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Informed design of educational technology for teaching and learning? Towards an evidence-informed model of good practice

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Abstract

The aim of this paper is to model evidence-informed design based on a selective critical analysis of research articles. We draw upon findings from an investigation into practitioners' use of educational technologies to synthesise and model what informs their designs. We found that practitioners' designs were often driven by implicit assumptions about learning. These shaped both the design of interventions and the methods sought to derive evaluations and interpret the findings. We argue that interventions need to be grounded in better and explicit conceptualisations of what constitutes learning in order to have well-informed designs that focus on improving the quality of student learning.

Keywords: Learning design; educational technology; university teaching; student learning; technology enhanced learning, evidence-informed practice.

Introduction

The aim of this paper is to model evidence-informed design of educational technology (ET) used for teaching and learning in higher education, based on a selective critical analysis of research findings. It is not uncommon in ET for greater attention to be given to the technology and its implementation than its impact upon student learning (Kirkwood & Price, 2013b). However a fundamental question remains as to whether the increased time spent on implementing ET is benefiting student learning and not wasting their time, or the time that their teachers have invested. Slavin (2008) states that

> Throughout the history of education, the adoption of instructional programs and practices has been driven more by ideology, faddism, politics, and marketing than by evidence (p. 5).

Policy makers tend to eschew evidence in their development of policy relating to ET, while practitioners, enmeshed in a bustling teaching environment, tend to rely on tacit knowledge (Anderson & Biddle, 1991; Fitz-Gibbon, 1999). Fitz-Gibbon (1997, pp. 35–36) further argues that evidence-based approaches are necessary in order to

- challenge the implementation of untested practices
- address problems and prevent damaging practices
- generate improvements that lead to more effective learning

Cohen, Manion and Morrison (2011, p. 336) question whether

> [i]t is bordering on the unethical to implement untried and untested recommendations in educational practice, just as it is unethical to use untested products and procedures on hospital patients without their consent.

Research evidence to substantiate the value of technology in enhancing learning has not been adequately established (Kirkwood & Price, 2013a). Equally, limited attention has been given to what is actually informing ET designs. Fundamental problems arise from insufficient understanding by practitioners and researchers of variations in the nature of learning and teaching (Kember & Kwan, 2000; Samuelowicz & Bain, 1992, 2001; Trigwell & Prosser, 1996). This is often accompanied by insufficient reference to explicit theoretical models or research evidence to inform designs (de Laat, Lally, Simons, & Wenger, 2006; Kirkwood & Price, 2013b). For example, while Mishra & Koehler (2008) advance a design framework that emphasises the importance of three components (content, pedagogy and technology) for effective teaching with ET, their depiction of 'pedagogy' focuses on techniques rather than on recognising the underlying strategic influence of differing conceptions of teaching and learning.

Some of the approaches used to investigate the impact of interventions reveal that 'teaching' and 'learning' are taken for granted and that technology is viewed as the agent of improvement in outcomes (Kirkwood & Price, 2014). Hence there is a need for both practitioners designing learning programmes and researchers investigating ET interventions to be informed about the educational implications of using technologies for student learning. Unless interventions are underpinned by evidence and interpreted through a theoretical lens our future ET learning designs will likely be underpinned by opinions rather than evidence.

The use of evidence is important for constructing a firm basis for informing designs with technology that are built upon solid and explicit theoretical assumptions (Price & Kirkwood, 2013). This informs wise 'investments' by *teachers* who design curricula, *institutions* that support the curricula, and *students* who we expect to learn through our curricula. It also avoids unnecessary duplication of effort and expense. "The most important benefits, ultimately, are the learning outcomes, the improvements in understanding and skills implicit in the learning objectives" (Laurillard, 2006, p.30).

In this paper we use a selective critical analysis of research findings to model evidence-based practices. We uncover assumptions made by researchers and practitioners about learning and teaching. We examine these assumptions to model how the use of evidence, or lack of it, impacts upon the learning design and the subsequent evaluation of the success of educational technology interventions.

What informs pedagogical designs using technology?

Assumptions about learning and teaching influence how we go about designing resources and activities that use technology for our students' learning (Kirkwood & Price, 2013a). Although models and theories may not be expressed explicitly, they nonetheless underpin all design activities (Kirkwood & Price, 2013a). Research shows considerable variation in conceptions of learning (Price, 2014; Richardson, 2000). Historically, student learning was most often seen as a quantitative change, an increase in knowledge, encompassing the absorption of facts and procedures (see Bransford, Brown, & Cocking, 2000). Later educational research recognised that when learners were engaged conceptually rather than through rote learning they could generalise and apply their learning better to a greater variety of circumstances (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Hounsell, 1987; Martin & Ramsden, 1987; Marton, Dall'Alba, & Beaty, 1993; Perry, 1970; Säljö, 1979; Van Rossum & Schenk, 1984; Vermunt & Rijswijk, 1988; Vermunt, 1996).

Teachers also conceive of teaching in a variety of different ways (Kember & Kwan, 2000; Prosser, Trigwell, & Taylor, 1994; Samuelowicz & Bain, 1992, 2001). Trigwell and Prosser (1996) found that teachers' approaches to teaching – what they do in practice – corresponds to their conceptions of teaching, which in turn relates to their conceptions of how their students learn. Consequently, teachers with a conception that focuses on 'the transmission of knowledge' usually adopt a teaching-centred approach and conceive of student learning as an increase in knowledge (Säljö, 1979). In contrast, those teachers who regard teaching as 'promoting conceptual development in learners' are likely to adopt a learning-centred approach and conceive of learning as a qualitative improvement in understanding. Thus, how teachers conceive of teaching informs how they approach their teaching (Price, 2014). It also shapes how they design teaching and learning resources and activities that use technologies, and how they subsequently evaluate student learning in interventions (Kirkwood & Price, 2014). Individual teachers have considerable influence upon the design both of interventions and their evaluation, particularly as practitioners often conduct research investigations into their own innovations (Hammersley, 2007).

Often what influences the design of ET innovations is not theoretical understandings and evidence about learning improvement drawn from the literature. More prevalent is technological determinism and an experimentalist approach that reflects opinion-based practice (Boyle, 2004) as opposed to evidence-informed practice (Kirkwood & Price, 2013a, 2013b). This raises several questions about the role of evidence to inform designs as well as assumptions about learning and teaching that may underpin not only ET designs, but how any subsequent evaluation might be interpreted. Principally:

- For ET interventions, what assumptions are made about the nature of *teaching* and *learning*?
- Are those assumptions derived from *explicit* or *implicit* theoretical models or understandings?
- How do implicit or explicit theoretical models inform the design of ET interventions?

- How do implicit or explicit theoretical models inform the evaluation approach, the research methods employed and the interpretation of findings?
- Do research/evaluation results inform pedagogical practice or ET designs?

We now critically analyse our selection of the literature to uncover implicit assumptions about ET and evidence, and how these influence ET designs and interpretations about their success.

Methods

Theoretical approach

Assumptions about the design of learning and teaching with technology are frequently not made explicit (Price & Kirkwood, 2013; Thorpe, 2008). So scrutinising underpinning assumptions does not have a strong tradition upon which to draw. Examining the 'effects' of interventions is complicated by the differing ideological positions of researchers in terms of what they considered as evidence, and how that is characterised (Price & Kirkwood, 2013). For example, a well-established method of examining the collective impact of a body of interventions is through a meta-analysis approach (see for example Means, Toyama, Murphy, Bakia, & Jones, 2010; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). However, this approach only deems a certain experimental method (with strict inclusion/exclusion criteria) as acceptably rigorous and valid.

Most interventions that take place within HE institutions are relatively small-scale and it is unlikely that any evaluation or research concerning their effectiveness could be conducted with the rigour that would produce conclusive evidence. Cumulatively, however, evidence gathered from a number of similar interventions can provide a useful indication of benefits that might be achieved. As Slavin (2003, p. 15) has pointed out:

> Rather than evaluate one large, definitive study, researchers must usually look at many small studies … if these studies tend to find consistent effects, the entire set of studies may produce a meaningful conclusion.

Investigating learning and teaching is a complex activity as there are multiple factors that can influence student learning outcomes (Price, 2014). We draw on the 4P model (Price, 2014) and specifically focus on teachers' conceptions of teaching (Kember & Kwan, 2000; Prosser et al., 1994; Samuelowicz & Bain, 1992, 2001) and teachers' approaches to teaching (Prosser et al., 1994; Trigwell & Prosser, 1996) as indicative of interpretations about student learning (Trigwell & Prosser, 1996).

We also draw on Kirkpatrick's (1994) model of evaluation which proposes that the effectiveness of education/training should be evaluated at four progressively challenging levels – *Reaction*, *Learning*, *Behaviour* and *Results*. Sophisticated evaluations need to attend to multiple levels, i.e. all four levels, while more naïve evaluations focus on elementary levels

such as *reaction* and *learning*. While we acknowledge that Kirkpatrick's model might not be appropriate for all forms of educational evaluation, it does offer one useful means of uncovering implicit assumptions about learning as evidenced through evaluation strategies.

A further foundation of our approach is the pedagogical goal of an ET intervention. Kirkwood and Price (Kirkwood & Price, 2014) argue for a more holistic approach to examining the impact of learning and teaching interventions that allows for scrutiny across a range of factors within the parameters of their own design. This identifies any intervention as relating to one of three goals: ***replicating, supplementing*** and ***transforming***. This has the advantage of allowing consideration of contextual factors – important in research with human participants (Clegg, 2005; Hammersley, 2007; Kirkwood & Price, 2013a). In our synthesis we use a multi-faceted and cumulative approach to model how theory (implicit or explicit) and practice inform ET designs and the interpretation of their success.

Sources of data

The starting point was a review of literature undertaken for the UK Higher Education Academy to investigate how practitioners used ET to support student learning. That review considered the kinds of evidence that were produced to substantiate claims of improvements achieved (Price & Kirkwood, 2011). It revealed that practitioners were not making good use of current research to inform their designs. A further analysis of those articles is presented here, explicitly examining the theoretical models/evidence and assumptions (whether explicit or implicit) that underpin interventions and their relationship with the specific design, the evaluation/research undertaken and the interpretation of findings. This examination of real cases offers the opportunity to model 'informed pedagogical designs that use technology' with a view to facilitating more robust approaches to improving student learning.

The data sources were acquired by searching for articles published during the period 2005 to 2010 using the 'Web of Science' and 'Academic Search Complete' online databases. The keywords applied were "technology" and "university *or* higher education" and "teaching *or* learning" and "evidence *or* empirical". Several hundred abstracts were scrutinised, but a shortened list of articles was read in full. A total of 46 articles were included. The remainder were excluded because they were not concerned with evidence generated from actual interventions in the higher education context.

Data analysis

The fundamental unit of analysis was each individual research paper. Using content analysis (similar to Hew & Cheung, 2013) each article was characterised according to the following five parameters (see Table 1). Each parameter is associated with a data category and were appropriate is related to its theoretical underpinning.

TABLE 1 NEAR HERE

The criteria in Table 1 provide an indication of how each intervention was designed in terms of

- whether theoretical underpinnings of teaching and learning have explicitly informed the design and evaluation,
- conceptions of learning in terms of what 'measures' were used to evaluate the intervention,
- how the complexity of the evaluation approach reflects the sophistication of the design and its impact on learning.

Results and discussion

Table 2 shows an analysis of the articles using the criteria in Table 1. We used the first criterion (Pedagogical basis of intervention or study) as an overarching lens through which to construe what informs design. In the first category 'Replicating existing teaching practices', the articles contained implicit assumptions about teaching and learning, a quantitative expression of student learning, and evidence collected was concerned with the lower levels of Kirkpatrick's evaluation model.

TABLE 2 NEAR HERE

In Category 1 all but one of the articles made implicit assumptions about learning. In other words, there was little or no discussion in the articles about what 'learning' involved. This category of design tended to reflect an assumption that learning improvement was about increasing knowledge acquisition which, in turn, was evidenced by students achieving higher grades. This relates to a transmissive model of teaching (Trigwell, Prosser, & Taylor, 1994), where learning improvement is viewed as a quantitative gain (Trigwell & Prosser, 1996). The last article in Category 1 also focuses on replication, but in this instance it compared campus-based and distance learners. While an explicit theoretical model was evident, the actual design suggests that underlying assumptions about teaching are again transmissive, with learning being seen as an increase in knowledge.

The first 9 articles in Category 2, 'Supplementing existing teaching practices', focus on designs that make current course materials or resources available more flexibly. All of the articles in this category make implicit assumptions about learning. The evaluation strategy is also quantitative, indicating that teaching and learning are conceived as quantitative activities. The remaining 14 articles in this category are characterised as adopting or developing additional learning resources or tools for students to use. Most of these expressed explicit theoretically grounded assumptions about learning. Eleven of these 14 articles considered learning gains to be about qualitative improvements in understanding, which they sought to evaluate through predominantly qualitative methods. This illustrates a more student-centred approach to teaching. In many cases technology was used to promote developments in learning that were not being met by other means. The remaining three articles in this category had implicit assumptions about learning. In these articles the

intervention studies were not concerned with qualitative improvements in learning, but focused more on students' reactions to and/or perceptions of the technology-based interventions. Overall, articles in this category did not focus on the higher levels of Kirkpatrick's model.

Interventions included in Category 3 'Transforming the learning experience' sought improvements through making structural changes and pedagogical designs that exploited the use of technology. They tended to make explicit underpinning theories of learning and qualitative approaches were used to evaluate student learning outcomes. The articles in this category were also more concerned with the higher levels in Kirkpatrick's model. The first 8 papers in this category focused on redesigning parts of modules to provide active learning experiences for students. All of the designs were informed by explicit theoretical assumptions about learning. Again, all of these focused on achieving qualitative differences in learning. The last 6 articles in this category explored which ET designs were more effective in promoting qualitatively richer student learning. In this category the theoretical assumptions were more explicit where the pedagogical designs that used ET were more complex.

Collectively, this analysis illustrates that the designs of ET interventions are based upon assumptions about student learning. These assumptions also reflect teachers' conceptions of teaching and their approaches to teaching, i.e. their educational practice. For example, presentational forms of teaching with technology (for example PowerPoint shows, podcasts of lectures and webcasts) tend to buttress the practices of teaching-centred teachers, through replicating or supplementing their existing ways of teaching. In contrast, teachers with learning-focused conceptions of teaching are more likely to exploit technologies that expedite and support the learning and development of students. Examples include designs where students are required to interrogate sources of information or data, to undertake group tasks, or to reflect upon and demonstrate developments in their understanding and practices (using wikis, blogs, discussion forums, portfolios, etc.). Often these are associated with endeavours to transform the learning experience through active engagement in knowledge building and sharing, and reflection upon learning and development episodes and processes. These variations in teachers' conceptions and approaches to teaching help us to understand the different ways in which technology is used for university teaching (Kirkwood & Price, 2012).

Evaluation approaches and how they reflect theoretical assumptions

Evaluation methods too are underpinned by theoretical assumptions. The replication designs prevalent in Category 1 in Table 2 are largely related to implicit assumptions about learning and many adopted comparative methods to examine student performance. These compare and contrast the performance of 'with-technology' and 'non-technology' groups of students. Comparative methods remain a common approach in ET research (Means et al., 2010; Tamim et al., 2011). However they conceal assumptions about learning as being a quantitative accumulation of knowledge, with the expectation of demonstrating that students have 'learned more' following the introduction of technology. The evaluation methods are predicated upon a technologically deterministic perspective, where the technology *in and of itself* is considered to be the agent of change. It also assumes a transmissive approach to

teaching. The evaluations in Category 1 studies tended to use fewer evidence collection methods. Further, the nature of the evaluation focuses on the lower levels of Kirkpatrick's four-level model.

Where studies have relied primarily upon self-report surveys to gauge students' and teachers' reactions to and satisfaction (Kirkpatrick Level 1) with technology-based interventions, the findings reveal nothing about any learning improvements achieved. Studies that focus mainly upon test scores or assignment grades achieved (Kirkpatrick Level 2) indicate that learners have been able to acquire knowledge, but may not have developed greater understanding.

Interventions in the Category 2 are split between those that aimed to make existing teaching resources available in a supplementary form, and those that added additional resources with the intention of improving learning. Interventions in the first group were mostly related to implicit assumptions about learning predicated on the accumulation of information (quantitative) and, again, reflect a transmissive approach to teaching. This group also tended to use relatively few evaluation methods, while the nature of the evaluation concentrated at the lower levels of Kirkpatrick's model.

In comparison, articles in the second group within Category 2 tended to focus on how to enhance some aspect of the educational process. Here more explicit and theoretically-underpinned discussions about learning are evident. The nature of the evaluations also changed in terms of their increased complexity and more sources of evidence were sought. This category included constructivist approaches to learning, in which the evidence gathered focuses upon the qualitative developments in student learning.

In Category 3 explicit consideration of theories of learning becomes prevalent. Designs in the first 8 articles focus on introducing a different pedagogical approach or way of working, for example promoting students' explicit reflection upon the development of professional practices or the completion of group tasks with shared outputs. Evidence of the effect of these designs sought to establish that the new or re-conceptualised design enabled better quality student learning. Increased complexity in the evaluation methods is particularly evident in the second group of Category 3 studies. More sources of evidence are sought to demonstrate the impact of the intervention. In addition, the nature of the evaluation examined more complex levels of Kirkpatrick's model.

This review has illustrated considerable under-utilisation of theoretical models of learning to drive pedagogical designs of ET interventions (Kirkwood & Price, 2013a). Implicit models and assumptions were, nevertheless, informing the design of interventions. We argue that a scholarly approach to designing teaching and learning with technology was often missing (Kirkwood & Price, 2013b). However, we found that explicit and more sophisticated theories of learning tended to underpin better-informed designs.

Towards an evidence-informed model

Our analysis has shown that practitioners' use of ET was driven by a variety of assumptions about the nature of learning. These influenced how teachers approached their teaching and

how they used ET in their designs. What is particularly striking was the link between implicit assumptions, the design of the ET intervention and the methods employed to evaluate the effectiveness of their intervention. Practitioners do not appear to be capitalising on existing evidence and theories about learning and teaching, particularly with technology (Kirkwood & Price, 2013a, 2013b, 2014; Price & Kirkwood, in press, 2011). More emphasis appears to be placed on experimentation with technology or opinion-based practice rather than drawing upon existing theories and evidence to inform new designs and to interpret the findings.

A practice-based model

Figure 1 illustrates a practice-based model and the relationships we have found in our analysis between

- theoretical models and assumptions about teaching and learning,
- the pedagogical design of resources and activities for learning using technology, and,
- the approach adopted to evaluate that design and the interpretation of evaluative findings.

It also shows how these findings feedback to either reinforce or modify the theoretical models and assumptions.

FIGURE 1 NEAR HERE

Figure 1. A practice-based model of ET design

For example, if the teacher's model assumes that learning is about accumulating more information, then the design will focus on creating situations from which students acquire more knowledge. The subsequent evaluation will seek to establish, through a test, how much 'extra' information students have acquired when compared with a similar non-intervention group. If the test scores indicate an improvement, this will act to 'demonstrate' the impact of technology and to reinforce the assumptions made about learning and teaching. In contrast, teachers with a more complex model of learning will adopt a multi-faceted approach to ET design and to the evaluation of outcomes.

A partially-informed model

From our analysis we conclude that many designs for using ET have *not* been informed by explicit theoretical understandings and appropriate evidence. However, some had been (see Table 2). We illustrate a model of ET design that is partially informed by research evidence and theory (see Figure 2). In this model explicit research evidence and theory underpin models of and assumptions about student learning and the pedagogical design.

FIGURE 2 NEAR HERE

Figure 2. A partially-informed model of ET design

Evidence and theory not only influence the pedagogical design, but also (indirectly) the strategy for evaluating the effects of an intervention and the interpretation of the results. So, by adopting a more evidence-informed approach to ET interventions, designs that are more likely to lead to qualitative improvements in learning can be developed. However, we refer to this as 'partially-informed' because integration of these conceptions with the *educational context* is lacking.

An evidence-informed model – including the influence of context

What has not been discussed explicitly in this article is the role of contextual factors. Nonetheless, they can shape designs significantly. The teaching context can influence what a teacher is able to do in terms of pedagogic possibilities and it may influence what students can do in terms of access to technologies. For example, if a teacher is presented with a large cohort of students and assigned a large lecture hall for their teaching activities, then these circumstances reinforce a lecture-model approach to teaching as well as an information-accumulation model for learning.

Context also influences the methods adopted for evaluating the effectiveness of the intervention. The comparative study method (in which ET use is compared with teaching without the use of technology) may be influenced by pragmatic matters. Given a particular context, convenience and expediency often determine how participants are selected for an intervention and the evaluation conducted. For example, participants might be concurrent groups of students within the same cohort, or consecutive cohorts of students taking seemingly the same module.

Further, the departmental and institutional contexts within which university teachers operate and their disciplinary affiliation exert considerable influence upon teachers' beliefs and practices about teaching and learning (Lindblom-Ylänne, Trigwell, Nevgi, & Ashwin, 2006). In the articles we reviewed, the contextual particularities of any ET intervention were often found to be under-specified or paid insufficient attention. This made it difficult for us to draw particular conclusions about the role of context in many cases. The deficiency also limited the potential to generalise from the findings.

Other influences can also be important. For example, the nature of the academic development and support that practitioners receive can influence academics' confidence and skill in using particular technologies. Institutional policy-makers play key roles in determining the integration of technology, as they influence the culture within which practitioners operate and hence their actions (Price & Kirkwood, 2008). We argue that informed designs need to take account of various contexts: the teaching context, the institutional context and the student context. To counter the deficiencies revealed in the literature review, we add contextual constraints and influences to the model in Figure 3.

FIGURE 3 NEAR HERE

Figure 3. An evidence-informed model of learning design with technology constrained by contextual factors

How can we influence informed design in educational technologies that enhance learning?

We argue that informed design of ET interventions needs to be grounded in a better conceptualisation of what constitutes and shapes learning rather than a focus on technology as the primary agent of change. Further, contextual factors relating to the environment within which teaching and learning takes place often influence uses of technology to a greater extent than is usually acknowledged.

Havnes (2004) argues that a social approach to learning is necessary in order to broaden attention from the actions of individuals (students and/or teachers) to the social system and the surrounding institutional practices. Changing just one constituent part of any educational programme is unlikely to bring about a substantial alteration to the whole. If the transformation that many teachers seek is to be achieved, consideration must be given to the interaction of each part with the others. A holistic view that draws on good evidence to inform designs is required to make good choices, whether within a course or programme, or across a whole institution.

At the institutional level, clarity is necessary in terms of the goals and aims to be served by the ever-greater adoption of technology. Academic policies and strategies need to be co-ordinated across all relevant parts of the faculty and institution. Implementation of ET is not just confined to interventions aimed at enhancing student learning. It necessitates reviewing the underpinning infrastructure that will be required to support such interventions, establishing what changes in processes are required, and what changes in the skill sets of staff will be necessary.

Concluding comments

This synthesis of the research literature has revealed an under-specification of both theoretical models and evidence from relevant research and evaluation studies to inform the design of ET interventions in HE and to interpret their effectiveness. It was found that practitioners' use of technology was driven by a varying set of (often implicit) beliefs about the nature of teaching, learning and technology and a range of assumptions that underpin those beliefs. These implicit or explicit assumptions influenced the design of ET interventions, the approach to evaluating their effectiveness, and the interpretation of the findings (Kirkwood & Price, 2013a). Context exerts considerable influence upon academics' beliefs and practices concerning teaching and learning. Nonetheless, many interventions provided insufficient explicit recognition of the constraints imposed by departmental, institutional and disciplinary contexts within which interventions took place.

Based upon our critical analysis and the gaps identified, we argue that evidence-informed design of ET interventions needs to be grounded in a better conceptualisation of what constitutes and shapes learning and how interventions can be integrated within the context of their implementation, rather than a focus on technology as the agent of change.

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Table 1. Characteristics of the five parameters used for content analysis.

Parameter	Data category	Theoretical underpinning
Pedagogical basis of ET intervention (explicit or implicit)	1 *Replicating* existing teaching practices, 2 *Supplementing* existing teaching, or 3 *Transforming* the learning experience	Kirkwood's & Price's (2014) model of enhancements
Assumptions about learning and teaching	Explicit or implicit	
Assumptions about learning and conceptions of learning	Learning viewed as *quantitative* or *qualitative*	Säljö's (1979) hierarchical scheme
Number of data collection sources involved	Count of methods used	
Focus of evaluation - what aspects were addressed	Identification of highest level of evaluation: 1= *Reaction* (participants' satisfaction with an intervention) 2 = *Learning* (what knowledge participants gain) 3 = *Behaviour* (what participants can do differently) 4 = *Results* (how participants apply the knowledge and skills gained)	Kirkpatrick's (1994) 4-level model of evaluation

Table 2. A categorisation of the reviewed interventions involving technology for teaching and learning.

Pedagogic Basis (Design) of Intervention or Study	Illustrative Research Articles	Assumptions about Teaching and Learning	Theoretical Assumptions about Improvements in Learning (what they are considered to be)	No. of Data Collection Types	Learning viewed as Quantitative or Qualitative	Highest level in Kirkpatrick's model
1. Replicating existing teaching practices: characterised by replicating an element of conventional teaching for delivery to students using some form of technology (8 studies)	Connolly *et al.* (2007)	Implicit	An improvement in grades	4	Quantitative	2
	Delialioglu and Yildirim (2008)	Implicit	An improvement in achievement, retention, attitude and satisfaction	3	Quantitative	2
	de Grez, Valcke and Roozen (2009)	Explicit	Social cognitive theoretical perspective towards self-regulated learning	1	Qualitative	2
	Hui, Hu and Clark (2007)	Implicit	More efficient knowledge acquisition	2	Quantitative	2
	Lorimer and Hilliard (2008)	Implicit	An improvement in grades	2	Quantitative	2
	Neumann and Hood (2009)	Implicit	Increase in knowledge and an improvement in grades (constructivist model)	3	Quantitative	2
	Stephenson, Brown and Griffin (2008)	Implicit	Increase in knowledge and an improvement in grades - but did distinguish between different types of questions around Bloom's taxonomy	2	Quantitative	2
	Woo *et al.* (2008)	Implicit	Lectures can be replaced by web-based technologies	4	Quantitative	1
1. Replicating existing teaching practices: characterised by comparing differing technologies for delivering the same material or resources to campus-based or distance learners (1 study)	Griffin, Mitchell and Thompson (2009)	Explicit	Bloom's taxonomy: improvement in different types of skills shown through MCQ (but implicit assumption about information transfer)	2	Quantitative	2
2. Supplementing existing teaching practices: characterised by making available versions of existing course materials/ resources/tools that	Copley (2007)	Implicit	An increase in knowledge	2	Quantitative	1
	Cramer *et al.* (2007)	Implicit	An increase in performance	3	Quantitative	2
	Dalgarno *et al.* (2009)	Implicit	An increase in knowledge measured by test performance	3	Quantitative	2
	Evans (2008)	Implicit	An increase in knowledge measured by test performance	1	Quantitative	1

students can access and use whenever they want (9 studies)	Fernandez, Simo and Sallan (2009)	Implicit	Information transmission – student perceptions of its value	5	Quantitative	1
	Lonn and Teasley (2009)	Implicit	An increase in knowledge and performance	3	Quantitative	1
	Swan and O'Donnell (2009)	Implicit	An increase in knowledge and performance	5	Quantitative	2
	Taylor and Clark (2010)	Implicit	Better information transmission to student	3	Quantitative	1
	Tynan and Colbran (2006)	Implicit	Better experiences through using podcasts	1	Quantitative	1
2. Supplementing existing teaching practices: characterised by adopting or developing additional learning resources or tools for students to use (14 studies)	Cubric (2007)	Explicit	Constructivist theory – developing learning through the support of group work	3	Qualitative	2
	Demetriadis *et al.* (2008)	Explicit	Better quality problem solving	3	Qualitative	2
	Elgort, Smith and Toland (2008)	Explicit	Constructivist approach to learning – assessed through better group work and high quality development on wiki	4	Qualitative	3
	Hramiak, Boulton and Irwin (2009)	Explicit	Qualitative changes in learning for reflection and professional development	2	Qualitative	3
	Kerawalla *et al.* (2009)	Explicit	Student-centred – developments in reflection upon development	2	Qualitative	3
	de Leng *et al*. (2009)	Explicit	Developing critical thinking	4	Qualitative	3
	McLoughlin and Mynard (2009)	Explicit	Developing higher order thinking	1	Qualitative	3
	Murphy and Ciszewska-Carr (2007)	Implicit	Good communication experiences – information transmission	1	Quantitative	1
	Ng'ambi and Brown (2009)	Explicit	Development of student engagement	2	Qualitative?	2
	Sorensen *et al.* (2007)	Implicit	Better internet use implies better learning and practice	5	Quantitative	2
	Wheeler and Wheeler (2009)	Explicit	Constructivist approach – better quality writing	2	Qualitative	1
	Wyatt *et al.* (2010)	Implicit	Information transmission	2	Quantitative	2
	Xie, Ke and Sharma (2008)	Explicit	Qualitative improvements in reflective thinking skills	3	Qualitative	3
	Zorko (2009)	Explicit	Better collaborative learning	4	Qualitative	3

3. Transforming the learning experience: characterised by redesigning learning activities or substantial parts of modules to provide active learning opportunities for students (8 studies)	Coller and Scott (2009)	Explicit	Better engagement leads to better quality learning	3	Qualitative	3
	Cooner (2010)	Explicit	Qualitative changes in learning acknowledging learning complexity	2	Qualitative	3
	Dalsgaard and Godsk (2007)	Explicit	Social constructivist model – learning to qualitative improvements	3	Qualitative	2
	Hakkarainen, Saarelainen and Ruokamo 2007	Explicit	Constructivist approach to improving meaningful learning	3	Qualitative	1
	Hemmi, Bayne and Land (2009)	Explicit	Developing reflection and identity – considers what is happening as opposed to specific focus on learning	6	Qualitative	3
	Herman and Kirkup (2008)	Explicit	Developing learners as reflective professionals	5	Qualitative	2
	Lee, McLoughlin and Chan 2008	Explicit	Constructivist learning with students as producers and active participants in the process	1	Qualitative	2
	Tormey and Henchy (2008)	Explicit	Increased student engagement	3	Qualitative	1
3. Transforming the learning experience: characterised by investigating how ET activities could most effectively promote qualitatively richer learning among students (6 studies)	Chen, Chen and Tsai (2009)	Explicit	Improving various aspects of the learning process	4	Qualitative	2
	Downing *et al.* (2007)	Explicit	Collaborative learning to improve the quality of learning	3	Qualitative	1
	Kanuka, Rourke and Laflamme (2007)	Explicit	Collaborative learning to improve the quality of learning	2	Qualitative	3
	Kirkwood (2006)	Explicit	Role of assessment in improving student access to and use of online resources	1	Qualitative	1
	Melrose and Bergeron (2007)	Explicit	Using affective factors to support good quality student interactions	2	Qualitative	1
	Thorpe (2008)	Explicit	Better engagement and interaction leads to better learning	5	Qualitative	3

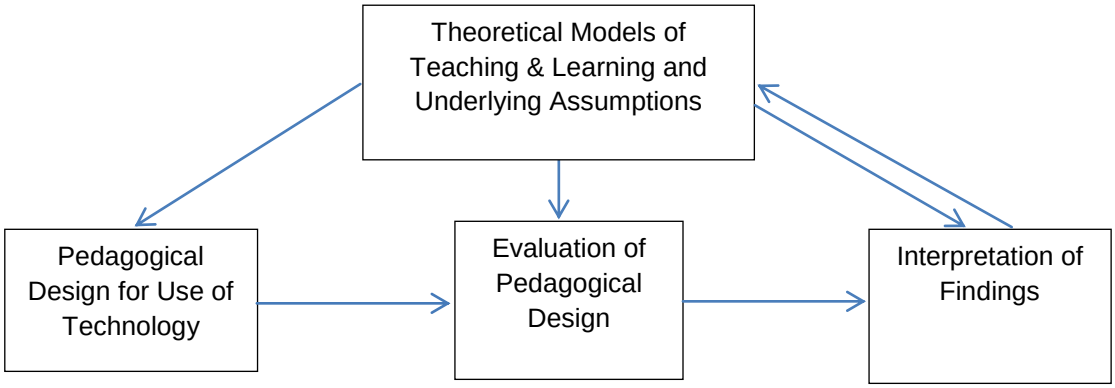

Figure 1. A practice-based model of ET design

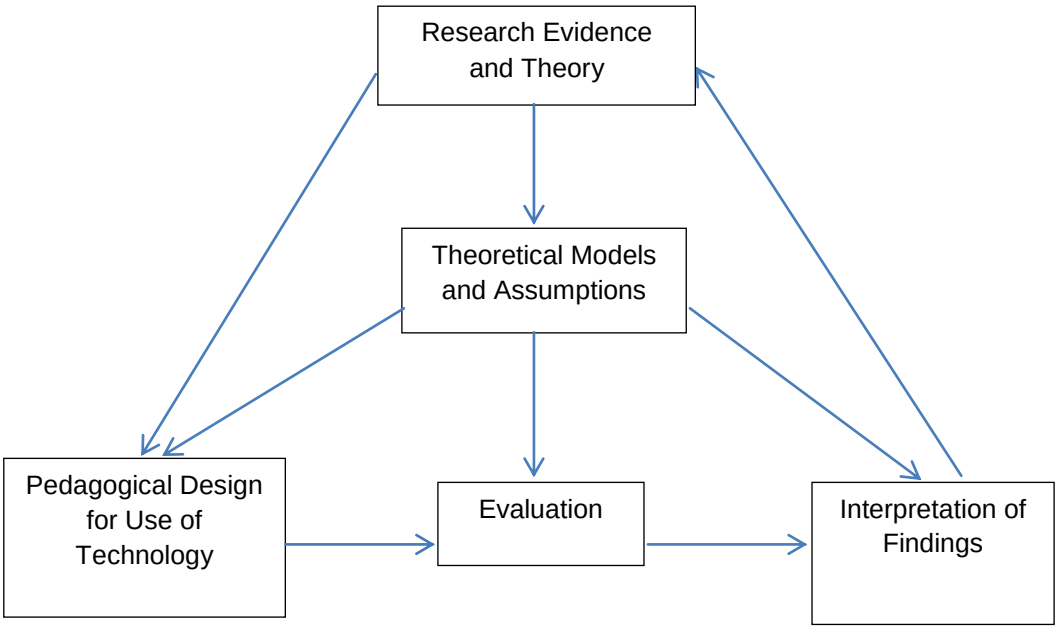

Figure 2. A partially-informed model of ET design

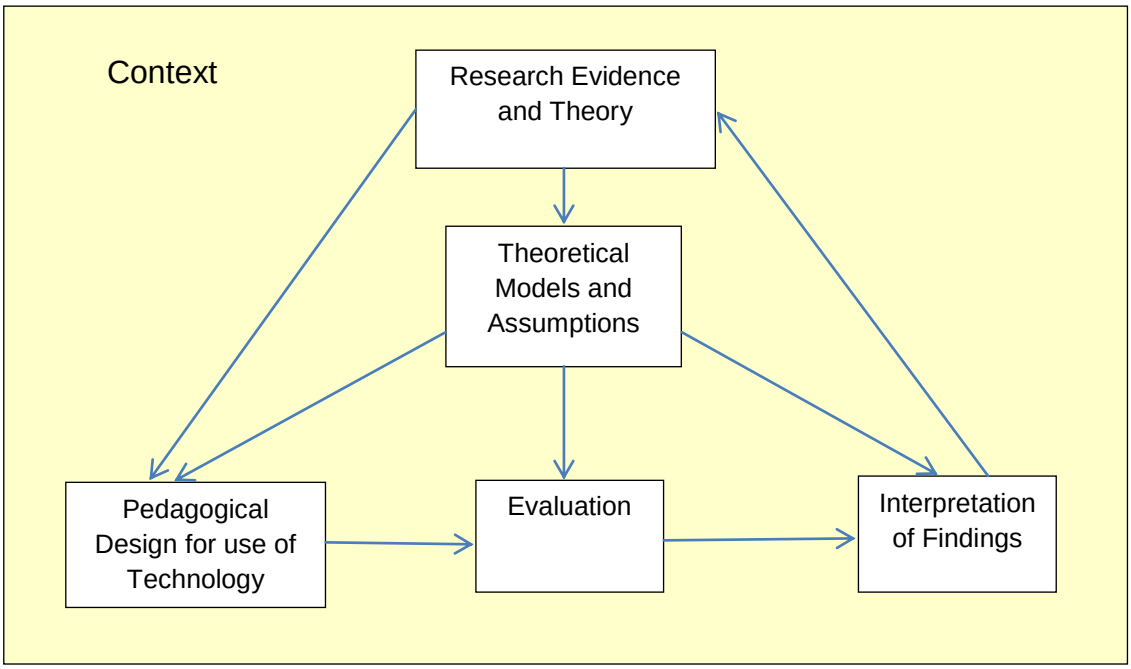

Figure 3. An evidence-informed model of learning design with technology constrained by contextual factors