomes	Online learning 7 studies looked at K–12 students ES 0.16
Other focus	Rosen & Salomon, 2007	0.11 0.46	Mathematics achievement Constructivist vs traditional	Constructivist Technology-Intensive Learning Environments
Other focus	Sitzman et al. 2006	0.15		Web-based instruction
Other focus	Vogel et al., 2006	0.07	Cognitive gains	Games and simulations

Identifying themes in the findings from meta-analysis

A number of areas can be identified in the meta-analyses which have been systematically explored through moderator analysis. In some cases, the evidence is inconsistent or inconclusive so these themes should be considered as indicative and worthy of further research or exploration in schools. Frustratingly, it is not possible to identify if particular kinds of technologies or certain kinds of application (such as tutorial, practice software, use as a tool: Liao, 1992; Khalili & Shashaani 1994; Fletcher-Flinn & Gravatt 1995) are more effective. This variation suggests that *how* (or how *well*) technology is used is the important consideration rather than the choice of a particular technology or a particular approach.

Collaborative use of technology (in pairs or small groups) is usually more effective than individual use. This can be identified in separate meta-analyses (e.g. Liao, 2005) where it has been identified as a cause of variation, and as a general trend in technology studies (Lou et al. 2001). However some pupils, especially younger children, may need support in collaborating effectively.

Technology can be used very effectively as a short but focused intervention to improve learning (Bayraktar 2001; Moran et al. 2008), particularly when there is regular and frequent use (about three times a week: Bangert-Drowns, 1993; Cheung & Slavin; 2011) over the course of about a term (5 -10 weeks: LeJeune, 2002; Sandy-Hanson, 2006). Sustained use over a much longer period is usually less effective at improving attainment (e.g. Liao 1992; Sandy-Hanson, 2006). However the inconsistency in the evidence about duration and intensity of use makes it difficult to draw firm conclusions.

Remedial and tutorial use of technology can be particularly effective for lower attaining pupils (Lou et al. 2001), or those with special educational needs (Li & Ma, 2010; Sandy-Hanson 2006; Sisson, 2008) or those from disadvantaged backgrounds (Kuchler, 1998, but see also Cheung & Slavin, 2011) in providing intensive support to enable them to catch up with their peers.

In researched interventions, technology is best used as a supplement to normal teaching rather than as a replacement for it (Liao, 1998; Khalili & Shashaani, 1994; Bayraktar, 2001 Cheung & Slavin; 2011) Kulik, 2003; Sisson, 2008). This suggests some caution is the way in which technology is adopted or embedded in schools.

Tested gains in attainment tend to be found across the curriculum with comparatively greater effects in mathematics and science (Khalili & Shashaani 1994; Fletcher-Flinn & Gravatt 1995 Li & Ma, 2010; Seo & Bryant, 2009; Tokpah, 2008; Kulik, 2003; Bayraktar, 2001; LeJeune, 2002; Onuoha, 2007). However, this is also a more general finding in meta-analysis (Hattie, 2008) and may be at least partly a measurement artefact. In literacy, the impact tends to be greater in writing interventions (Goldberg et al., 2003; Kulik, 2003; Morphy & Graham, 2012) compared with reading (Blok et al., 2002; Soe et al., 2000) or spelling (Torgerson & Zhu, 2003).

Training and professional development for teachers is an important component of successful approaches. At least a full day's support (Ryan, 1991) or on-going professional inquiry-based approaches appear the most successful (Conlon, 2004). The implication is that such support should go beyond teaching skills in technology use and focus on the effective pedagogical use of the technology to support teaching and learning aims (Cheung & Slavin, 2011).

There is not a consistent picture about age with some meta-analyses finding inconsistent variation associated with age or school type (Liao, 1998; Roblyer, 1989; Goldberg et al. 2003; Li & Ma, 2010), and others not (Bayraktar 2001; Fletcher-Flinn & Gravatt 1995; Blok et al. 2002: Cheung & Slavin; 2011).

Of course, this is evidence about what has happened in the past, with older technologies and across a wide range of diverse settings and contexts. It is a record of what *has worked*, and is not a prediction of what the impact of new and emerging technologies will be.

Conclusions and recommendations

Overall, the research evidence over the last 40 years about the impact of computer and digital technologies on learning consistently identifies positive benefits. The increasing variety of digital technologies and the diversity of contexts and settings in which the research has been conducted, combined with the challenges in synthesising evidence from different methodologies make it difficult to identify clear and specific implications for educational practice in schools.

Studies linking provision and use of technology with attainment tend to find consistent but small positive associations with educational outcomes. However, a causal link cannot be inferred from this kind of research. It seems probable that more effective schools and teachers are more likely to use ICT and digital technologies more effectively than other schools. We need to know more about where and how it is used to greatest effect, then investigate if this information can be used help to improve learning in other contexts.

Research findings from experimental and quasi-experimental designs which have been combined in meta-analyses indicate that overall technology-based interventions tend to produce just slightly lower levels of improvement when compared with other researched interventions. The range of impact identified in these studies suggests that it is not whether technology is used (or not) which makes the difference, but how well the technology is used to support teaching and learning. This alignment of technology and learning is important. There is no doubt that technology engages and motivates young people. However this benefit is only an advantage for learning if the activity is effectively aligned with what is to be learned. It is therefore the pedagogy of use of technology which is important: the *how* rather than the *what*.

With computer and digital technologies there is a recurrent and specific challenge in understanding and applying the research evidence as it takes time for robust evidence to emerge in education and the rapid pace of change of technology makes this difficult to achieve. With this in mind the findings from the synthesis of the 45 meta-analyses published since 1990 indicates the following overall trends:

- Collaborative use of technology (in pairs or small groups) is usually more effective than individual use, though some pupils, especially younger children, may need support in collaborating effectively.

- Technology can be used very effectively as a short but focused intervention to improve learning, particularly when there is regular and frequent use (about three times a week) over the course of about a term (5 -10 weeks). Sustained use over a longer period is usually less effective at improving attainment.

- Remedial and tutorial use of technology can be particularly effective for lower attaining pupils or those with special educational needs or those from disadvantaged backgrounds in providing intensive support to enable them to catch up with their peers.

- In researched interventions, technology is best used as a supplement to normal teaching rather than as a replacement for it. This suggests some caution in the way in which technology is adopted or embedded in schools.

- Tested gains in attainment tend to be greater in mathematics and science (compared with literacy for example) though this is also a more general finding in meta-analysis and may be at least partly a measurement artefact. In literacy, the impact tends to be greater in writing interventions compared with reading or spelling.

- Training and professional development for teachers is an important component of successful approaches. At least a full day's support or on-going professional inquiry-based approaches appear the most successful. The implication is that such support should go beyond teaching skills in technology use and focus on the effective pedagogical use of the technology to support teaching and learning aims.

Overall the key implication is that the technology is solely a *catalyst* for change. What is it that teachers or learners actually do which brings about any improvement in learning? Focusing on the change (and the process of change) in terms of learning is essential in supporting effective use.

Recommendations

1. The rationale for the impact of digital technologies on teaching and learning needs to be clear:
    - Will learners work more efficiently, more effectively, more intensively? Will the technology help them to learn for longer, more deeply, more productively? Or will the teacher be able to support learners more efficiently or more effectively?

2. The role of technology in learning should be identified:
    - Will it help learners gain access to learning content, to teachers or to peers? Will the technology itself provide feedback or will it support more effective feedback from others?

3. Technology should support collaboration and effective interaction for learning:
    - The use of computer and digital technologies is usually more productive when it supports collaboration and interaction, particularly collaborative use by learners or when teachers use it to support discussion, interaction and feedback.

4. Teachers and/or learners should be supported in developing their use of digital and computer technologies to ensure it improves learning.
    - Skills training is not usually sufficient to support teachers and pupils in getting the best from technology. On-going professional development and support to evaluate the impact on learning is likely to be required.

5. Identify what learners and teachers will *stop* doing:
    - The use of computer and digital technologies is usually more successful as a supplement rather than as a replacement for usual teaching. It is therefore important to identify carefully what it will replace or how the technology activities will be additional to what learners would normally experience.

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Appendix 1: Some contemporary myths and fallacies about digital technology use in education

These personal reflections arose from discussions with the EEF team and are an attempt to communicate the complexity of the evidence about digital technologies and learning. They are included here to summarise in a less formal way what I see as the key messages in this field.

Steve Higgins

Myth 1: New technologies are being developed all the time, the past history of the impact of technology is irrelevant to what we have now or will be available tomorrow.
After more than fifty years of digital technology use in education this argument is now wearing a bit thin. We need a clear rationale for why we think the introduction of (yet another) new technology will be more effective than the last one. The introduction of technology has consistently been shown to improve learning, the trouble is most things improve learning in schools when they are introduced, and technology is consistently just a little bit less effective than the average intervention.

Myth 2: Today's children are digital natives and the 'net' generation – they learn differently from older people.
There are two issues with this myth. First, there is no evidence the human brain has evolved in the last 50 years, so our learning capacity remains as it was before digital technologies became so prevalent. It may be that young people have learned to focus their attention differently, but their cognitive capabilities are fundamentally the same as 30 years ago. Second, just because young people have grown up with technology it does not mean they are experts in its use for their own learning. Being an expert at playing Halo 5 requires different skills and knowledge from having an active Facebook account. Most young people are fluent in their use of some technologies, but none are expert at all of them.

Myth 3: Learning has changed now we have access to knowledge through the internet, today's children don't need to know stuff, they just need to know where to find it.
The web has certainly changed access to information, but it this only becomes knowledge when it is used for a purpose. When this requires understanding and judgement, information alone is insufficient. Googling is great for answers to a pub quiz, but would you trust your doctor if she was only using Wikipedia? To be an expert in a field you also need experience of using the information and knowledge, so that you understand where to focus your attention and where new information will help you in making decisions and judgements. It is important to recognise the relevance or importance of different pieces of information. Easy access to information can help, but it is no substitute for experience, understanding and expertise.

Myth 4: Students are motivated by technology so they must learn better when they use it.
It is certainly true that *most* young people do enjoy using technology in schools to support their learning. However, the assumption that any increased motivation and engagement will automatically lead to better learning is false. It is possible that increased engagement or motivation may help increase the time learners spend on learning activities, or the intensity with which they concentrate or their commitment and determination to complete a task. However, it is only when this engagement can be harnessed for learning that there will be any academic benefit. There is another caveat here as the motivation in school may be partly because using technology is either novel in school, or simply a change from what they usually experience. It may not be the case that this motivation will be sustained over time.

Myth 5: The Everest Fallacy: we must use technology because it is there!
We should use some of the wide range of digital technologies that are available to us to support learning and teaching in schools, but this should be where they improve aspects of teaching and learning and help to prepare children and young people for their lives after school. The curriculum and the way in which pupils work and are assessed should reflect the society and culture they are preparing pupils to be a part of when they leave formal

education. However the challenge is knowing *which* technology is the best to choose for use in schools and for *what* purposes and learning outcomes they should be employed.

Myth 6: The "More is Better" Fallacy
Enthusiasts assume that if a little technology is a good thing then a lot will be much better. The evidence does not support this assumption, for two reasons. First, large-scale international studies of very high use of technology – e.g. pupils using the internet more than four hours per day – do not show with better learning. Second, the effect of technology and length of interventions where more is clearly not always better! This suggests that there is an optimum level of technology which can support learning, too little and you don't see the benefit, too much and the gains decline. A better notion might be the Goldilocks effect: it is about getting the amount of technology, and learners' access to it "just right"!

Appendix 2: Summary table of Meta-analyses of the Impact of Computer and Digital Technologies on Attainment Published between 2000 and 2012

Table 1: Meta-analyses of the Impact of Computer and Digital Technologies on Attainment published between 2000 and 2012			
Title	**Overall ES**	**Abstract**	**Moderator variables**
Bayraktar 2001 A Meta-analysis of the Effectiveness of Computer-Assisted Instruction in Science Education	0.273	This meta-analysis investigated how effective computer-assisted instruction (CAI) is on student achievement in secondary and college science education when compared to traditional instruction. An overall effect size of 0.273 was calculated from 42 studies yielding 108 effect sizes, suggesting that a typical student moved from the 50th percentile to the 62nd percentile in science when CAI was used. The results of the study also indicated that some study characteristics such as student-to-computer ratio, CAI mode, and duration of treatment were significantly related to the effectiveness of CAI.	The results of this analysis also indicated that all variables except educational level were related to effect size. The **strongest relationships were found for the following variables: length of treatment, student-to-computer ratio, and publication year**. Effect sizes did not vary by publication status and educational level. This study detected a significant relationship between CAI effectiveness and instructional role of computers. Effect sizes were **higher (ES = 0.288) when computers were used as a supplement** to the regular instruction and lower when the computer entirely replaced the regular instruction, {ES = 0.178). This finding was consistent with the previous meta-analyses (Kulik et al., 1983; Liao, 1998) suggesting that using the computer as a supplement to regular instruction should be the preferred choice instead of using it as a replacement. This meta-analysis indicated that there were **no significant effect size differences in different school levels**. This result supports the meta-analysis conducted by Flinn & Gravat (1995) reporting an effect size of 0.26 standard deviations for elementary grades, an effect size of 0.20 standard deviations for secondary grades, and an effect size of 0.20 standard deviations for college. However, this finding is not consistent with the majority of meta-analyses (Bangert-Drowns, 1985; Burns &: Bozeman, 1981; Liao, 1998; Roblyer, 1989) that report significant effect size differences for different school levels. The results of this study indicated that the length of the treatment was strongly related to the effectiveness of CAI for teaching science. CAI was especially **effective when the duration of treatment was limited to four weeks or less**. The average effect of CAI in such studies was 0.404 standard deviations. In studies where treatment continued longer than four weeks, the effects were less clear (ES =

			0.218). A similar relationship between length of treatment and study outcome has been reported in previous meta-analyses. Kulik et al. (1983), for example, reported an effect size of 0.56 for 4 weeks or less, 0.30 for 5-8 weeks, and 0.20 for more than 8 weeks. This study concluded that the results found in ERIC documents were more positive (ES = 0.337) than results found in journal articles (ES = 0.293) and dissertations (ES = 0.229).
Blok et al. 2002 Computer-Assisted Instruction in Support of Beginning Reading Instruction: A Review	0.254 SE 0.056 SD 0.288	How effective are computer-assisted instruction (CAI) programs in supporting beginning readers? This article reviews 42 studies published from 1990 onward, comprising a total of 75 experimental comparisons. The corrected overall effect size estimate was d = 0.19 (± 0.06). Effect sizes were found to depend on two study characteristics: the effect size at the time of pre-testing and the language of instruction (English or other). These two variables accounted for 61 percent of the variability in effect sizes. Although an effect size of d = 0.2 shows little promise, caution is needed because of the poor quality of many studies.	We found two study characteristics to be related to study outcomes. Effect sizes were higher when (a) the experimental group displayed an advantage at the pretest, and (b) the language of instruction was English. The effects of these two predictors reduced the variability of the study outcomes by a sizable 61 percent. Several other study characteristics appeared not to be related to study outcomes. Among these were design characteristics (subject assignment, size of experimental group, type of post-test score), population characteristics (regular or dyslexic readers, mean age of students), and treatment characteristics (type of experimental program, program length, program duration).
Camnalbur & Erdogan 2008 A Meta Analysis on the Effectiveness of Computer-Assisted Instruction: Turkey Sample	1.05 (d) CI 0.91 to 1.19 Random effects	Studies focusing on the effectiveness of computer-assisted instruction have been growing recently in Turkey. In this research, quantitative studies comparing the effectiveness of computer- assisted instruction to traditional teaching method and conducted between 1998 and 2007 are studied by meta analysis. Seventy eight studies that have eligible data were combined with meta analytical methods by coding protocol from the 422 master’s and doctoral degree and 124 articles. As a result for the study, the effect size of computer-assisted instruction method for academic achievement calculated 1.048. This is large scale according to Thalheimer and Cook, large and Cohen, Welkowitz and Ewen (2000). Recommendations were made based on the	78 studies

		results of the study.	
Cassil 2005 A Meta Analysis: The Effectiveness Of The Use Of Mobile Computers On The Attitude And Academic Outcomes Of K–12 Students	0.43 (unweighted mean)	Statistical meta analyses performed for this study included 32 primary studies conducted between 1993–2005. Two independent meta analyses were conducted regarding student attitudes and academic outcomes. The overall meta analysis mean by author was .23, indicating that student use of mobile computers had a small and positive effect on student attitudes and academic outcomes. The consistent pattern of positive effect size results indicated that student use of mobile computers was effective in improving student attitudes and academic outcomes. The small number of samples in the independent meta analyses suggests a need for further research regarding mobile computers.	21 studies with data on academic outcomes The highest effect size for knowledge of computers and the Internet (.58) is moderate and positive. Academic tests and subject areas (.44) and Higher Order Thinking Skills (.26). The average academic outcome effect size mean (.43) is small and positive. The negative correlation (-.56) suggests that pre-experimental designs are more likely to obtain higher effect sizes than quasi-experimental designs. Duration of Study: Less than a year .39; More than a year but less than two years .22; More than two years .15
Cheung & Slavin 2011 The Effectiveness of Educational Technology Applications for Enhancing Mathematics Achievement in K-12 Classrooms: A Meta-Analysis	0.15 Random effects	No abstract provided A total of 75 qualifying studies were included in our final analysis with a total sample size of 56,886 K-12 students: 45 elementary studies (N=31,555) and 30 secondary studies (N=25,331). The overall weighted effect size is +0.15. Types of intervention. With regards to intervention types, the studies were divided into three major categories: Computer-Managed Learning (CML) (N=7), Comprehensive Models (N=8), and Supplemental CAI Technology (N=37). Over 70% of all studies fell into the supplemental program category, which consists of individualized computer-assisted instruction (CAI). These supplemental CAI programs, such as Jostens, PLATO, Larson Pre-Algebra, and SRA Drill and Practice, provide additional instruction at students' assessed levels of need to supplement traditional classroom instruction. Computer-managed learning systems included only Accelerated Math, which uses computers to assess students' mathematics levels, assign	A marginally significant between-group effect (QB =5.58, df=2, p<0.06) was found, indicating some variation among the three programs. The **37 supplemental technology programs produced the largest effect size**, +0.18, and the seven computer-managed learning programs and the eight comprehensive models produced similar small effect sizes of +0.08 and +0.06, respectively. The effect sizes for low, medium, and high intensity were +0.03, +0.20, and +0.13, respectively. In general, **programs that were used more than 30 minutes a week had a bigger effect than those that were used less than 30 minutes a week**. The average effect size of studies with a **high level of implementation (ES=+0.26) was significantly greater** than those of low and medium levels of implementation (ES=+0.12). The effect sizes for low and high SES were +0.12 and +0.23, respectively. The difference between elementary studies (ES=+0.17) and secondary studies (ES=+0.13) was not statistically different. No publication bias was found. No trend toward more positive results in recent years. The

		mathematics materials at appropriate levels, score tests on this material, and chart students' progress. One of the main functions of the computer in Accelerated Math is clerical (Niemiec et al., 1987). Comprehensive models, such as Cognitive Tutor and I Can Learn, use computer assisted instruction along with non-computer activities as the students' core approach to mathematics.	mean effect sizes for studies in the 80s, 90s, and after 2000 were +0.23, +0.15, and +0.12, respectively. The mean effect size for quasi-experimental studies was +0.19, twice the size of that for randomized studies (+0.10). The mean effect size for the 30 small studies (ES=+0.26) was about twice that of large studies (ES=+0.12, p<0.01). Large randomized studies had an effect size of +0.08, whereas small randomized studies had an effect size that was twice as large (ES=+0.17).
Christmann & Badgett 2003 A Meta-Analytic Comparison of the Effects of Computer-Assisted Instruction on Elementary Students' Academic Achievement	0.34 (unweighted mean)	This meta-analysis compared the academic achievement of elementary students who received either traditional instruction or traditional instruction supplemented with CAI. From the 68 effect sizes, an overall mean effect size of 0.342 was calculated, indicating that, on average, students receiving traditional instruction supplemented with CAI attained higher academic achievement than did 63.31% of those receiving only traditional instruction. However, a -0.463 correlation between effect size and years indicates that the effect of CAI on academic achievement has declined between the years 1969 and 1998.	39 studies "meta-analysis is a method of reexamining existing research; it is not a forecaster of prospective developments" p 100
Goldberg et al. 2003 The Effect of Computers on Student Writing:- A Meta-Analysis of Studies from 1992 to 2002	0.50 (quantity) 0.41 (quality) (Hedges' g)	Meta-analyses were performed including 26 studies conducted between 1992–2002 focused on the comparison between k–ı2 students writing with computers vs. paper-and-pencil. Significant mean effect sizes in favor of computers were found for quantity of writing (d=.50, n=14) and quality of writing (d=.41, n=15). Studies focused on revision behaviors between these two writing conditions (n=6) revealed mixed results. Other studies collected for the meta-analysis which did not meet the statistical criteria were also reviewed briefly. These articles (n=35) indicate that the writing process is more collaborative, iterative, and social in computer classrooms as compared with paper-and-pencil environments. For	As described above, regression analyses were performed to explore factors that may influence the effect of word processing on the **quantity** of student writing. These analyses indicated that student supports (i.e., keyboard training, technical assistance, teacher feedback, and peer editing) were not significant factors affecting the quantity of student writing. Similarly, student characteristics (i.e., keyboard experience prior to the study, student achievement level, school setting, and grade level) also were not significant factors affecting the quantity of student writing, although grade level did approach statistical significance. Finally, the study characteristics (i.e., publication type, presence of control group, pre-post design, length of study) were not related to the effect of word processing on the quantity of student writing. Recognizing that studies that lasted for less than six weeks

		educational leaders questioning whether computers should be used to help students develop writing skills, the results of the meta-analyses suggest that, on average, students who use computers when learning to write are not only more engaged and motivated in their writing, but they produce written work that is of greater length and higher quality.	may not provide enough time for the use of word processors to impact student writing, a separate set of regression analyses were performed for the sub-set of studies that lasted more than six weeks. For this sub-set of studies, a significant relationship between school level and effect size was found. **On average, effect sizes were larger for studies that focused on middle and high school students as compared to elementary students**. All other factors remained insignificant. This suggests that the relationship between school level and quality of writing occurred regardless of the length of study.
Graham & Perin 2007 A Meta-Analysis of Writing Instruction for Adolescent Students (see also Morphy and Graham, 2012)	0.56 (unweighted mean)	There is considerable concern that the majority of adolescents do not develop the competence in writing they need to be successful in school, the workplace, or their personal lives. A common explanation for why youngsters do not write well is that schools do not do a good job of teaching this complex skill. In an effort to identify effective instructional practices for teaching writing to adolescents, the authors conducted a meta-analysis of the writing intervention literature (Grades 4–12), focusing their efforts on experimental and quasi-experimental studies. They located 123 documents that yielded 154 effect sizes for quality of writing. The authors calculated an average weighted effect size (presented in parentheses) for the following 11 interventions: strategy instruction (0.82), summarization (0.82), peer assistance (0.75), setting product goals (0.70), word processing (0.55), sentence combining (0.50), inquiry (0.32), prewriting activities (0.32), process writing approach 0.32), study of models (0.25), grammar instruction (– 0.32).	The study focuses on general approaches to improve writing. 18 studies of word processing approaches has an ES of 0.56 (0.43 to 0.67) SD. No overall pooled effect for the meta-analysis. Effects of different approaches ranged from ranged from Strategy Instruction 1.03 and setting product goals (1.0) to Grammar approaches (-0.22).
Kulik 2003 Effects of Using Instructional Technology in	0.30 writing quality 0.84 WTR – in K 0.4 WTR – G1 0.25 WTR – G2+ 0.06 reading/ILS	This report reviews findings from controlled evaluations of technology applications in elementary and secondary schools published since 1990 located through computer searches of library databases… and summarises reviews	Reading 27 controlled evaluation studies on instructional technology and reading which focused on three major applications of technology to reading instruction: (a) integrated learning systems; (b) writing-based reading programs; and (c)

Elementary and Secondary Schools: What Controlled Evaluation Studies Say (a) Reading and writing	0.43 – AR 0.30 WP on writing quality	of studies published before 1990.	reading management programs. Integrated learning systems: Nine controlled studies conducted during the last decade suggest that ILSs have done little to improve teaching effectiveness of reading programs. In each study, reading scores of children learning with ILSs were as high as reading scores of those studying in traditional classrooms, but results for ILS instruction were significantly better in only three of the nine studies. **The median effect of ILS instruction in the nine studies was to raise students reading scores by 0.06 standard deviations, a trivial increment**. Writing-based reading programs: Writing to Read (WTR) is a program that attempts to teach young children to read by stimulating them to write. Twelve evaluation studies conducted during the past decade found that WTR effects were large in kindergartens (0.84), moderate in size in Grade 1 (0.4), and small in grades beyond Grade 1 (0.25). Reading management programs: **Reading management programs, such as Accelerated Reader (AR), help students make book selections and then test the students on their understanding of what they have read. Results of three controlled comparisons suggest that AR has an effect of 0.43 standard deviations.** Writing: 12 controlled studies of technology effects on student writing. The 12 studies fall into three categories: (a) word processing studies; (b) studies of computer writing prompts; and (c) studies of computer enrichment. Word processing: Four evaluation studies from the past decade also examined word processing effects on writing skills. In three out of the four studies, word processing produced significant positive effects on student writing skills. In the remaining study, however, writing with word processors had a significant negative effect on student writing skills. The median effect in the four studies was **to increase writing skill, as measured by ratings of quality of their compositions, by 0.30 standard deviations.** Computer writing prompts Prompting seems to be effective when students receive unsolicited writing prompts, but

			prompting seems to be ineffective when students must ask the computer for prompts. Clearly, more research is needed to confirm this conclusion. Computer enrichment: Five out of the six studies found that computer enrichment helped students to improve their writing skills. In the remaining study, computer enrichment had a small, statistically significant, negative effect on student writing. The median effect size of **computer enrichment programs in the six studies was an increase in writing scores of 0.34** standard deviations.
Kulik 2003 Effects of Using Instructional Technology in Elementary and Secondary Schools: What Controlled Evaluation Studies Say (a) Mathematics and Science	0.38* -ILS on maths 0.59* - Computer tutorials in science] 0.32* - Simulations in science] 0.01* - Live labs (*median ES)	This report reviews findings from controlled evaluations of technology applications in elementary and secondary schools published since 1990 located through computer searches of library databases… and summarises reviews of studies published before 1990.	Mathematics and Science Also reviewed in this report are 36 controlled studies of technology effects on mathematics and science learning. The 36 studies covered computer applications in four areas: (a) integrated learning systems in mathematics; (b) computer tutorials; (c) computer simulations; and (d) microcomputer-based laboratories. Integrated learning systems in mathematics. 16 controlled studies all positive on mathematics test scores; in nine the ILS effect was statistically significant and educationally meaningful. **The median ILS effect 0.38** SD. NB Lower effects when students do both reading and maths ILS. Computer tutorials. Six studies of **computer tutorials in the natural and social sciences**. In all but one of the six cases, the effect of computer tutoring was large enough to be considered both statistically significant and educationally meaningful. In the remaining study, the boost from computer tutoring was near zero. **Median case 0.59** SD. Computer simulations. Four of the six studies found positive effects on student learning, and two studies found negative effects. Median case 0.32 SD. Microcomputer-based laboratories (e.g. electronic sensors collecting data which is represented live). Seven of the eight studies found either small negative or small positive effects of MBL instruction on student learning. Median ES 0.01.
LeJeune 2002	0.34 Lower order outcomes	The purpose of this study was to synthesize the findings from existing research on the effects of	0.14 K-12 LOTS (0.49 College/Adult) 0.42 K-12 HOTS

A meta-analysis of outcomes from the use of computer-simulated experiments in science education	0.38 Higher order outcomes 0.19 retention follow up test	computer simulated experiments on students in science education. Results from 40 reports were integrated by the process of meta-analysis to examine the effect of computer-simulated experiments and interactive videodisc simulations on student achievement and attitudes. Findings indicated significant positive differences in both low-level and high-level achievement of students who use computer-simulated experiments and interactive videodisc simulations as compared to students who used more traditional learning activities. No significant differences in retention, student attitudes toward the subject, or toward the educational method were found. Based on the findings of this study, computer-simulated experiments and interactive videodisc simulations should be used to enhance students' learning in science, especially in cases where the use of traditional laboratory activities are expensive, dangerous, or impractical.	0.39 Physical Sciences LOTS 0.27 Biological Sciences LOTS 0.35 Physical Sciences HOTS 0.41 Biological Sciences HOTS 0.46 More than one week 0.33 Less than one week Lower ES for most recent studies
Li & Ma 2010 A Meta-Analysis of the Effects of Computer Technology on School Students' Mathematics Learning	0.71	This study examines the impact of computer technology (CT) on mathematics education in K-12 classrooms through a systematic review of existing literature. A meta-analysis of 85 independent effect sizes extracted from 46 primary studies involving a total of 36,793 learners indicated statistically significant positive effects of CT on mathematics achievement. In addition, several characteristics of primary studies were identified as having effects. For example, CT showed advantage in promoting mathematics achievement of elementary over secondary school students. As well, CT showed larger effects on the mathematics achievement of special need students than that of general education students, the positive effect of CT was greater when combined with a	Four characteristics of the studies remained statistically significant collectively. Two of them indicated large effects. With other statistically significant variables controlled, **special education status showed a magnitude of 1.02 SD** in favor of applying technology to special need students over general education students, and method of teaching showed a magnitude of **0.79 SD in favor of using technology in school settings where teachers practiced constructivist** approach to teaching over school settings where teachers practiced traditional approach to teaching. Meanwhile, two characteristics indicated moderate and small effects of technology on mathematics achievement. Year of publication showed a moderate magnitude of 0.32 SD in favor of publications before the turn of the century (before 1999) over publications after the turn of the century (after 1999), with other statistically significant variables controlled. Type (or level) of education showed **a small magnitude of 0.22 SD**

		constructivist approach to teaching than with a traditional approach to teaching, and studies that used non-standardized tests as measures of mathematics achievement reported larger effects of CT than studies that used standardized tests. The weighted least squares univariate and multiple regression analyses indicated that mathematics achievement could be accounted for by a few technology, implementation and learner characteristics in the studies.	**in favor of using technology at the elementary school level** over second school level, with other statistically significant variables controlled.
Liao 2005 Effects of computer-assisted instruction on students' achievement in Taiwan: A meta-analysis	0.55	A meta-analysis was performed to synthesize existing research comparing the effects of computer-assisted instruction (CAI) versus traditional instruction (TI) on students' achievement in Taiwan. 52 studies were located from our sources, and their quantitative data was transformed into effect size (ES). The overall grand mean of the study-weighted ES for all 52 studies was 0.55. The results suggest that CAI is more effective than TI in Taiwan. In addition, two of the seventeen variables selected for this study (i.e., statistical power, and comparison group) had a statistically significant impact on the mean ES. The results from this study suggest that the effects of CAI in instruction are positive over TI. The results also shed light on the debate of learning from media between Clark and Kozma.	Significantly higher effect sizes for underpowered studies (1.39 versus 0.48) and for no comparison group studies 1.30 (versus 0.43 with TI controls), but all pre-post controlled studies ES is 0.56. Other non sig, differences highest effect sizes for 4-18 hours of treatment (1.18). **Use as supplement to (0.54) higher than replacement for (0.53). Small (<5) group (0.96) higher than individual (0.56).** Subjects: maths (0.29), language (0.66), science (0.49) computer (0.76). Age Grades 1-6 0.41, 7-9 0.85, 10-12 0.23, College 0.82. Publication type: Journal article 0.45, dissertation/thesis 0.53, NSC project 0.67
Lou et al. 2001 Small Group and Individual Learning with Technology: A Meta-Analysis	0.16	This study quantitatively synthesized the empirical research on the effects of social context (i.e., small group versus individual learning) when students learn using computer technology. In total, 486 independent findings were extracted from 122 studies involving 11,317 learners. The results indicate that, on average, small group learning had significantly more positive effects than individual learning on student individual achievement (mean ES = +0.15), group task performance (mean ES =	The overall effect of social context on individual achievement was based on 178 independent effect sizes extracted from 100 studies. The mean weighted effect size (d+) was +0.16 (95% CI is +0.12 to +0.20; and QT = 341.95, df = 177, p < .05) before outlier procedures. Individual effect sizes ranged from -1.14 to +3.37, with 105 effect sizes above zero favoring learning in groups, 15 effect sizes equal to zero, and 58 effect sizes below zero favoring individual learning. Fifteen outliers with standardized residuals larger than ±2.00 were identified. After outlier procedures, the mean effect size was +0.15

		+0.31), and several process and affective outcomes. However, findings on both individual achievement and group task performance were significantly heterogeneous. Through weighted least squares univariate and multiple regression analyses, we found that variability in each of the two cognitive outcomes could be accounted for by a few technology, task, grouping, and learner characteristics in the studies. The results of Hierarchical Regression Model development indicate that the effects of small group learning with CT on individual achievement were significantly larger when: (a) students had group work experience or specific instruction for group work rather than when no such experience or instruction was reported; (b) cooperative group learning strategies were employed rather than general encouragement only or individual learning strategies were employed; (c) programs involved tutorials or practice or programming languages rather than exploratory environments or as tools for other tasks; (d) subjects involved social sciences or computer skills rather than mathematics, science, reading, and language arts; (e) students were relatively low in ability rather than medium or high in ability; and (f) studies were published in journals rather than not published. When all the positive conditions were present, students learning in small groups could achieve 0.66 standard deviation more than those learning individually. When none of the positive conditions were present, students learning individually could learn 0.20 standard deviation more than those learning in groups.	(95% confidence interval is +0.11 to +0.19). The results indicate that, on average, there was a small but significantly positive effect of small group learning on student achievement as measured by individually administered immediate or delayed post-tests. Effect sizes were **significantly larger when students were learning with tutor programs (d+ = +0.20) or programming languages (d+ = +0.22) than when using exploratory or tool programs (d+ = +0.04).** Effect sizes **greatest for low attaining learners (0.34) as compared with medium (0.09), high (0.24) or mixed(0.12).** The effects of social context on student individual achievement were larger when the subjects involved were computer skills (d+ = +0.24), social sciences and other (d+ = +0.20) than when the subjects were math/science/language arts (d+ = +0.11). The effect sizes were significantly positive for both heterogeneous ability groups (d+ = +0.21) and homogeneous ability groups (d+ = +0.22). Effect sizes were significantly more positive when **specific cooperative learning strategies were employed (d+ = +0.21)** than when students were generally encouraged to work together (d+ = -0.04) or when students in groups worked under individualistic goals or when no group learning strategy was described in the study (d+ = +0.08), with the latter two means not significantly different from zero. **Significantly more positive when students worked in pairs (d+ = +0.18)** than when they worked in three to five member groups (d+ = +0.08). Type of feedback, types of tasks, task familiarity, task difficulty, number of sessions, session duration, grade level, gender, computer experience, instructional control, and whether achievement outcomes measured were of higher-order skills or lower-order skills were not found to be significantly related to the variability in the effects of social context on student individual achievement. Individuals appear to benefit from computer-based feedback but groups do better without computer-based

			feedback when completing group tasks.
Means et al. 2009 Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies	0.24	A systematic search of the research literature from 1996 through July 2008 identified more than a thousand empirical studies of online learning. Analysts screened these studies to find those that (a) contrasted an online to a face-to-face condition, (b) measured student learning outcomes, (c) used a rigorous research design, and (d) provided adequate information to calculate an effect size. As a result of this screening, 51 independent effects were identified that could be subjected to meta-analysis. The meta-analysis found that, on average, students in online learning conditions performed better than those receiving face-to-face instruction. The difference between student outcomes for online and face-to-face classes—measured as the difference between treatment and control means, divided by the pooled standard deviation—was larger in those studies contrasting conditions that blended elements of online and face-to-face instruction with conditions taught entirely face-to-face. Analysts noted that these blended conditions often included additional learning time and instructional elements not received by students in control conditions. This finding suggests that the positive effects associated with blended learning should not be attributed to the media, per se. An unexpected finding was the small number of rigorous published studies contrasting online and face-to-face learning conditions for K–12 students. In light of this small corpus, caution is required in generalizing to the K–12 population because the results are derived for the most part from studies in other settings (e.g., medical training, higher education). Few rigorous research studies of the effectiveness of online learning for K–12	Students who took all or part of their class online performed better, on average, than those taking the same course through traditional face-to-face instruction. Learning outcomes for students **who engaged in online learning exceeded those of students receiving face-to-face instruction, with an average effect size of +0.24 favoring online conditions**. The mean difference between online and face-to-face conditions across the 51 contrasts is statistically significant at the $p < .01$ level. Interpretations of this result, however, should take into consideration the fact that online and face-to-face conditions generally differed on multiple dimensions, including the amount of time that learners spent on task. The advantages observed for online learning conditions therefore may be the product of aspects of those treatment conditions other than the instructional delivery medium per se. Instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction. **The mean effect size in studies comparing blended with face-to-face instruction was +0.35, $p < .001$.** This effect size is larger than that for studies comparing purely online and purely face-to-face conditions, which had an average effect size of +0.14, $p < .05$. An important issue to keep in mind in reviewing these findings is that many studies did not attempt to equate (a) all the curriculum materials, (b) aspects of pedagogy and (c) learning time in the treatment and control conditions. Indeed, some authors asserted that it would be impossible to have done so. Hence, the observed advantage for online learning in general, and blended learning conditions in particular, is **not necessarily rooted in the media used per se and may reflect differences in content, pedagogy and learning time.** Studies in which learners in the online condition spent more time on task (0.46) than students in the face-to-face condition found a greater benefit for online learning…compared with +0.19 for studies in which the

		students have been published. A systematic search of the research literature from 1994 through 2006 found no experimental or controlled quasi-experimental studies comparing the learning effects of online versus face-to-face instruction for K–12 students that provide sufficient data to compute an effect size. A subsequent search that expanded the time frame through July 2008 identified just five published studies meeting meta-analysis criteria.	learners in the face-to-face condition spent as much time or more on task. **Effect sizes were larger (0.42) for studies in which the online and face-to-face conditions varied in terms of curriculum materials and aspects of instructional approach in addition to the medium of instruction rather than those which replicated the instruction and curriculum (0.20).** The meta-analysis did not find differences in average effect size between studies published before 2004 (which might have used less sophisticated Web-based technologies than those available since) and studies published from 2004 on (possibly reflecting the more sophisticated graphics and animations or more complex instructional designs available). Nor were differences associated with the nature of the subject matter involved. Finally, the examination of the influence of study method variables found that effect sizes did not vary significantly with study sample size or with type of design.
Moran et al. 2008 Technology and Reading Performance in the Middle-School Grades: A Meta-Analysis with Recommendations for Policy and Practice (Also Pearson, 2005, The Effects of Technology on Reading Performance in the Middle-School Grades: A Meta-Analysis with Recommendations for Policy and Practice)	0.49	The results of a meta-analysis of 20 research articles containing 89 effect sizes related to the use of digital tools and learning environments to enhance literacy acquisition for middle school students demonstrate that technology can have a positive effect on reading comprehension (weighted effect size of 0.489). Very little research has focused on the effect of technology on other important aspects of reading, such as metacognitive, affective, and dispositional outcomes. The evidence permits the conclusion that there is reason to be optimistic about using technology in middle-school literacy programs, but there is even greater reason to encourage the research community to redouble its efforts to investigate and understand the impact of digital learning environments on students in this age range and to broaden the scope of the interventions and outcomes studied.	1. The effect sizes were greater for interventions aimed at general populations than those with specific needs (i.e., students who are learning disabled or struggling readers). For the 57 effect sizes reported for a general, undifferentiated population of middle school students, the mean effect size was 0.52, whereas **the effect size for targeted populations of students (e.g., students classified as possessing learning disabilities or as struggling readers) was 0.32**: this was a statistically reliable difference. We can only speculate about why this might be the case, and we surely need more evidence before reaching a definitive conclusion. However, issues of engagement and appropriate levels of support and feedback suggest themselves as reasonable explanations. 2. Standardized measures from test companies (0.30), were less sensitive to treatment effects than researcher-developed measures in several of the studies in this meta-analysis measures were less sensitive to treatment effects than experimenter-designed assessments (0.56). 3. Sample size was a robust predictor of effect size; small n studies (30 or less) produced 14 effect sizes averaging

			0.77, while large n (31 or more) studies produced 75 effect sizes with a mean of 0.38, Q D 3:24; p < 0:20. Studies with smaller sample sizes were much more likely to achieve substantial effects than those with larger sample sizes. This counter-intuitive finding is puzzling because of what we know about the increase in statistical power that comes with larger experimental samples. On the other hand, there may be a trade-off between statistical power and experimental precision; that is, it may be easier for researchers to maintain a high degree of fidelity to treatment in smaller studies because of the greater manageability prospects. 4. **Technologies that were created by a research team (1.20) had a much larger effect size than those technologies either adapted from the commercial market (0.28) or those that merely used the technology as a delivery system (0.34).** This finding may be related to the fact that those technologies created by researchers tended to have a clear theoretical focus that was matched by the assessments employed by the team. In short, alignment between intention and outcome measure may be the operative variable behind this robust finding. 5. Studies that used some sort of correlated design (pretests used as covariates for posttest or repeated measures designs in which the same subjects cycle through different interventions) are more likely to find reliable differences between interventions than are independent group designs. 6. **Effect sizes in studies lasting two to four weeks (0.55) were larger than those in studies lasting less than a week (0.48) but much larger than those from studies lasting five or more weeks (0.34).**
Morphy & Graham 2012 Word-processing programs and weaker writers/ readers: a meta-analysis of research findings	0.52 - writing quality 0.48 – length 0.66 - development/ organization of text 0.61 mechanical correctness	Since its advent word processing has become a common writing tool, providing potential advantages over writing by hand. Word processors permit easy revision, produce legible characters quickly, and may provide additional supports (e.g., spellcheckers, speech recognition). Such advantages should remedy common difficulties among weaker	While basic word processing impacted writing quality positively, neither the addition of external instructional support (WP+; $\Delta = -0.28$; $p = 0.123$) nor the use of voice recognition (VR; $\Delta = -0.20$; $p = 0.26$) differed significantly from basic word processors alone. Conversely, three interventions which added internal support to the word processor (WP++) were associated with considerable gains in writing quality ($\Delta d = 0.91$; $p = 0.002$) when

		writers/readers in grades 1–12. Based on 27 studies with weaker writers, 20 of which were not considered in prior reviews, findings from this meta-analysis support this proposition. From 77 independent effects, the following average effects were greater than zero: writing quality (d = 0.52), length (d = 0.48), development/organization of text (d = 0.66), mechanical correctness (d = 0.61), motivation to write (d = 1.42), and preferring word processing over writing by hand (d = 0.64). Especially powerful writing quality effects were associated with word processing programs that provided text quality feedback or prompted planning, drafting, or revising (d = 1.46), although this observation was based on a limited number of studies (n = 3).	compared to P&P. Random assignment and rater blinding were both associated with larger writing quality effects, but only random assignment proved statistically significant.
Onuoha 2007 Meta-Analysis Of The Effectiveness Of Computer-Based Laboratory Versus Traditional Hands-On Laboratory In College And Pre-College Science Instructions	0.26	The purpose of this research study was to determine the overall effectiveness of computer-based laboratory compared with the traditional hands-on laboratory for improving students' science academic achievement and attitudes towards science subjects at the college and pre-college levels of education in the United States. Meta-analysis was used to synthesis the findings from 38 primary research studies conducted and/or reported in the United States between 1996 and 2006 that compared the effectiveness of computer-based laboratory with the traditional hands-on laboratory on measures related to science academic achievements and attitudes towards science subjects. The 38 primary research studies, with total subjects of 3,824 generated a total of 67 weighted individual effect sizes that were used in this meta-analysis. The study found that computer-based laboratory had small positive effect sizes over the traditional hands-on laboratory (ES = +0.26) on measures related to students' science academic achievements and	A total of 35 independent primary studies with a total of 3,284 subjects met the inclusion criteria to answer the primary research question. The 35 primary studies generated 35 weighted effect sizes (w), one effect size (d) for each primary study. The individual effect sizes ranged from a low negative effect size of -0.38, to a large positive effect size of + 1.12. The overall mean effect size (ES), calculated at 95% confidence interval was + 0.26 standard deviation units. Twelve primary studies representing 34% of the studies analyzed reported negative effect sizes. the overall mean effect size (ES) for physical science subjects (physics and chemistry) was +0.34 standard deviation units, while biological science was +0.17 standard deviation units. The effect on Pre-College studies was +0.24 standard deviation units compared to +0.21 obtained for College level studies. ES for science attainment in studies between 1996 and 2000 +0.33 compared with +0.19 standard deviation units for studies conducted between 2001 and 2006.

		attitudes towards science subjects (ES = +0.22). It was also found that computer-based laboratory produced more significant effects on physical science subjects compared to biological sciences (ES = +0.34, +0.17).	
Rosen & Salomon 2007 The Differential Learning Achievements Of Constructivist Technology-Intensive Learning Environments As Compared With Traditional Ones: A Meta-Analysis	0.11	Different learning environments provide different learning experiences and ought to serve different achievement goals. We hypothesized that constructivist learning environments lead to the attainment of achievements that are consistent with the experiences that such settings provide and that more traditional settings lead to the attainments of other kinds of achievement in accordance with the experiences they provide. A meta-analytic study was carried out on 32 methodologically-appropriate experiments in which these 2 settings were compared. Results supported 1 of our hypotheses showing that overall constructivist learning environments are more effective than traditional ones (ES = .460) and that their superiority increases when tested against constructivist-appropriate measures (ES = .902). However, contrary to expectations, traditional settings did not differ from constructivist ones when traditionally-appropriate measures were used. A number of possible interpretations are offered among them the possibility that traditional settings have come to incorporate some constructivist elements. This possibility is supported by other findings of ours such as smaller effect sizes for more recent studies and for longer lasting periods of instruction.	Grade level was found to moderately affect the results—although the effect sizes favored CTILE regardless of grade level, **still the effect size for grades 1-6 were significantly smaller than those for grades 7-9** (d+ = .413, d+ = 0.583 respectively, Qb = 5.29, $p < .05$). **Constructivist learning environments yielded significantly higher achievements** than traditional ones when math instruction lasted for up to six weeks as compared with instruction that lasted for seven weeks or more (d+ = .686, d+ = .408 respectively, Qb = 10.76, $p < .01$). Also year of publication made a difference—CTILE yielded larger effect sizes when the studies were published between 1986 and 1991 than between 1992 and 2002 (d+ = .554, d+ = .388 respectively, Qb = 6.16, $p < .05$).
Sandy-Hanson 2006 A meta-analysis of the impact of computer technology versus traditional	0.24 (SD 0.47; SE 0.017)	Meta-analytical research has shown that computer technology can play a significant role in increasing positive learning outcomes of students. Research on this topic has resulted in conflicting findings on academic achievement and other measures of student outcomes. The	Studies reported from 2000-2003 ES 0.09; 2004-2006 ES 0.24. Grade level: Pre-K-5 – 0.49; Grade 6-8 0.07; Grade 9-12 0.31; Multiple levels 0.23. Sample size <100 – 0.55; 101-200 – 0.52; >200 0.24 Subjects: English 0.07; Science 0.51; mathematics 0.28;

instruction on students in Kindergarten through 12th Grade in the United States.		current meta-analysis sought to assess the level of differences that existed between students being instructed with computer technology versus the academic achievement outcomes of students instructed with traditional methods. Based on specified selection criteria, 31 studies were collected and analyzed for homogeneity. From this original group, 23 studies were systematically reviewed under standard meta-analytical procedures. According to Cohen's (1988) classification of effect sizes in the field of education, the obtained weighted mean effect size of .24 shows a medium difference. This finding indicates that students who are taught with technology outperform their peers who are taught with traditional methods of instruction. In addition, five secondary analyses were conducted on higher-order thinking skills, ES = .82, motivation, ES = .17, retention-attendance rates, ES = .16, physical outcomes, no data were found, and social skills, ES = .21. Eleven ancillary analyses were then conducted to assess study findings across various dimensions including duration of study, type of technology used, and grade-level analyzed.	History -0.20 (one study). Student type: **General education 0.24; Special Ed 0.60;** Mixed 0.01. Test type: standardized 0.24; intelligence test 0.58; Teacher/researcher 0.13; GPA 0.12 Duration: **Up to 2 weeks 0.57; 3-4 weeks 0.50; 5 to 35 weeks 0.26; 36 weeks or more 0.26** Technology type: CAI tools 0.52; Whole environment -0.04; Online/distance 0.26; Hardware/software 0.50
Seo & Bryant 2009 Analysis of studies of the effects of computer-assisted instruction on the mathematics performance of students with learning disabilities	NPE	The purpose of this study was to conduct a meta-study of computer-assisted instruction (CAI) studies in mathematics for students with learning disabilities (LD) focusing on examining the effects of CAI on the mathematics performance of students with LD. This study examined a total of 11 mathematics CAI studies, which met the study selection criterion, for students with LD at the elementary and secondary levels and analyzed them in terms of their comparability and effect sizes. Overall, this study found that those CAI studies did not show conclusive effectiveness with relatively large effect sizes. The methodological problems in	CAI versus teacher instruction: The four group-design studies were associated with a small to medium effect size (d = 0.09, 0.33, 0.45, and 0.75). Comparison of CAI types: The two group-design studies compared the effectiveness of drill and practice CAI with game CAI for enhancing the addition skills of students with LD. Results of these studies demonstrated contradictory findings (d = 0.71 and -0.47 for drill and practice CAI). Enhanced CAI: The two group-design studies were related with either a small or large effect size (d = 0.87 and 0.30). The purpose of this study was to conduct a meta-study of mathematics CAI studies for students with LD. The 11 mathematics CAI studies were selected and examined their effectiveness for enhancing the mathematics

		the CAI studies limit an accurate validation of the CAI's effectiveness. Implications for future mathematics CAI studies were discussed.	performance of students with LD with their effect sizes. The results of this study found that the CAI studies in mathematics did not show conclusive effectiveness for the mathematics performance of students with LD with relatively large effect sizes.
Sisson 2008 A Meta-Analytic Investigation Into The Efficacy Of Fast ForWord Intervention On Improving Academic Performance	0.35 (mean ES) 0.22 – on Standardised reading tests	There has been contradictory evidence concerning the validity of auditory temporal processing deficits as a cause for reading and language problems. In spite of the controversy, Merzenich and Tallal helped develop a popular computer-based intervention, Fast ForWord (Scientific Learning Corporation [SLC], 2006). Although a variety of studies have examined the effectiveness of FFW on academic performance, the findings have been inconsistent, creating the need to quantitatively synthesize findings of experimental studies on Fast ForWord. Thirty-one studies met the stipulated inclusion criteria, which generated 163 effect sizes aggregated across academic skills (e.g., reading, language, phonological processing). The overall mean effect size was in the small to medium range, and no particular reading, language, or phonological processing skill appeared to be significantly more responsive to FFW than another skill. All mean effect sizes were associated with sizable variability, often equal to or exceeding effect size, which decreased the confidence one could place in the "true" effect of FFW. Aggregations were also made across moderator variables (e.g., grade, ethnicity, diagnostic category). This paper provides supporting evidence on the need for the study, a review of the related auditory temporal processing literature, and the purpose, procedure, and findings of the meta-analysis.	Word recognition 0.28; Comprehension 0.28; Fluency 0.57; Vocabulary 0.37; Standardised reading tests 0.22 Spelling 0.21 Elementary grades 0.43 Special Education students 0.52 Outside school hours 0.48 / 0.28 regular school day SLC sponsored studies 0.43 / independent studies 0.20
Soe et al. 2000 The effect of	0.26 (r= 0.1316)	Whether computer-assisted instruction (CAI) can improve reading achievement of students has been a crucial question addressed by	The overall finding of this meta-analysis is that computer-assisted instruction has a positive impact on reading achievement. However, there is a wide range in the foci,

computer-assisted instruction (CAI) on reading achievement		studies in the past. This meta-analysis reviewed 17 research studies based on students K-12 and revealed that CAI does have a positive effect on reading achievement. Although the effects of CAI in 17 studies were not homogeneous, there seems to be no particular study characteristic that might have caused the heterogeneity.	procedures, materials, and findings among the studies included in this meta-analysis. In some cases, a scarcity of acceptable studies was evident in many categories. Therefore, the results given here must be interpreted with caution until a greater number of similar studies with similar reporting styles is available to confirm or refute the findings. Lack of sufficient numbers of studies in key areas could perhaps be the greatest barrier to the systematic assessment of the impact of CAI on the teaching of reading. Findings indicate that computer applications can play a significant role in teaching and learning. However, the precise nature of that role still needs to be researched with greater depth and precision.
Strong et al. 2011 A systematic meta-analytic review of evidence for the effectiveness of the 'Fast ForWord' language intervention program		Fast ForWord is a suite of computer-based language intervention programs designed to improve children's reading and oral language skills. The programs are based on the hypothesis that oral language difficulties often arise from a rapid auditory temporal processing deficit that compromises the development of phonological representations. Methods: A systematic review was designed, undertaken and reported using items from the PRISMA statement. A literature search was conducted using the terms 'Fast ForWord' 'Fast For Word' 'Fastforword' with no restriction on dates of publication. Following screening of (a) titles and abstracts and (b) full papers, using pre-established inclusion and exclusion criteria, six papers were identified as meeting the criteria for inclusion (randomised controlled trial (RCT) or matched group comparison studies with baseline equivalence published in refereed journals). Data extraction and analyses were carried out on reading and language outcome measures comparing the Fast ForWord intervention groups to both active and untreated control groups. Results: M-eta-analyses indicated that	For the 4 analyses of Fast ForWord compared to untreated control groups, the pooled effect size was .079 (95% CI -.09 to .25), .17 (-.17 to .52) for passage comprehension, .01 (-.25 to .28) for receptive language and -.04 (95% -.33 to .25) for expressive language. For comparisons with the treated control groups the equivalent pooled effect sizes were -.026 (95% CI -.40 to .35), -.10 (-.40 to .21) for passage comprehension, .02 (-.27 to .31) for receptive language and -.06 (-.33 to .20) for expressive language. None of the 8 pooled effect sizes were reliably different from zero, and 4 of the effect sizes were actually negative (indicating worse performance in the Fast ForWord treatment group than the control group). Thus from the studies we have identified and analysed here there is no convincing evidence that Fast ForWord is effective in improving children's single word reading, passage reading comprehension, receptive language or expressive language skills.

		there was no significant effect of Fast ForWord on any outcome measure in comparison to active or untreated control groups. Conclusions: There is no evidence from the analysis carried out that Fast ForWord is effective as a treatment for children's oral language or reading difficulties.	
Tokpah 2008 The Effects Of Computer Algebra Systems On Students' Achievement In Mathematics	0.38	This meta-analysis sought to investigate the overall effectiveness of computer algebra systems (CAS) instruction, in comparison to non-CAS instruction, on students' achievement in mathematics at pre-college and post-secondary institutions. The study utilized meta-analysis on 31 primary studies (102 effect sizes, N= 7,342) that were retrieved from online research databases and search engines, and explored the extent to which the overall effectiveness of CAS was moderated by various study characteristics. The overall effect size, 0.38, was significantly different from zero. The mean effect size suggested that a typical student at the 50th percentile of a group taught using non-CAS instruction could experience an increase in performance to the 65th percentile, if that student was taught using CAS instruction. The fail-safe N, Nfs, hinted that 11,749 additional studies with nonsignificant results would be needed to reverse the current finding. Three independent variables (design type, evaluation method, and time) were found to significantly moderate the effect of CAS. The current results do not predict future trends on the effectiveness of CAS; however, these findings suggest that CAS have the potential to improve learning in the classroom. Regardless of how CAS were used, the current study found that they contributed to a significant increase in students' performance.	The average effect size for CAS in a tutorial role ($d = 0.40$) did not differ significantly from the average effect size for CAS in a tool role ($d=0.39$), ns. The average effect sizes for studies that controlled for the effect of teacher (different teachers) and studies that did not control for the effect of teacher (same teacher) were found to be 0.41 and 0.30, respectively. The average effect size for studies in which CAS were used during evaluation ($d = 0.31$) was significantly lower than the average effect size for studies in which CAS were not used during evaluation ($d = 0.42$), $QB(1) =4.35$, $p < 0.05$ The average effect size for studies conducted from 1990 to 1999 ($d = 0.51$) was significantly larger than the average effect size for studies conducted from 2000 to 2007 ($d = 0.24$), $\chi2(1) = 27.78$, $p < 0.05$. While no other pair of comparison was significant, the difference between the average effect size for studies conducted in the 1980's ($d = 0.34$) was less than that of studies conducted from 1990 to1999. Published studies ($d = 0.38$) unpublished studies ($d = 0.39$) ns
Torgerson & Zhu 2003	0.890 (C.I. 0.245 to 1.535) – word	What is the evidence for the effectiveness of ICT on literacy learning in English, 5-16?	A range of five different kinds of ICT interventions emerged from the twelve included RCTs in the review: (1) computer-

A systematic review and meta-analysis of the effectiveness of ICT on literacy learning in English, 5-16	processing on writing 0.204 (C.I. –0.168 to 0.576) – ICT on spelling –0.047 (C.I. –0.33 to 0.236) – Computer texts on reading comprehension/ questioning effect size 0.282 C.I. –0.003 to 0.566) Computer texts on reading comprehension/story retelling	Studies were retrieved from the three electronic databases. PsycInfo and ERIC were the richest sources for retrieving RCTs for this review. 5.1.2 Mapping of all included studies Forty-two RCTs were identified for the effectiveness map. 5.1.3 Nature of studies selected for effectiveness in-depth review The 12 included RCTs were assessed as being of 'medium' or 'high' quality in terms of internal quality: 'high' quality in terms of relevance to the review; 'medium' or 'high' in terms of the relevance of the topic focus; and 'medium' or' high' for overall weight of evidence. All 12 studies were undertaken in the USA with children aged between 5 and 14. Seven of the RCTs included samples where all or half of the participants experienced learning disabilities or difficulties or specific learning disabilities. All 12 studies focused on the psychological aspects or representations of literacy.	assisted instruction (CAI), (2) networked computer system (classroom intranet), (3) word-processing software packages, (4) computer-mediated texts (electronic text) and (5) speech synthesis systems. There were also three literacy outcomes: (1) reading, including reading comprehension and phonological awareness (pre-reading understandings), (2) writing and (3) spelling. Six RCTs evaluated CAI interventions The CAI interventions consisted of studies designed to increase spelling abilities, reading abilities or phonological awareness (pre-reading understandings). One RCT evaluated a networked computer system intervention and two RCTs evaluated word-processing interventions; three RCTs evaluated computer mediated texts interventions and one RCT evaluated a speech synthesis intervention. In synthesis (1), for five different ICT interventions, overall we included 20 comparisons from the 12 RCTs: 13 were positive and seven were negative. Of the positive ones, three were statistically significant, whilst of the seven negative trials, one was statistically significant. These data would suggest that there is little evidence to support the widespread use of ICT in literacy learning in English. This also supports the findings from previous systematic reviews that have used data from rigorous study designs. It also supports the most recent observational data from the Impact2 study. These findings support the view that ICT use for literacy learning should be restricted to pupils participating in rigorous, randomised trials of such technology. In synthesis (2), we undertook three principal meta-analyses: one for each of the three literacy outcomes measures in which we were interested. In two, there was no evidence of benefit or harm; that is, in spelling and reading the small effect sizes were not statistically significant). In writing, there was weak evidence for a positive effect, but it was weak because only 42 children altogether were included in this meta-analysis.
Torgerson and Elbourne 2002 A systematic review	0.37 CI -0.02 to 0.77	Recent Government policy in England and Wales on Information and Communication Technology (ICT) in schools is heavily influenced by a series of non-randomised	No UK RCTs found. Our review found that the evidence base for the teaching of spelling by using a computer was very weak. It was particularly surprising that so few randomised controlled

and meta-analysis of the effectiveness of information and communication technology (ICT) on the teaching of spelling		controlled studies. The evidence from these evaluations is equivocal with respect to the effect of ICT on literacy. In order to ascertain whether there is any effect of ICT on one small area of literacy, spelling, a systematic review of all randomised controlled trials (RCTs) was undertaken. Relevant electronic databases (including BEI, ERIC, Web of Science, PsycINFO, The Cochrane Library) were searched. Seven relevant RCTs were identified and included in the review. When six of the seven studies were pooled in a meta-analysis there was an effect, not statistically significant, in favour of computer interventions (Effect size = 0.37, 95% confidence interval =-0.02 to 0.77, p = 0.06). Sensitivity and sub-group analyses of the results did not materially alter findings. This review suggests that the teaching of spelling by using computer software may be as effective as conventional teaching of spelling, although the possibility of computer-taught spelling being inferior or superior cannot be confidently excluded due to the relatively small sample sizes of the identified studies. Ideally, large pragmatic randomised controlled trials need to be undertaken.	trials had been undertaken in this area. This lack of evidence of effectiveness should not be interpreted as evidence that computer spelling programmes should instantly be withdrawn - the quality of the trials was variable, there may be unmeasured benefits, and there is no evidence that the programmes will harm children's spelling. Nevertheless, these conclusions are based on the best-available research appropriate to answering questions about the effectiveness of ICT on teaching and learning spelling. The onus should be on those wishing to introduce interventions such as these to first evaluate them formally, using rigorous research methods (large pragmatic RCTs), illuminated by the relevant theoretical developments.
Vogel et al. 2006 Computer Gaming And Interactive Simulations For Learning: A Meta-Analysis	0.07	Substantial disagreement exists in the literature regarding which educational technology results in the highest cognitive gain for learners. In an attempt to resolve this dispute, we conducted a meta-analysis to decipher which teaching method, games and interactive simulations or traditional, truly dominates and under what circumstances. It was found that across people and situations, games and interactive simulations are more dominant for cognitive gain outcomes. However, consideration of specific moderator variables yielded a more complex picture. For example, males showed no preference while females showed a	

		preference for the game and interactive simulation programs. Also, when students navigated through the programs themselves, there was a significant preference for games and interactive simulations. However, when teachers controlled the programs, no significant advantage was found. Further, when the computer dictated the sequence of the program, results favored those in the traditional teaching method over the games and interactive simulations. These findings are discussed in terms of their implications for exiting theoretical positions as well as future empirical research.	
Waxman et al. 2002 A Quantitative Synthesis of Recent Research on the Effects of Teaching and Learning With Technology on Student Outcomes	0.39 on cognitive outcomes CI -.050 to .830	To estimate the effects of teaching and learning with technology on students' cognitive, affective, and behavioral outcomes of learning, 138 effect sizes were calculated using statistical data from 20 studies that contained a combined sample of approximately 4,400 students. The mean of the study-weighted effect sizes averaging across all outcomes was .30 ($p < .05$), with a 95-percent confidence interval (CI) of .004 - .598. This result indicates that teaching and learning with technology has a small, positive, significant ($p < .05$) effect on student outcomes when compared to traditional instruction. The mean study-weighted effect size for the 13 comparisons containing cognitive outcomes was .39, and the mean study-weighted effect size for the 60 comparisons that focused on student affective outcomes was .208. On the other hand, the mean study-weighted effect size for the 30 comparisons that contained behavioral outcomes was -.154, indicating that technology had a small, negative effect on students' behavioral outcomes. The overall study-weighted effects were constant across the categories of study characteristics, quality of	The relationship of each of the 56 conditioning (i.e., independent) variables to the mean study weighted effect size was tested for significance using ANOVA. The results indicate that none of the variables had a statistically significant ($p < .01$) impact on the study-weighted effect size. In other words, the overall findings suggest that the results do not differ significantly across categories of technology, instructional characteristics, methodological rigor, characteristics of the study, and subject characteristics.

		study indicators, technology characteristics, and instructional/teaching characteristics.	
Waxman et al. 2003 A Meta-Analysis of the Effectiveness of Teaching and Learning With Technology on Student Outcomes *(update of Waxman et al. 2002)*	0.44 (on cognitive outcomes) CI .171 to .724	To estimate the effects of teaching and learning with technology on students' cognitive, affective, and behavioral outcomes of learning, 282 effect sizes were calculated using statistical data from 42 studies that contained a combined sample of approximately 7,000 students. The mean of the study-weighted effect sizes averaging across all outcomes was .410 ($p < .001$), with a 95-percent confidence interval (CI) of .175 to .644. This result indicates that teaching and learning with technology has a small, positive, significant ($p < .001$) effect on student outcomes when compared to traditional instruction. The mean study-weighted effect size for the 29 studies containing cognitive outcomes was .448, and the mean study-weighted effect size for the 10 comparisons that focused on student affective outcomes was .464. On the other hand, the mean study-weighted effect size for the 3 studies that contained behavioral outcomes was -.091, indicating that technology had a small, negative effect on students' behavioral outcomes. The overall study-weighted effects were constant across the categories of study characteristics, quality of study indicators, technology characteristics, and instructional/teaching characteristics.	The relationship of each of the 57 conditioning (i.e., independent) variables to the mean study-weighted effect size was tested for significance using ANOVA. The results indicate that none of the variables had a statistically significant ($p < .01$) impact on the study-weighted effect size. In other words, the overall findings suggest that the results do not differ significantly across categories of technology, instructional characteristics, methodological rigor, characteristics of the study, and subject characteristics.

Appendix 3: Summary table of Meta-analyses of the Impact of Computer and Digital Technologies on Attainment Published between 1990 and 1999

Meta-analyses of the Impact of Computer and Digital Technologies on Attainment Published between 1990 and 1999			
Author/Title	Overall ES	Abstract	Moderator variables
Azevedo & Bernard 1995 A Meta-Analysis of the Effects of Feedback in Computer-Based Instruction	0.80	A quantitative research synthesis (meta-analysis) was conducted on the literature concerning the effects of feedback on learning from computer-based instruction (CBI). Despite the widespread acceptance of feedback in computerized instruction, empirical support for particular types of feedback information has been inconsistent and contradictory. Effect size calculations from twenty-two studies involving the administration of immediate achievement posttests resulted in a weighted mean effect size of .80. Also, a mean weighted effect size of .35 was obtained from nine studies involving delayed posttest administration (SD 0.17). Results indicate that the diagnostic and prescriptive management strategies of computer-based adaptive instructional systems provide the most effective feedback. The implementation of effective feedback in computerized instruction involves the computer's ability to verify the correctness of the learner's answer and the underlying causes of error.	d (Rosenthal) (SD 0.57) Feedback effects on learning and retention were found to vary with CBI typology, format of unit content and access to supplemental materials.
Bangert-Drowns 1993 The Word Processor as an Instructional Tool: A Meta-Analysis of Word Processing in Writing Instruction	0.27	Word processing in writing instruction may provide lasting educational benefits to users because it encourages a fluid conceptualization of text and frees the writer from mechanical concerns. This meta-analysis reviews 32 studies that compared two groups of students receiving identical writing instruction but allowed only one group to use word processing for writing assignments. Word processing groups, especially weaker writers, improved the quality of their writing. Word processing students wrote longer documents but did not have more positive attitudes toward writing. More effective uses of word processing as an instructional tool might include adapting instruction to software strengths and adding metacognitive prompts to the writing program.	(SE 0.11) Frequency: once a week 0.04; 2-3 times per week 0.25; , more than 3 times a week 0.36. **Duration: 1-10 weeks -0.02; 11 to 20 weeks 0.39; more than 20 weeks 0.28;** Nine studies provided remedial writing instruction to students who had demonstrated difficulty with writing. These nine studies yielded an average effect size of 0.49. Students using **word processing during writing instruction reliably begin to produce longer documents** than students who do not have access to word processing. The average effect size for document length was 0.52 standard deviations.
Becker 1992 Computer-Based Integrated Learning Systems In The	NSPE (No single pooled effect)	Currently, schools are investing substantial funds in integrated learning systems (I.L.S.'s)—networked comprehensive basic skills software from a single vendor. Although rational arguments can be made for the effectiveness of I.L.S.'s, districts want—and vendors are supplying—empirical evidence for decision making. This article re-	Four randomized designs with ES 0.17 and ES 0.26. Other median ES for the different products varied were 0.0. 0.15, 0.17, 0.33, 0.40.

Elementary and Middle Grades: A Critical Review and Synthesis of Evaluation Reports		analyzes results reported in thirty evaluations of I.L.S.'s by using a common "effect size" statistic and correcting, where possible, for deficiencies in the original designs and reports. Some studies (including the most widely cited) substantially over-report I.L.S. effectiveness. On average, I.L.S.'s show a moderately positive effect on student achievement. However, the poor quality of most evaluations and the likely bias in what does get reported at all provide too weak a platform for district purchasing decisions.	
Fletcher-Flinn & Gravatt 1995 The Efficacy of Computer Assisted Instruction (CAI): A Meta-Analysis	0.24	There has been a long-standing dispute about the efficacy of computer assisted instruction (CAI) with regard to the interpretation of effect size estimates in reviews using techniques of meta-analysis. It has been claimed that the data used to calculate these estimates come from studies which are methodologically flawed. The aim of this study was to provide an updated meta-analysis on the learning effect of (CAI) over a broad range of study features with particular attention focused on the effectiveness debate. Using standard procedures, the results and estimates were similar to previous reviews and showed a learning benefit for CAI. The mean effect size for CAI was (.24) for the years 1987-1992, with more recent studies showing an average of (.33). Although moderate, these estimates tended to raise the average student from at least the 50th and 60th percentile. However, studies which controlled for teacher and materials, and were of longer duration, and studies using pencil and paper equivalents of CAI showed no learning advantage over traditional forms of instruction. It is suggested that what accounts for the typical learning advantage of CAI in this meta-analysis and others is the better quality instruction provided by CAI materials. These materials seem versatile enough to be used effectively over a broad range of subjects and educational settings. While the materials did not seem to improve substantially over the past two decades as reflected by effect sizes, these estimates did not include the newer multimedia technology. It is concluded that educational approaches should be judged by a number of criteria including achievement gains and when this is done CAI may far surpass other forms of instruction.	Glass’ Δ Effect size did not differ significantly with educational level… 0.22 adults; 0.20 secondary; 0.26 elementary; 0.55 Preschool and K. Special education 0.32 High ability 0.16; low ability 0.08 Maths 0.32; Literacy 0.12; Science 0.26; Arts 0.26 **Duration up to 4 weeks 0.22; more than 4 weeks 0.27** Drill and practice 0.23; Simulation/ thinking 0.25; word processing 0.22 Random assignment 0.23; non-random 0.25
Khalili & Shashaani 1994 The effectiveness of computer applications: A meta-analysis.	0.38 (unweighted mean)	A meta-analysis of 36 independent studies showed that computer applications hove a positive effect on students' academic achievement from elementary school to college. The average effect size from 151 comparisons was .38; this indicates that use of computer applications raised students' examination scores by .38 standard deviation. Effects differed as a function of the computer	Effect sizes ranged from -.88 to 1.54. The mean of the 151 effect sizes in this study was .38. **Duration: 1-3 Weeks .14; 4-7 Weeks .94; 8-11 Weeks .37; 12-15 Weeks .36; > 15 Weeks .32**

		study feature. Effect sizes were higher in studies that used Logo programming language, when different teachers taught the experimental and the control group, when treatment was applied in a period of one to two months, and when subjects were selected from high schools.	Type of use: CAI .37; Logo .45; Other Programming Languages .33; Drill and Practice .11; Tutorial .26; Simulation .79; Problem Solving .41; Unspecified .39 Subject: Mathematics .52; Computer Science .28; Science .12; Reading/Language .17; Age: High schools was significantly larger than in all other groups: Elementary .34; Middle School .11; High School .62; College .45 Supplement/ replacement: Replacement for Instruction .34; Supplement for Instruction .38 Design: Pretest-Posttest .38; Posttest Only .38; Repeated Measurement 1 .45 Random .29; Nonrandom .54 Study Setting: Regular Classroom .27; Computer Lab .47 Teacher: Same .35, Teacher .45
Kuchler 1998 The effectiveness of using computers to teach secondary school (grades 6-12) mathematics: A meta-analysis	0.28 (Hedges' g)	The purpose of this meta-analysis is to integrate the findings contained in sixty-five primary studies, selected from published studies, ERIC documents, and dissertations, which investigated the use of computers to teach secondary school mathematics in the United States during the last twenty years and to extract new knowledge from these studies. This analysis suggests that at the secondary school level computer-assisted instruction (CAI) has only an overall small positive effect on mathematics achievement but a possible medium positive effect on retention of mathematical concepts and skills of secondary school students. LOGO as the most effective. CAI is used the most frequently and is the most effective for teaching general mathematics courses. CAI appears to be equally effective across gender and grade level, but has a greater positive impact on students from low socioeconomic backgrounds. From the perspective of research, CAI mathematics instruction appears to be the most effective when subjects are randomly selected/assigned, when commercial/standardized evaluation instruments are used, and when the same instructor teaches all subjects. This analysis detects no significant difference in mean CAI effectiveness between published studies and dissertations and no significant trend in CAI effectiveness over the period of this study.	65 studies Min ES -0.47 to Max 2.59 Hedges g 0.32 Mean 0.44 SD 0.55 Outliers removed: 61 studies Hedges' g 0.28 CI 0.17 to 0.39 (mean 0.36 0.42 SD CI 0.25 to 0.47) 0.55 for low attainers Grade level not significant **Low SES benefit most** Random higher than non random allocation From the perspective of implementation within a classroom, CAI mathematics instruction appears to be the most effective when it is used to **supplement** regular instruction (0.38), when the students work **interactively** on microcomputers located in the classroom, when the students are homogeneously grouped by ability, when students work **collaboratively (0.51 vs 0.21)** in pairs, and when the duration of the instruction is **longer than a semester (0.61 vs 0.38).**
Kulik & Kulik 1991	0.30 (unweighted	A meta-analysis of findings from 254 controlled evaluation studies showed that computer-based instruction (CBI) usually produces	Glass' Δ SE 0.029 **Duration: Short duration (4 weeks or less)**

Effectiveness of Computer-Based Instruction: An Updated Analysis	mean)	positive effects on students. The studies covered learners of all age levels -- from kindergarten pupils to adult students. CBI programs raised student examination scores by 0.30 standard deviations in the average study, a moderate but significant effect. Size of effect varied, however, as a function of study feature. Effects were larger in published rather than unpublished studies, in studies in which different teachers taught experimental and control classes, and in studies of short duration. CBI also produced small but positive changes in student attitudes toward teaching and computers, and it reduced substantially the amount of time needed for instruction.	**0.42 (SE = 0.07); long 0.26 (SE = 0.03).**
Kulik 1994 Meta-analytic studies of findings on computer-based instruction	0.32 (unweighted mean)	Introduction: What do evaluation studies say about computer-based instruction? It is not easy to give a simple answer to the question. The term computer-based instruction has been applied to too many different programs and the term evaluation ahs been used in too many different ways. Nonetheless, the question of what the research says cannot be ignored. Researchers want to know the answer, school administrators need to know and the public deserves to know. How well has computer-based instruction worked? Conclusion: Meta-analysts have demonstrated repeatedly that programs of computer-based instruction usually have positive effects on student learning. This conclusion has emerged from too many separate meta-analyses to be considered controversial.	Book chapter – analysis on the basis of conceptual clarity of usage types (L1, L2 & L3). L1 is general tech/no tech - 0.32; L2 – tutoring 0.38; L3 Stanford CCC 0.4 97 studies 0.32 equivalent to 3 months additional progress Tutoring effective Compares Computer tutoring with other approaches (p 24) - mid range.
Lee 1999 Effectiveness of computer-based instructional simulation: A meta analysis	0.41 (unweighted mean)	The purpose of this paper is to analyze evidence concerning the effectiveness of simulation by examining the relationship between two forms of simulations, pure and hybrid, and two modes of instructions, presentation and practice. A review of previous reviews is discussed concerning the effectiveness of instructional simulation. Via a meta-analysis, 19 studies are examined. The meta-analysis leads to following conclusions: 1. Within the presentation mode, the hybrid simulation is much more effective than the pure simulation. 2. Simulations are almost equally effective for both presentation and the practice modes if the hybrid simulation is used. 3. Specific guidance in simulation seems to help students to perform better. 4. When students learn in the presentation mode with the pure simulation, they showed a negative attitude toward simulation.	Glass' Δ 7 of the 19 studies are elementary or high school 0.41 on academic achievement
Liao 1992 Effects of computer-assisted instruction on cognitive	0.48 (unweighted mean)	A meta-analysis was performed to synthesize existing research concerning the effects of computer-assisted instruction (CAI) on cognitive outcomes. Thirty-one studies were located from three sources, and their quantitative data were transformed into Effect Size (ES). The analysis showed that 23 (74%) of	Glass' Δ Range of study effects from -0.91 to 3.31. The overall grand mean for all 31 study-weighted ESs was 0.48. The overall grand median for all 31 study-

outcomes: A meta-analysis.		the study-weighted ESs were positive and favored the CAI group over the control group. The overall grand mean of the study-weighted ESs for all 31 studies and 207 comparisons was 0.48; this suggests that students who had CAI experiences scored about 18 percentile points higher on various cognitive-ability tests than students who did not have CAI experiences. In addition, 6 of the 29 variables selected for this study had a statistically significant impact on the mean ES. The findings suggest that the outcomes of using CAI go beyond the content of that specific software or subject.	weighted ESs was 0.34. The standard deviation of 0.91 reflects the great variability of ESs across studies. Duration: the mean comparison of studies in which the duration of treatment was **less than 6 months showed higher mean ESs than the mean ESs of studies in which duration of treatment was more than 6 months.** Application type: **tutorial software was significantly higher** than drill-and-practice software, problem-solving software, and simulation (other differences non sig.)
Liao 1999 Effects of Hypermedia on Students' Achievement: A Meta-Analysis	0.41 (unweighted mean)	A meta-analysis was performed to synthesize existing research comparing the effects of hypermedia verse non-hypermedia instruction (e.g., CAI, text, traditional, videotape instruction) on students' achievement. Forty-six studies were located from three sources, and their quantitative data were transformed into Effect Size (ES). The overall grand mean of the study-weighted ES for all 46 studies was 0.41. The results suggest that hypermedia instruction is more effective when there is no instruction for the comparison group or when the comparison group used videotape instruction. However, CAI and text instructions are slightly more effective than hypermedia instruction. As a whole, the results of this analysis suggest that the effects of hypermedia instruction on students' achievement are mixed, depends on what type of instruction it compares to. In addition, four of the seventeen variables selected for this study (i.e., instrumentation, type of research design, type of delivery system, and comparison group) had a statistically significant impact on the mean ES.	Glass' Δ Study ES range -0.91 to 3.13. (SD 0.87) Instrumentation - unspecified (researcher vs standardised non sig.) Type of research design: Single group repeated measures sig. higher (pretest-posttest control group, nonequivalent control group, and posttest only control group designs all non sig.) Type of delivery system: **simulators significantly higher than interactive multimedia** Age: non sig. Supplement: **ES for supplement group was 0.18 SD higher than the replacement group** Duration: The mean ESs for **studies lasting 1-4** **months or less than 1 week were higher, while the mean ESs for studies lasting 1-4 weeks or over 4 months were lower.**
Ryan 1991 Meta-Analysis of Achievement Effects of Microcomputer Applications in Elementary Schools	0.31 (unweighted mean)	This meta-analysis was undertaken to clarify existing knowledge of computer use in instruction and to provide information concerning implementation factors that would be helpful to educational administrators. A meta-analysis technique was used to synthesize the results of 40 independent studies. Variables analyzed included characteristics of students, teachers, physical settings, and instructional formats.	Glass' Δ 40 studies 58 effects Mean 0.309 Median 0.296 range -0.482 to 1.226 Effect sizes higher with more than 10 hours training or CPD (0.40) **Teacher written software 0.82** higher than commercial 0.29

Appendix 4: Bibliography of Meta-analyses of the Impact of Computer and Digital Technologies on Education

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