Pachler, N. & Turvey, K. (2018) Looking back, moving forward: impact and measurability of educational technology use In Voogt, J., Knezek, G., Christensen, R. and Lai, K.-W. (eds) *International Handbook of Information Technology in Primary and Secondary Education*. 2nd edition. New York: Springer.

Looking back, moving forward: Impact and measurability of the use of educational technology

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Abstract

In this chapter we carry out a critical review of the various historical analyses of the impact of technological interventions in education. The purpose is to analytically explore and learn from some of the methodological limitations and strengths of the approaches adopted to measure and capture the impact of educational technology. This retrospective examination is then used to explicate methodological design principles that can increase the use and value of research evidence regarding the impact of educational technology. Capturing and understanding the impact of digital technologies in and on learning is inherently problematic. It is exacerbated by the continually developing nature of digital technologies and their crossing of formal and informal boundaries. We posit methodological design principles that are sympathetic to the fact that evidence of the pedagogical application of digital technologies is both borne out of, and brought to bear in, complex and dynamic contexts that are mediated by, and impact upon, the various ways in which technologies are appropriated for educational purpose. The chapter concludes with a call for methodological perspectives that are not confined by paradigm, but that are able to bridge and integrate research paradigms in order to respond to the complex socio-cultural ecologies within which digital technologies are implicated.

Introduction

This chapter, presents the case for a nuanced and qualitative understanding of the impact of digital technologies on learning; that is, an understanding that complements but also recognises the limitations of the quantitative turn seen globally with the proliferation of large datasets or quantitative meta analyses of education interventions.

The concepts of measurability and impact are inherently problematic in education. This is exacerbated when focusing on technology-supported learning, due to the continually developing nature of digital technologies and their crossing of boundaries between formal and informal contexts (Voogt and Knezek, 2008; Cox, 2013; Cox, in press). It is necessary to frame any discussion of impact and its measurability, in a way that enables us to learn from critical debate surrounding methods and what they do or do not afford. Otherwise, we simply run the risk of being confined by methodological paradigms and learn little of any consequence. Conceptualising impact merely as a post hoc concept or measure of ‘what works’ is problematic. Impact in the field of education, we contest, is not an abstract or singular entity that can be isolated from context and adequately measured post hoc; rather impact is borne out of constituent action(s) carried out by sentient agents with and without technologies in a socio-cultural ecology of factors, giving rise to pedagogical and methodological tensions and opportunities (Turvey and Pachler, 2016). Even in the realm of physical matter and materials, designers and engineers work with tolerances, because of the

range of variable factors at play in any context. There is merit in looking back historically at methods for measuring impact in technology supported learning with a concern for how we design contingencies for future desirable impact, in new and emerging contexts.

With these concerns in mind, we structure the first half of this chapter around a retrospective critical examination of some of the various historical analyses of the impact of technological interventions in education. Our concern is to look back in order to move forward in terms of what we can learn from the methodological approaches adopted, their limitations and their innovations. We acknowledge that we are unable to offer a fully comprehensive review of the literature, but a pragmatic and valid starting point. In the second half of the chapter we identify four methodological design principles based on key lessons from the evidence of impact and methodological approaches taken. Our concern here is to examine emergent research paradigms in the field of technology-supported learning and what methodological design principles can be identified to improve the reliability and validity of the data and evidence for sustainable innovation in the field of educational technology. Again, we acknowledge that this will fall short of a comprehensive review, but we believe a genealogical approach focusing on some of the methodological innovations, enables this chapter to make a valid contribution to the debate and knowledge surrounding the issues of measurability and impact where digital technologies are used to mediate learning.

Looking back

Defining terms and parameters

At the outset of this diachronic review, it seems necessary to touch briefly on definitional matters. In the literature, many terms are used, often interchangeably, to discuss technology use in educational contexts such as, among others, IT, ICT, new technologies, digital technologies and educational technology. To underscore our interest in learning, we use the term ‘educational technology’ here and its definition by the Association for Educational Communications and Technology (AECT):

> “Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources.” (Januszewski and Molena, 2008, p. 1)

Another important precursor to evaluating the impact of educational technology and the quality and findings of related research is to clarify the purposes underlying work in the field. Pachler (2009, p. 2) argues that a discussion about the appropriateness of research methods needs to take into account the specific aims, objectives and questions posed by individual researchers and research projects. He references Kjeldskov and Graham (2003) who delineate the following research purposes for the field of human-computer interaction: understanding, engineering, re-engineering, evaluating and describing. Judgements, therefore, about specific pieces of educational technology research arguably need to be made in terms of the appropriacy of the chosen methods relative to the underlying epistemological and ontological framing, the intended aims and objectives as well as research questions. This is in line with advice given in a recent paper by Twining et al. (2017) who set out to address the problem of the imbalance in the number of quantitative and qualitative papers published by highly ranked journals. They deduce a set of guidelines for the design, implementation and reporting of qualitative research. Their paper includes the recommendation to be clear about the theoretical stance underpinning the research, and to ensure it aligns across methodology, design, methods, instruments, data and analysis.

In contextual terms, it is important to bear in mind when examining the available research that a key policy driver behind the integration of technology over recent decades has been the perceived need to compete at a system level internationally in the wake of the increasing importance of global comparisons such as PISA. As a result, research in the field is often judged in terms of its ability to inform policy decisions.

The focus on efficacy, i.e. impact, in turn, is very much a result of the growing importance of accountability and financial exigency in education. It also reflects the significance of spending normally associated with and required for technology-supported educational interventions at an organisational (class, school) or system (local authority/district, state/national) level. And, in the wider policy arena, recent decades have seen an increasing emphasis on evidence-informed decision making which, in turn, can arguably be seen to have led to persistent educational reform programmes. These have often included technology-supported interventions and innovations.

Identifying the gaps

The use and efficacy of educational technology research has been a topic of considerable interest to researchers for some decades and, consequently, a large number of studies have been published in the field. As Cox and Marshall (2007, p. 59) note, despite the efforts of generations of researchers from a range of perspectives, several questions about the long and short term impact of technology on students' learning remain and unambiguous answers are elusive. An important omission from existing studies can be seen to be "major policy analyses that encompass a wide range of settings and look for commonalities and differences as a result of systemic conditions" (ibid, p. 60).

Particularly important findings from education technology research arguably are that very specific uses of ICT have the most impact on attainment (Cox and Abbott, 2004) and that teachers' knowledge about their subject and of pupils' understanding of the subject influence the effect of educational technology on attainment (Cox et al., 2004); this has clear implications for generalisability of research findings:

> "The effect on attainment is greatest when pupils are challenged to think and to question their own understanding, either through pupils using topic-focused software on their own or in pairs, or through a whole-class presentation." (p. 3).

Thus, it is of particular concern that many research papers in the field appear to lack a clear description of how teachers and/or students are using technology as well as valid and reliable measures of their use of technology for teaching and learning. As Bebell et al. (2007) point out, measuring the use of technology by teachers has become increasingly difficult in view of the growing complexity and dispersal of technology (p.4) and much research limits itself to focusing on technology access as a proxy (p. 3).

Bebell et al. (2007) report a widely held view amongst researchers and others that much of educational technology research is methodologically weak. Weaknesses, according to them (p. 2), include limitations in the way technology use is measured with poor alignment between prior achievement and control groups, and paper-based assessment with insufficient sensitivity to detect changes in learning. These weaknesses are also compounded by a failure to account for hierarchical structures of schools, that "mediate the relationship between technology use and achievement" (p.13).

Reeves and Oh (2016) provide a more recent overview of goals and methods of educational technology research. They categorise the goals of educational technology research as follows: theory development / synthesis; exploratory / hypothesis testing; descriptive / interpretivist; critical / postmodern; design / development; and action / evaluation (p. 2).

In their review of available research, Cox and Marshall (2007) draw attention to considerable difficulties with assessment and evaluation tools owing to their rootedness in particular educational paradigms, ones that "usually fail to examine the cognitive processes which students employ to reach their goals" (p. 61) with instruments and evaluation processes which often have only a poor match with the inherent goals of the technology-supported interventions they are used to measure. They go on to identify the following five problems with educational technology research (pp. 62-68) which, they argue, need to be addressed in order to provide robust and reliable research results:

- a failure to understand how learners think;
- a problem with identifying actual types of educational technology use contributing to learning gains;
- a lack of knowledge about the kinds of curriculum implementation and classroom settings that are most influential;
- the variability in teachers' knowledge and pedagogical use of educational technology; and
- a lack of match of learning objectives and the learning outcomes being measured.

Jenkins (2009, p. 274) posits that educational technology research often fails to provide significant insights into how students interact with the learning tools and how new knowledge has developed through the use of technology. She highlights the gap between knowledge and understanding as being significant, for knowledge is "more readily captured with traditional methods of evaluation" whereas, "understanding, given its emergent nature, is more elusive" (p. 276).

Among other areas, Kirkwood and Price (2014) identify difficulties in attributing causality and the types of evidence gathered. They note, and rightly in our view, that whilst quantitative measures of student interaction might be comparatively easy to collect, they do not necessarily contribute a lot to our understanding of how participation in collaborative processes can promote qualitative developments in learning (p. 24). Kirkwood and Price also make the point that technology-based interventions often necessitate, or are accompanied by substantial curricular changes and that it is often not clear what led to improvements and/or gains made.

Latchem (2014, p. 9) draws his readers' attention to the fact that educational technology research tends to be carried out by individuals or small groups working in isolation and that work in the field would benefit from multi-site, multi-perspective, cyclical collaboration into a larger number of similar interventions at different stages of development across different sectors. He recommends the development of indicators that are designed to capture the immediate, short- to medium-term, and longer-term positive improvements in the learning and lives of those involved (p.9)

In their review of educational technology research, Ross et al. (2010, p. 18) conclude that because of the significant diversity of approaches to educational technology research, it is very difficult to offer 'even a characterization of the field today' and they note the importance of a wide range of research approaches including:

- highly controlled basic research studies of cognitive processes relating to the interaction with computers;
- descriptive and evaluative studies of how learners use educational technologies as tools;
- context-specific design-based studies focusing on how particular technologies operate in particular environments; and/or

- applied research focusing on solving specific problems.

Aggregation, opportunities and limitations

In order to critically evaluate a large body of research evidence, meta-analyses and systematic reviews have become popular in educational, social science and medical research. This also applies to the field of educational technology. Whilst different methodological approaches to such reviews exist, they tend to share the purpose of combining the results of comparable studies and improve the power of small or inconclusive studies. According to Pérez-Sanagustín et al. (2017) meta-analyses can bring together insights from a wide range of settings and help "identify gaps in current research and formulate a research agenda that poses new ideas and directions for future investigation in the field" (p. A2). They cannot, however, improve the limitations of original studies such as a lack of quality of original reporting.

Examples of recent meta-analyses and literature reviews in the field of educational technology research include:

- Higgins et al. (2012), who conclude that "taken together, the correlational and experimental evidence does not offer a convincing case for the general impact of digital technology on learning outcomes" (p. 3);
- ICF Consulting (2015), who come to the view that there is conclusive evidence that educational technology can support attainment in general and in maths and science in particular; that there is indicative evidence that it can support attainment in literacy and that it can close the attainment gap between groups; and that there is promising evidence that educational technology can provide assistance to overcome challenges faced by some learners, employability skills and knowledge of career pathways, improved communications with parents and time efficiencies for teachers (pp. 3-4);
- Kirkwood and Price (2014), who identify several desired enhancements to learning and teaching in higher education through technology: operational improvement (increase in flexibility and accessibility), quantitative change in learning (increased engagement and attainment), and qualitative change in learning (promotion of reflection, deeper engagement and richer understanding) (p. 14);
- Livingstone (2012), who offers up three forms of critique of the claims made in support of educational technology: an 'analytic critique', which requires a sceptical analysis of claims made as a result of which she concludes that the 'jury is still out' on whether educational technology supports learning; an 'explanatory critique' which asks about competing theories and alternative explanations; and an 'ideology critique' exploring technology in relation to the societal configurations in which they exist (pp. 20-21).

A recent report published by the OECD in 2015 provides an international comparative analysis of digital skills acquired by students. It concludes that there is a lag between the promise and reality of technology in schools and that "their impact on student performance is mixed at best" (p. 3). This by-and-large reflects the findings of an earlier review by Luckin et al. (2012) who found that often the impact identified is relatively modest in scale and that the focus tends to be on how educational technology supports existing practices rather than on transforming them (p. 9). Whilst Luckin et al. conclude that "much existing teaching practice may well not benefit greatly from new technologies" (p. 64), they also claim to have found proof that educational technology can work, i.e. that different technologies can improve learning by augmenting and connecting proven learning activities, by putting learning first (p. 63).

The key gaps in the literature identified by Pérez-Sanagustín et al. (2017, p. A12) are:

- a preponderance of quantitative research;
- a lack of research from different parts of the world;
- a gap with regards research from the humanities, natural and 'formal' sciences;
- a lack of pre-school studies;
- studies which lack a focus on teachers' pedagogical actions with limited value;
- only few studies involving participants in their design;
- a need to increase sample sizes in research with objectivist approaches; and
- a lack of private sector funded studies.

The field has also seen the publication of a second-order meta-analysis by Tamim et al. (2011) which provides an overview of 37 of 60 or-so meta-analyses published since 1980 capturing some 1050 primary studies out of a total of 1250 or so primary studies covered by meta-analyses with nearly 110,000 participants. It helpfully sets out the codebook developed for the study covering inter alia information about the identification of studies, contextual, methodological and analysis features. This data is important to ensure transparency and comparability.

Theoretical positioning

In addition to exploring the efficacy of research methodology, an important antecedent of determining the impact of educational technology is how learning is defined and what the purpose of education is. Depending on one's conceptualisation of learning, different uses and affordances of technology will come to the fore which are susceptible to different types of measurements and instruments. A focus on basic skills and the recall of content, for example, can normally be measured fairly efficiently through standardized tests to determine attainment gains linked to educational technology. If, however, learning is viewed more in line with Kalantzis and Cope (2004, p. 46), as conditions of belonging and transformation, i.e. engaging the learner's identity and taking them on a 'journey into the unfamiliar', or with Kirschner (2006, p.11) as interaction-based and dialogic, standardized tests become problematical as measures of attainment gain linked to technology use.

In her critical reflections on the literature, Livingstone (2012), for example, references the work of Turkle (1995, p. 35) who characterises the modernist to post-modernist transformations brought about by the emergence of the internet, which she characterises as a shift "from a culture of calculation" to a "culture of simulation based on tinkering and experimentation," much less concerned with hierarchical structures or rules (p. Livingstone 2012, p. 17). In such a paradigm, different ways of measuring learning gain are required.

One strand of educational technology research has focused on barriers to and enablers of the integration of technology into formal education. In their overview of related research, Hew and Brush (2007, p. 241) identify the relationship and interaction between what Ertmer et al. (1999) have called first-order (lack of resources, institution, subject culture, assessment) and second-order (attitudes and beliefs, knowledge and skills) barriers. Shortcomings in teacher preparation and development, and teachers' pedagogic beliefs and knowledge, are issues identified by several studies as an important barrier in effective technology uptake, as are integration strategies.
Scardamelia (2006) outlines three areas where technology can be seen to have the potential to contribute to depth of understanding: computer-assisted instruction; simulations, games and laboratory instruments; and discourse.
With the emergence of mobile technologies, learning environments characterised by one-to-one computing and bring-your-own-device (BOYD) have increasingly become the focus of research. Alas, often the same limitations apply to these emerging research fields that we diagnosed for traditional educational technology research: they tend to be under-theorised,

i.e. do not tend to build on explicit or sufficiently robust conceptualisations of key concepts such as clear definitions of learning and learning gain; are small-scale, short-term, one-off and 'piecemeal' rather than large-scale, longitudinal and cumulative; are qualitative rather than mixed mode or quantitative; are descriptive or exploratory rather than correlational, quasi-experimental or randomized mixed-mode; are over-reliant on self-reported perceptual data; and are often characterised by weak documentation of research methodology (see e.g. Hew and Brush, 2007, p. 246).

Ross et al. (2010, p. 24) stress the importance of educational technology research achieving a balance between rigour, what they call 'internal validity', and relevance, what they call 'external validity' in order to be able to help tackle 'real-world' educational problems. Internal validity, they argue, enables the drawing of valid conclusions about the causal effects of one variable on another and external validity enables the generalization of results to conditions of interest. They further suggest that randomized controlled trials can maximise internal validity but can be liable to low external validity (p. 25).

A number of studies appear to point towards the dependency of efficacy of educational technology on its integration in teaching programmes. In order to understand the most effective way of designing new teaching programmes utilising educational technology, Bai et al. (2016), for example, carried out a clustered randomized controlled trial. According to Sibbald and Roland (1998), randomised controlled trials are the most rigorous way of establishing cause and effect between an intervention and its outcome as well as its cost effectiveness. One key advantage can be the reduction in selection bias by random allocation to treatment or control group of participants once subjects have been checked against eligibility criteria for participation.

Crook et al. (2010, pp. 7-8) identify two broad forms of impact research: relatively short-term studies focusing on particular educational technology supported practices in a rather unsystematic way which they call 'contained interventions'; and 'system-wide' interventions, which focus on large-scale adoption of educational technology. Both, they argue, are characterised by methodological and interpretative challenges and can lead to unjustified scepticism about the value of investment in educational technology. Given the complexity of sites of teaching and learning, Crook et al. argue for a broadening of the definition of impact and related research that yields a better understanding of learning practice and outcomes. To achieve this, they call for "research that documents the reported experience of integrating technology into ongoing practices of teaching and learning, as they are pursued at the classroom level" but also within the broader ecology of educational practice as even "piecemeal approaches disturb the larger ecology of teaching, not just the ecology of individual lessons" (p. 8).

The impact of educational technology is predicated on increasingly sophisticated technology being integrated into complex education systems and ecologies as well as the perpetual obsolescence of technologies making replication studies difficult. The growth in personal ownership of devices adds further complexity and leads to a diffusion of the technological infrastructure involved in many research projects. In turn, this impacts on the locus of control with an increase in user agency and use in informal contexts governed by different social and cultural practices than that of formal education settings and a decrease in influence on the research context by the researcher (see e.g. Pachler, 2009, p 3). Therefore, research and evaluation models are required that reflect this complexity. This can involve the re-casting of the role of learners into co-researchers. Technology can be seen to 'disappear' more and more by virtue of its integration and by being embedded further and less visibly into our physical and social world (Bruce and Hogan, 1998). Consequently, what is needed, we argue, are approaches to educational technology research that capture the complexity of technology-based interventions at a micro (classroom, programme), meso (institutional) and macro (system) level from multiple perspectives rather than a dogmatic application of

particular research designs. Jenkins (2009), for example, argues the case for design-based research to capture the 'messy' elements of technology interacting with the educational endeavour, because of the collaboration between researchers and practitioners it affords.

Recognising the increasing complexity of technology use in educational contexts, in part as a result of technological transformations and the increasing affordances of educational technologies, VasabØ and Gudmundsdottir (2014, p. 2) problematize how best to research networked learning within multi-faceted technology environments. They ask what research designs to use, how to interact with the key stakeholders, how to capture and understand interaction between contexts and across different dimensions, and how meaning is made in and across physical places and virtual spaces. Their questions, coupled with Crook et al.'s (2010) analysis and the shortcomings we have identified above, point towards the need for a paradigm shift in educational technology research to which we turn now.

Moving forward

To identify the character of such a paradigm shift we consider four research design principles that could help shape this shift and increase the efficacy of research attempting to measure the impact of educational technology. The principles we outline here are by no means extensive but we believe what is most important is that they are rooted firmly in the methodological lessons emerging from past educational technology research and motivated by the need for a progressive framing of sustainability in educational technology research. As Bachmair and Pachler (2015, p. 1) argue, there is a need for both pedagogical and methodological practices associated with educational technology to establish the 'ability to maintain innovation over time and to become embedded into mainstream practice'. This can only come from methods that offer the potential for increased understanding of the appropriation of digital technologies in the lives of both students and teachers across formal and informal boundaries. We also enter the caveat that although these design principles are numbered and discussed linearly in what follows, they are inter-related as our discussion of such will reveal. The following methodological design principles could, we believe, act as a catalyst for sustainable methodological innovation that progresses the field of educational technology research. We express these principles thus:

1. Methodological and pedagogical interoperability should be prioritised, which means a call for far-sighted innovation that resists becoming confined by methodological or pedagogical paradigms.
2. The quantitative should be qualified, as far as possible.
3. Post hoc analysis should be accompanied by concurrent description and analysis.
4. Impact needs to be both defined broadly but also theorised rigorously, to understand and document the complex social cultural ecology into which educational technology is integrated.

We briefly outline these principles in more detail below.

Interoperability

We define interoperability as the ability of one methodological or pedagogical design or system to make use of another through, for example, the exchange of data or methods and can be seen to be inherent in meta-analyses which aggregate and synthesise data across various studies. But how might this be achieved across qualitative studies or between quantitative and qualitative research? Without such interoperability, it is impossible to envisage how educational technology innovation could be built upon and sustained. This is not to reject either positivist or interpretivist paradigms but to concur with others who call for methodological innovation in educational technology research (Jenkinson, 2009; Crook and

Garratt, 2011; Cox, 2013; Latchem, 2014; Kirschner and Kester, 2016). Indeed, Crook and Garratt (2011, p.215) argue that critical reflection about methods, the ethical engagement with participants and, the significance of context can all be seen to emerge from the legacy of positivism, as can the conception of context as a 'social ecology rather than a structure of causal relations that is more rigidly mechanical'. Such concerns and problems of methodological design are not confined by paradigm so why should the data or analysis that is generated be confined and how do we render such data and analysis open to re-use? There are, of course, no simple answers to such questions, but it is important to imagine and begin to design methodologies that are genuinely more complementary in the way they bridge established research paradigms to promote efficacy. As Kirschner and Kester argue (2016, p.538), methodology should be free of "dogmas that split the world into quantitative, empirical positivists versus qualitative anecdotal ethnographers."

In imagining more complementary and sustaining research methodologies whose methods, outputs and outcomes lend themselves to greater levels of interoperability, our second design principle is invoked. There is a need for increased qualitative detail in datasets. Our retrospective review above found that methodological innovation is a necessary factor in being able to measure with increasing validity, reliability and granularity, the impact that technology can have on learner outcomes. It also highlights that increased granularity in measuring impact often comes from a richer understanding of the qualitative conditions of the context. Such a view, we contest, necessitates the development of methodologies with greater granularity across the increasingly leaky formal and informal boundaries that educational technologies encompass.

Qualifying the quantitative

There is an urgent need to qualify the quantitative if we are to design research methodologies that genuinely deepen our understanding of the complexities of learning with and through digital technologies. By 'qualify' we mean to offer rich or sufficient qualitative contextual detail. Meta analyses (see also Liao and Lai, in press) of the impact of various educational interventions, including those incorporating educational technologies, have gained favour with policy makers in recent years. They conveniently lend themselves to the relatively simple reporting of impact in the popular media and are also compatible with the global econometrics used to measure and make crude comparisons of the performance of international education systems. But what do they measure? (UNESCO, 2014; OECD, 2015). The key issues with meta-analyses and the experimental studies they synthesise, we argue, is a tendency to view their results and findings at face value and a failure, tendentiously, in the experimental research studies they synthesise to adequately qualify the quantitative effect sizes they produce. Higgins et al.'s meta-analysis of educational technology interventions (2012) found that the introduction of digital technologies on average can offer 'moderate learning gains' of approximately 4 months progress. Hattie (2009), using comparable methods estimates a similar potential effect size on average. But, the actual effect sizes of the different studies that Higgins et al. (2012) synthesised in their meta-analysis, vary significantly. Useful though these are, the only firm conclusion to be drawn is that digital technology can have positive, negative or indeed little to no impact on attainment and learning. Similarly, Haßler at al.'s (2016) meta-analysis focusing on the use of tablet devices in schools highlights the significant problem of redundant findings or data when there is a failure to qualify the quantitative. Out of 23 studies, Haßler et al. (2015) found 16 reported positive learning outcomes, 5 no difference and 2 negative learning outcomes. The authors make the important point that much of the research included in their review did not go beyond face value, stating that 'a large proportion of identified research offers limited or no details of the activities that learners engaged in,' making it difficult to identify important contextual detail necessary in recognising more or less effective use of the technology (Haßler et al., 2015, p.151).

Whilst there is increased availability and access to large quantitative data sets, singular or paradigmatically-confined approaches leave significant questions unanswered such as: how have people learned or not learned with the technology? And: are there significant characteristics of pedagogical design shared by those interventions where educational technology has had a negative, positive or no effect on learning? Similarly, how has the formal and wider informal context influenced this? One strand of the ImpaCT2 study (Somekh et al., 2002) complemented the quantitative analysis of the impact of educational technology through a rich picture of contextual detail using visual methods to capture important qualitative information pertaining to pupils' use of ICT in the home and broader community. This illustrates how questions of context and pedagogical design can only be addressed by invoking our third design principle that post hoc analysis should be accompanied by methods that also facilitate concurrent description and analysis.

Post hoc and concurrent analysis

By concurrent analysis we mean the analysis of data as close as possible to the source of any educational technology-based intervention. Concurrent data affords greater insight and lends itself to re-use and further methodological innovation or analysis. Jenkinson (2009, p.277) argues strongly that to answer questions about the numerous contextual and agent-centred variables influencing the impact of educational technology, there is a need for 'quantitative and qualitative data sets that tightly integrate concurrent and retrospective' data-capture and analysis. The recent systematic review we referred to in the first half of this chapter (Pérez-Sanagustín et al., 2016, p.12) claims studies that ignore what teachers do 'are unlikely to be of much value'. We fully concur with this view but would extend this to include as full a range of contextual and agent-centred variables as possible such as, inter alia: dispositions towards educational technologies and learning, prior experience with the technology both formal and informal, how learners experience or perceive educational technology and the subject in which it is being used. The more contextual and concurrent data (quantitative or qualitative) available, the more we can learn about the use of educational technology. This is particularly evident when comparing studies with greater and less scope.

For example, an area where limited methodological approaches are sometimes seen, is in some of the research into the use of mobile phones in schools. Beland and Murphy's (2015) research on mobile phone use in schools simply analysed, post hoc, the correlation between schools who banned or allowed the use of mobile phones (gathered via a headteacher survey) and data from the National Pupil Database (UK) on examination performance. The only thing of potential significance from this is that impact appeared to vary according to the students' different and current levels of attainment. That is, the use of mobile phones in school appeared to have no positive or negative impact on higher attaining children but was negatively correlated with lower attaining children. The concurrent variable in this limited study allowed some small yet potentially significant insight to emerge with regards different student characteristics as a moderating variable. But the research tells us very little beyond this about the use of mobile devices as educational technology.

Contrast this with another recent meta-analysis (Chauhan, 2017), which attempted to offer greater insight into the various correlations between the impact on learning outcomes and educational technology by differentiating a greater range of concurrent moderating variables. Chauhan synthesised a number of international experimental studies (N = 122) via moderating variables such as subject domain, type of digital application, duration of the intervention, and learning environments. Identifying such concurrent moderating variables can support increased contextual granularity. For example, differentiating by subject domain, highlighted greater effect sizes reported for digital technology supported interventions in Science, suggesting subject cultures can also influence the impact of educational

technology, although it should also be noted that there is a dearth of experimental research in the use of educational technology in subjects such as music and art. This still does not offer insights into the actual pedagogical designs and contexts in which Science teachers incorporated digital technologies across these studies. Whilst the use of concurrent moderating variables offers the potential for greater granularity, it also raises questions regarding potentially significant concurrent variables not captured, such as teacher knowledge and pedagogical design, learner dispositions and socio-economic characteristics or wider contextual influences. It would seem prudent for future studies to develop an agreed standard in terms of what concurrent moderating variables (quantitative and qualitative) should be included as a minimum expectation in educational technology research. Such agreement could lead to the increased power of both statistical and qualitative meta-analyses as a more 'robust and reliable taxonomy of the relationship between different ICT resources, teachers' pedagogies and students' learning' (Cox and Marshall, 2007, p.68). But there is also a risk here that we make assumptions, which is why we invoke our fourth design principle; that impact needs to be both defined broadly but also theorised rigorously, to understand and document the complex social cultural ecology into which educational technology is integrated.

Broadly defined but rigorously theorised

The principle of embracing a broadly defined yet rigorously theorised conception of impact may seem paradoxical but, we argue, it is prudent to assume that as well as not knowing what we should know after decades of research (Cox and Marshall, 2007), the constantly changing nature of educational technology, means we also cannot assume we know what we do not know. Those at the forefront of appropriating educational technology formally into practice have valuable insights to contribute in this respect and participatory methodologies such as narrative approaches (Pachler and Daly, 2009; Turvey, 2012) and learning design (Laurillard, 2012; Persico and Pozzi, 2015; see also Laurillard, in press) are significant. As various studies have shown, the teacher is the most significant variable in the appropriation of educational technology (Harrison et al., 2002; Cox et al., 2004; Somekh, 2007). From this perspective, design-based research methods such as those encompassed by the field of learning design are an important area of methodological innovation that can facilitate a bottom-up approach to measuring impact that, if rigorously theorised, can enable a greater understanding of the socio-cultural ecology of educational technology. As Laurillard asserts (2012, p.226), the pace of change and the potential impact of digital technologies more broadly not only enable the treatment of teaching 'as a design science, they also require it' .

Persico and Pozzi (2015, p.244) claim that learning design "addresses the decision-making process of individual teachers". Furthermore, innovations in learning design have attempted to synthesise the gap between quantitative and qualitative data by drawing on the ease of availability of online data (e.g. learning analytics) when learners engage in online platforms. The ease and speed with which such data can be available, combined with the computational processing power that can be used to provide teachers with data representations to inform their pedagogical designs, to some extent addresses our concern expressed in the third design principle regarding the bridging of post hoc and concurrent data analysis. Similarly, Mor et al. (2015, p. 221) encapsulate these design principles further in their defining of the focus of learning design which they claim is concerned primarily with "understanding how the intuitive processes undertaken by teachers and trainers can be made visible, shared, exposed to scrutiny" and improved further. That is, there is a concern with the micro and meso-level detail (qualitative and quantitative) influencing teachers' actions and motivations involving educational technology, as well as improving the visibility and therefore the re-usability and interoperability of pedagogical processes.

However, promising as such approaches are, Persico and Pozzi's (2015) note there is still the potential for misunderstanding with regards the use of educational technologies and pedagogical approaches. As they state, learning design research must guard against "producing a plethora of different representations, approaches and tools that are not interoperable" (2015, p.245). Whilst there is a need to broadly define impact, there is also a need for progressive focusing from the subjective towards a more objective shared understanding of the different kinds of impact that may emerge and how those more desirable impacts may be re-seeded through appropriate and re-usable pedagogical designs. This, we argue, can only come through understanding and articulating the various subjectivities involved as practitioners appropriate educational technology, a process that is facilitated significantly through dialogue and narrative. Narrative analysis in particular can support an inductive and iterative process that enables participants 'to achieve a certain degree of consensual interpretation' (Pachler et al., 2009, p.81).

The fields of learning design and narrative methodologies lend themselves to the rigorous scrutiny and theorising of the impact of pedagogical practice with educational technology in ways that other methodological approaches often omit. In their paper on sustainability and innovation in mobile learning Bachmair and Pachler (2015, p. 5) state that there is a need for 'relevant knowledge about the practices of mobile learning' and that 'we cannot succeed without objectified tools and operational implementation procedures'. Such knowledge and procedures cannot emerge from research designs that ignore or omit the need for carefully scrutinised and theorised pedagogical intervention and as Bachmair and Pachler (2015) go on to establish, hermeneutical research approaches that foreground intentional pedagogical intervention and professional dialogue have a significant role to play in addressing this issue.

It is beyond the scope of this chapter to give an in-depth review of learning design and narrative research methodologies other than to highlight the potential for innovation they offer. But this brief discussion also illustrates that the four design principles we have outlined are common concerns across various research paradigms. The challenge moving forward is how to shift out of the relative comfort zones that have been established in educational technology research in order to establish a more innovative and sustainable approach to impact and measurability in educational technology research.

Conclusion

The Programme for International Student Assessment (PISA) remains a globally influential dataset that lends itself predominantly to quantitative post hoc research analysis. Pérez-Sanagustín et al. (2016, p.12) call for a need to 'redress the balance between quantitative and qualitative research' as their systematic review of educational technology found only 55 out of 352 studies drew on qualitative methods over a period of 4 years. This rebalancing is an important step but we also ask: would such a rebalancing necessarily draw us out of our respective paradigmatic comfort zones, to achieve further sustainable methodological and pedagogical innovation? We argue that, together with redressing this balance, there is a need for further integration of paradigms and of quantitative and qualitative research designs. The latest cross-country analysis (OECD, 2015) of the purported impact of digital technologies on students' learning outcomes highlights further this need to qualify the quantitative through greater integration and innovation. It illustrates how face-value approaches to measuring impact that employ only post hoc instruments to find correlations or associations between technology take-up and school performance indicators simply raise more questions than they answer, without more detailed levels of granularity that complementary and concurrent qualitative data could afford. We concur with Alexander (2015) who questions this tendency to equate such measurable yet narrow proxies as attainment in education as the ultimate and only indicators of quality. Quantitative studies themselves illustrate that student characteristics and dispositions towards digital technologies, as well as teachers' pedagogical decisions and motivations about digital

technologies could well be the basis for the significant variability in their findings. But, such qualitative factors are not adequately captured or accounted for in many of the research approaches. Intervention, context and impact **is**, we argue, too often conceived as a simplistic mechanical causal structure rather than a socio-cultural ecology. Contemporary design-based approaches to research in this field are, attempting to address the problem of measurability and impact of educational technology. Drawing out principles of design, based on a genuine attempt to learn the lessons of past educational technology research is, we believe, a useful and sustainable way forward for further innovation in research methodology.

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