

## Article type

Full paper, double-blind peer review.

## Publication history

Received: 02 January 2020. Revised: 15 June 2020.  
Accepted: 16 June 2020. Published: 25 June 2020.

## Cover image

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**Special issue** Debating the status of ‘theory’ in technology enhanced learning research | **More at** <https://doi.org/10.21428/8c225f6e.dc494046>

## A tale of two studies: TEL research and the theory-practice nexus

Julia A. McDowell<sup>1</sup>, James B. McDowell<sup>2</sup>

<sup>1</sup> Lancaster Institute for Contemporary Arts, Lancaster University, Lancaster, United Kingdom

<sup>2</sup> Faculty of Arts and Social Sciences, Lancaster University, Lancaster, United Kingdom

### Keywords

theory, practice, design-based research, DBR, video, assessment, feedback, mobile learning, outdoor settings, digital disconnect, mobile capital

### Citation

McDowell, J. A., & McDowell, J. B. (2020). A tale of two studies: TEL research and the theory-practice nexus. *Studies in Technology Enhanced Learning*, 1(1), 171-190.

<https://doi.org/10.21428/8c225f6e.dc7eba12>

### Abstract

This paper explores the role of theory in two research studies conducted through a design-based methodological lens. Rejecting the binary distinction between interpretivist and positivist positions characterised by the paradigm wars, the authors ensured both that practical interventions were guided by relevant theoretical perspectives, and that the evaluation of these interventions subsequently informed the development of theory. In the first of these cases, a series of interventions introducing video-enhanced practice to two cohorts of undergraduate students was situated against a backdrop of both social and cognitive constructivist theories of learning, leading to the development of an integrated model of video-enhanced assessment and feedback. In the second case, a broad range of theoretical developments in the fields of social-constructivist, constructionist, contextualised, experiential and place-based learning informed the design of a series of outdoor mobile learning activities intended to enhance learner engagement of children with science topic work, leading to theoretical developments around digital capital and the digital disconnect. The paper argues that through embracing a pragmatist epistemology, design-based research offers a methodological approach underpinned by a symbiotic relationship between theory and practice in technology-enhanced learning research.

# 1. Introduction to design-based research

The origins of design-based research (DBR) can be found jointly in Brown's seminal paper on the area, in which she characterises her approach through a framework of design, development, deployment and evaluation of educational innovations (1992), and in both Brown's and Collins' discussions of *design experiments* in the context of educational technology (Brown, 1992; Collins, 1992). The emphasis on the development of innovative learning environments continued as DBR matured, and later came to be defined as:

... a systematic but flexible methodology aiming to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories. (Wang & Hannafin, 2005, p. 6)

This link between theory and practice also emerged as a key theme in the work of the Design Based Research Collective, which noted that research detached from practice might fail to account for context and complexity, and that ignoring these factors risked incompleteness in the outcomes of that research (Design Based Research Collective, 2003).

The Collective asserts that design-based research is characterised by five features:

1. "The central goals of designing learning environments and developing theories or 'proto-theories' of learning are intertwined."
2. "Development and research take place through continuous cycles of design, enactment, analysis, and redesign (Collins, 1992; Cobb, Confrey, DiSessa, Lehrer & Schauble, 2003)."
3. "Research on designs must lead to sharable theories that help communicate relevant implications to practitioners and other educational designers."
4. "Research must account for how designs function in authentic settings. It must not only document success or failure but also focus on interactions that refine our understanding of the learning issues involved."
5. "The development of such accounts relies on methods that can document and connect processes of enactment to outcomes of interest." (Design Based Research Collective, 2003, p. 5)

DBR places strong emphasis on the implementation of educational interventions in classroom contexts (Collins,

1992) and other learning environments, in order to test the ecological validity of a dominant theory, and to generate new theories and frameworks for conceptualising learning. To this end, DBR aims to "create and extend knowledge about developing, enacting, and sustaining innovative learning environments" (Design Based Research Collective, 2003, p. 5), and by forging a close relationship between theoretical discussion and practical application, DBR also responds to claims of a split between theory and practice in educational research (Cobb et al., 2003).

Underpinned by a high degree of flexibility, the adoption of DBR as an overarching research methodology affords an opportunity for researchers to study the influence of learner-focused and participant-driven interventions, to contribute to the advancement of practitioner knowledge, and to produce evidence with which to drive the development of theory.

## 1.1 Criticism of design-based research as a methodology

Embracing a mixed methods approach, and a pragmatist epistemology that is open to both quantitative and qualitative data in the collection and analysis process, design-based research locates itself between positivism and interpretivism, thereby inviting criticism from both these traditional parties to the paradigm wars (Gage, 1989). It is against a backdrop of suggestions made that educational research was insufficiently aligned with practice (Lagemann & Shulman, 1999) however, that criticism of DBR emerged principally from the positivist camp.

For proponents of the positivist position and supporters of the scientific method, criticisms of DBR have focused on a perceived lack of scientific rigour. Levin and O'Donnell (1999) identify two areas where they believe DBR is susceptible to criticism, contending first that design experiments lack scientific rigour as the use of on-the-fly adjustments mean that conventional standards by which the design of an experiment is determined and fixed prior to the commencement of a study are not met.

The second criticism, connected to the first through the issue of control, is that research is conducted in live classroom situations and real educational institutions rather than in controlled laboratory conditions, making the isolation and identification of the specific component(s) of an intervention which caused an outcome or demonstrated the strongest effect problematic.

Acknowledging this, Collins noted that independent vari-

ables which it would be desirable to monitor might include:

... the technologies, software, and associated activities; the number of machines and their configuration in the classroom; the roles that teachers and students play in working with the technologies; the maintenance and other kinds of support for teachers using technology; the amount of planning time and preparation for using the technologies; and the organization of the activities in the class period. (Collins, 1992, p. 7)

It is these uncontrolled variables which lead Levin and O'Donnell (1999) to conclude that the role of findings emerging from design experiments is to inform researchers of the feasibility of conducting conventional instructional development research.

## 1.2 Arguments in defence of DBR as a research methodology

While a weak defence of these criticisms might take a conciliatory position through recognition of the place of quantitative methods in mixed methods research, a cluster of four aggressive arguments provide a stronger defence. Contending that its data collection methods are sufficiently rigorous, and citing the direct relevance of its findings for practitioners in support of the claim that DBR should be recognised as a coherent, comprehensive and self-sustaining methodology, these arguments make a claim for recognition of DBR as a fully-fledged methodology on a par with other research methodologies.

### 1.2.1 Ecological validity: life is messy

The argument from ecological validity adopts Cziko's (1989) assertions that ultimate outcomes have little relationship to initial positions, suggesting that the nature of the living environments and classroom situations inherent within educational institutions is too uncontrollable for highly controlled experiments to generate useful data. Accordingly, only educational research methods with a built-in facility to recognise and adapt for independent variables that emerge during the course of a study and which are likely to impact on the success or failure of an intervention can be described as possessing ecological validity and, as a corollary, the power to persuade practitioners.

### 1.2.2 Intercultural differences

Collins (1992) differentiates between design sciences such as aeronautics or artificial intelligence, and analytical sciences such as physics or psychology, arguing that design

experiments should be judged differently to experiments within the natural sciences, and suggesting that the "science of education" sits more naturally amongst the former grouping (p. 4). This distinction is often overlooked by critics, including Levin and O'Donnell in their claims regarding the intended meaning of both 'design' and 'research' (1999).

### 1.2.3 Susceptibility to false-positive results

Underpinning arguments for the scientific method is an assumption that this constitutes a 'gold standard' by which the quality of other data collection methods can be measured. Proponents of DBR point to both the false positive within experiments based in the scientific method, and its tendency to make invalid claims based on false premises. The 'gold standard' also assumes that findings emerging from scientifically sound research can be generalised to larger populations, however this remains subject to the process of falsifiability (Popper, 1959), whereby claims based on findings emerging from rigorously conducted clinical trials have foundered on the discovery of false positive results (cf. Ioannidis, 2005).

### 1.2.4 Applicability for practitioners

Advancing the argument that characteristics of DBR make it inherently superior (or at least equal) to other methodologies, the cyclical, iterative nature of the design and development of interventions is cited as key to ensuring a high probability of a usable product emerging as an outcome of the process, and for practitioners this is paramount.

Further, it is argued that the presence of context means that teachers and practitioners are better able to interpret the results, appreciate the outcomes and adapt the approaches emerging from design-based research than is the case with controlled experiments where any specific context is notably absent, as it is this very context which enables teachers to interpret results and assess the extent and conditions under which an intervention might find application in their own practice.

## 2. Investigating the impact of integrated video-enhanced learning interventions

The first of the two cases described in this paper saw a qualitative investigation of the impact of integrated video-enhanced learning interventions designed to promote cohort-wide engagement with assessment and feedback, and to enhance inclusivity for learners affected by dyslexia and Asperger's Syndrome, for two successive cohorts of first-year

undergraduate Computing students at a north-of-England university.

Taking as a starting point a primary research question of “*How might asynchronous video influence the learner experience of assessment and feedback?*”, an emergent research design saw the development of design exemplars for video-enhanced learning, assessment and feedback, with three design-based research cycles exploring learner-artefact and learner-tutor interactions. The first cycle introduced instructional tutorial videos, freeing up time for formative feedback; the second cycle saw formative video-feedback situated within a conversational framework, and video-enhanced assessment activities replace documentation tasks; the third cycle introduced refinements to the frequency of feedback and regular video diaries, forming an integrated model of video-enhanced learning, assessment and feedback.

Qualitative data collection employed anonymous online questionnaires, semi-structured interviews and dialogic interviewing techniques, drawing on summative results data to inform methodological triangulation of the findings. Data analysis combined thematic analysis, constant comparison and direct interpretation within a grounded theory framework (Glaser & Strauss, 1967), and illustrative cases presented the findings as thick descriptions of the influence of video-based interventions on the experience of six purposively and representatively selected participants (McDowell, 2019a). The investigation revealed that an integrated model of asynchronous video-enhanced learning, assessment and feedback can promote increased reflexivity, enhance learner autonomy and encourage meta-cognitive self-awareness, while affording greater inclusivity for students affected by dyslexia or Asperger’s Syndrome (McDowell, 2019b).

## 2.1 The underlying theoretical framework

This research emerges against an underlying theoretical framework that draws on research into both cognitive and social theories of learning, and is underpinned by a pragmatist epistemological position which follows philosopher and educator John Dewey’s twin assertions that “[the] educational process has two sides, one psychological and one sociological, and that neither can be subordinated to the other or neglected without evil results following” (Dewey, 1929, p. 291). To this end, the investigation has taken place in a broadly constructivist space, drawing on and situated between social and cognitive constructivism.

## 2.2 The relationship between theory and practice

In the domain of theory, the investigation was framed

by social constructivist theorisations around learning that include the Community of Inquiry (CoI) Framework (Garrison, Anderson & Archer, 1999) and the Conversational Framework (Laurillard, 2002), while also drawing on the body of theoretical work from the field of cognitive psychology that forms the Cognitive Theory of Multimedia Learning (Mayer, 2001).

In the domain of practice, the investigation overlapped a broad range of areas explored by contemporary research into higher education, including assessment and feedback (Bloxham & Boyd, 2007), learner engagement (Gibbs & Simpson, 2004), threshold concepts (Meyer & Land, 2005), blended learning communities (Akyol, Garrison & Ozden, 2009), applications of technology-enhanced learning to support inclusivity (Woodfine, Nunes & Wright, 2005), and video-based technology-enhanced learning interventions (Griffiths & Graham, 2009).

With the investigation drawing on both cognitive and social constructivist theorisations, the study was situated within a broad horizon formed by the CoI Framework, the Conversational Framework and Multimedia Learning. Contrasting with these deep theorisations, evidence from practice-focussed work provided the closer set scenery of specific work into themes such as assessment and feedback, inclusivity, etc. This relationship between the ‘deep’ theoretical and practice-focussed environments provided an ecological backdrop to the investigation.

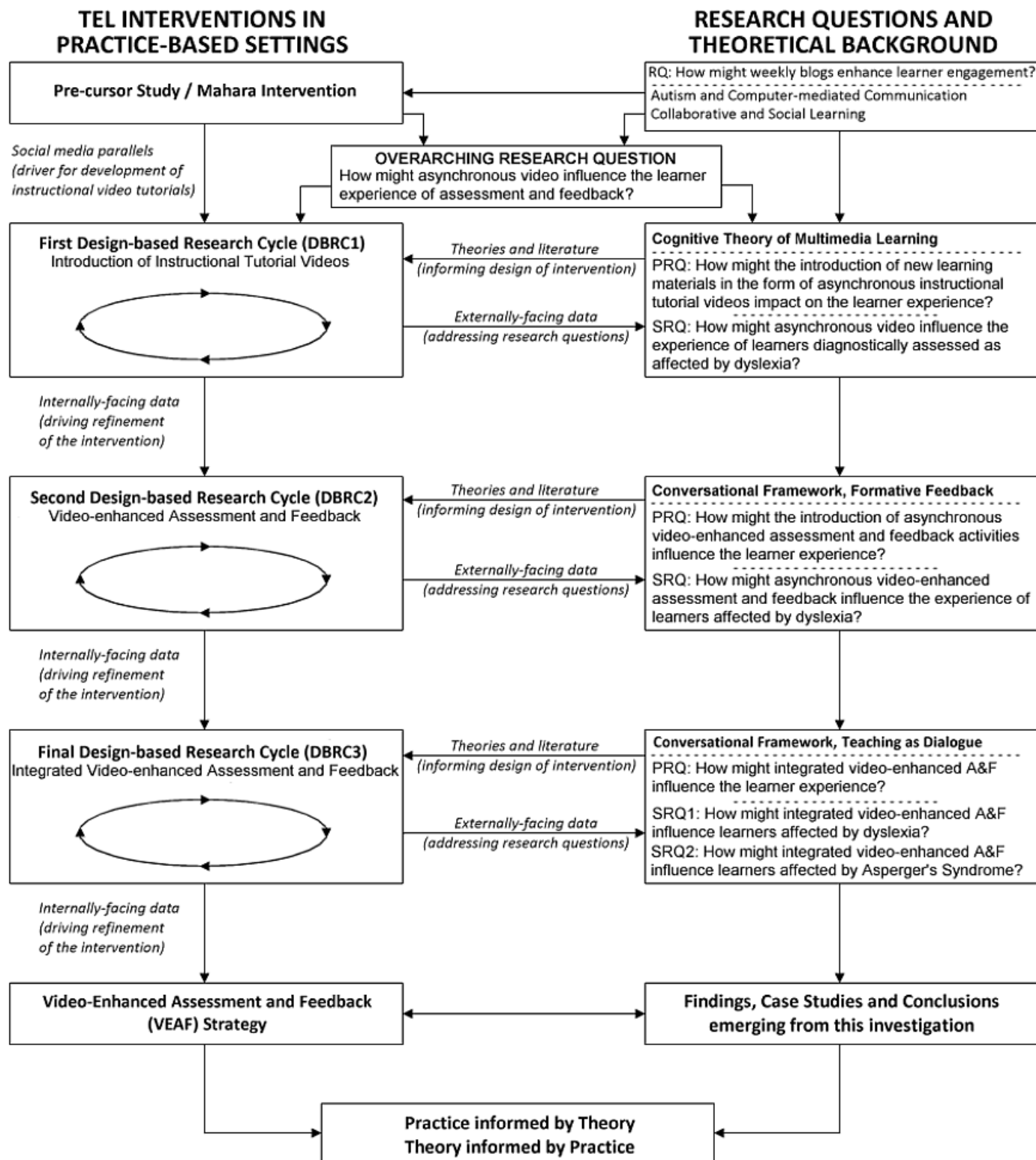
## 2.3 Data collection and analysis

In this investigation, data were collected for two fundamentally different purposes. As a study that employed a design-based research methodology wherein a series of technology-enhanced learning intervention were designed, implemented and evaluated, some work took place that can be described as ‘internally facing’. This included data collection as part of the evaluation process required to drive the research process forward, and was akin to feedback received from end-users in a software engineering exercise where the object is to develop robust systems based on user requirements.

In contrast to this internally facing data collection, there are also points where data was collected for the purposes of conducting and reporting on an educational research study which aimed to be of use to other practitioners, and this latter can be characterised as ‘externally facing’. As outlined above, DBR emphasises the importance of the interplay between theory and practice; Figure 1 illustrates the role of these two forms of data in the context of the overall research



Figure 1. The design-based research cycles, data types, and relationship between theory and practice



design, and situates them within the context of the relationship between theory and practice in this investigation.

Data collection methods employed over the course of this study included paper questionnaires, online questionnaires, direct observation, indirect observation, blog entry capture, semi-structured interviews, expert witness referrals (Yin, 2003), video-diary entries, dialogic interviewing (Knight & Saunders, 1999; Denzin, 2001), and interrogation of course results data. Further detail on the data collected within the context of the individual design-based research cycles that reflects the distinction between internal and external purpose for the collection of that data can be found in Figure 1.

Notwithstanding the distinction between data collected for internal and external purposes, the data analysis procedure described here focuses on those externally-facing data required for the purposes of addressing the study's research questions, rather than those internally-facing data collected for the purpose of addressing the development and refinement of the intervention.

Remaining consistent both with the methodological approach adopted and the dialogic nature of much of the data collection strategy employed, data analysis was conducted as an ongoing exercise in two phases. In the initial phase, the use of constant referral during the dialogic interviewing process saw data analysis take place hand-in-hand with its collection to ensure the validity of interpretation. The second phase employed the "constant comparative method" (Glaser & Strauss, 1967, p. 101), in which the coding framework and theorisations are developed in tandem. Transcribed interview data was compared with text- and video-based evidence available within an e-portfolio system to identify common categories, while correlations between these were identified through methodological triangulation of the various data sources, with theory generated through the identification of relationships between categories identified during this process.

## 2.4 First design-based research cycle (DBRC1)

Forging a synthesis of Reeves' (2000) four-step approach to design-based research (DBR) with Boehm's Spiral Model (1988) software engineering methodology, each cycle proceeded through four phases: Analysis; Design; Implementation; and Evaluation. The first cycle, DBRC1, therefore encompassed:

1. Analysis: the process of requirements capture
2. Design: the design of instructional tutorial videos (ITVs) based on those requirements

3. Implementation: the production and introduction of the ITVs
4. Evaluation: a learner-centred evaluation exercise.

### 2.4.1 Analysis phase and relationship to the literature

Situating this phase of the study against the background of established literature in the fields of cognitive psychology and research into learning difficulties, the development of the ITVs was informed by evidence-based theoretical work into the use of non-text that included the Cognitive Theory of Multimedia Learning (Mayer, 2001), and subsequent work to identify cognitive load reduction strategies (Mayer & Moreno, 2003).

The field of autism research has grown substantially in the 40 years since Wing & Gould's seminal work described how problems associated with communication, social interaction and imagination formed a Triad of Impairments (Wing & Gould, 1979), and since that time other studies have reported on how a range of autism-related traits with a bearing on this study overlap with cognitive theories of multimedia-based learning (e.g. Attwood, 2000). Of particular relevance to DBRC1, Attwood (2000) noted that learners affected by an autistic spectrum condition have experienced problems with the cognitive processing of high volumes of sensory inputs, and that a typical response to this over-stimulation of the autistic brain is to restrict the processing of information received through the auditory channel.

### 2.4.2 Pedagogic considerations influencing the design of the ITVs

The interdependence of theory and practice is key to design-based research (e.g. Brown, 1992; Collins, 1992; Reeves, 2000), and the design phase of DBRC1 highlighted how theory can inform practice in the design of a technology-enhanced learning intervention. The design of the ITVs took into account six of the seven principles forming the Cognitive Theory of Multimedia Learning (Mayer, 2001), while also acknowledging Mayer and Moreno's (2003) nine techniques for avoiding cognitive overload in multimedia instruction, and later work describing the Personalisation Effect in multimedia learning (Mayer, Fennel, Farmer & Campbell, 2004).

The Multimedia Principle and the Modality Principle are cornerstones in the argument for using asynchronous video in teaching, learning, assessment and feedback, and in conjunction with the Temporal Contiguity Principle, these form the three key principles of the Cognitive Theory of

Multimedia Learning informing the design and development of the ITVs in DBRC1.

Summarised as “students learn better from words and pictures than from words alone” (Mayer, 2001, p. 63), the Multimedia Principle highlights the general value of constructing both visual and aural mental models using dual channel processing (Paivio, 1990), without overloading the limited capacity of working memory (Baddeley, 1992).

Consistent with recent work that found audio feedback promoted strong teaching presence (TP) in learning communities (e.g. Belfer & Morgan, 2005; Ice, Curtis, Wells & Phillips, 2007), the Modality Principle asserts, “students learn better when words in a multimedia message are presented as spoken text rather than printed text” (Mayer, 2001, p. 134). To this end, off-loading was employed as a load-reduction strategy in the development of the ITVs (Mayer & Moreno, 2003).

The Temporal Contiguity Principle emphasises the benefit afforded when “corresponding words and pictures are presented simultaneously” (Mayer, 2001, p. 96), and the synchronising strategy was employed to ensure avoidance of “one or both channels [becoming] overloaded by the combination of essential processing and representational holding” (Mayer & Moreno, 2003, p. 49).

The evaluation phase of DBRC1 revealed assessment and feedback as key themes requiring further exploration in the subsequent cycle, to which we now turn.

## 2.5 Second design-based research cycle (DBRC2)

Having introduced asynchronous video into the teaching and learning process in the form of ITVs in DBRC1, the challenge for the second design-based research cycle (DBRC2) was to explore and evaluate innovative approaches through which video-based activities could be introduced into assessment and feedback. Against this background, the refined primary (PRQ) and secondary (SRQ) research questions underpinning DBRC2 therefore became:

*PRQ: How might the introduction of asynchronous video-enhanced assessment and feedback activities influence the learner experience of assessment and feedback?*

*SRQ: How might the introduction of asynchronous video-enhanced assessment and feedback activities influence the experience of learners diagnostically assessed as affected by dyslexia?*

### 2.5.1 Analysis phase and relationship to the literature

Given the emergent nature of the research design, and the importance of following the data as themes revealed themselves in the findings from each cycle, it was necessary to revisit sources of literature as part of the analysis phase for the subsequent cycle. Assessment and feedback were identified as key themes for this cycle, with feed-forward within a dialogic process playing a central role in linking DBRC1 and DBRC2.

Approached from an ontological perspective underpinned by a pragmatist epistemology, the Deweyan conceptualisation of teaching (Dewey, 1944) emphasised the role of learner-tutor dialogue, and this theme has been common in more recent literature which has examined the role of Conversation Theory (Pask, 1975), and later the Conversational Framework (Laurillard, 1996), before finding expression in the Community of Inquiry (CoI) framework (Garrison, Anderson & Archer, 2001). This latter highlighted the establishment of cognitive presence (CP), teaching presence (TP) and social presence (Garrison, Anderson & Archer, 1999) as key to facilitating the development of successful online and, later, blended learning communities.

The evaluation phase of DBRC2 revealed that the frequency of feedback and the integration of learning, assessment and feedback were key themes requiring further exploration in the subsequent cycle.

## 2.6 Third design-based research cycle (DBRC3)

With design-refinements identified in DBRC2 informing the work of DBRC3, the refined primary (PRQ) and secondary (SRQ) research questions underpinning DBRC3 asked:

*PRQ: How might an increased frequency of formative video-feedback in conjunction with regular video-diaries influence the learner experience of assessment and feedback?*

*SRQ1: How might an increased frequency of formative video-feedback in conjunction with regular video-diaries influence the experience of learners diagnostically assessed as affected by dyslexia?*

*SRQ2: How might an increased frequency of formative video-feedback in conjunction with regular video-diaries influence the experience of learners clinically diagnosed with Asperger's Syndrome?*

Against this background, the work of DBRC3 focused on the refinement of the video-enhanced assessment and

feedback (VEAF) interventions introduced in DBRC2, with the aim of increasing the frequency of VEAF activities through closer integration with the ITVs developed in DBRC1. VEAF activities designed in DBRC2 were adapted and amalgamated in the process of integrating these within a holistic system of video-enhanced learning, assessment and feedback, however no additional new VEAF techniques were introduced in DBRC3.

While design and implementation remained clearly differentiated during DBRC1, where the focus was on the development of artefacts such as the ITVs, this distinction began to blur in DBRC2 in the context of developing techniques such as the video-feedback loop (VFL), where the phases of design and implementation phases became less distinct. Exploring the refinement of those techniques into an integrated system for video-enhancement of learning, assessment and feedback, and, remaining both consistent with the design-based methodological approach and responsive to the emergent nature of the research, in DBRC3 it was the differentiation between the analysis and design phases of the work that became blurred. In keeping with the broad framework of the earlier cycles, a single phase of analysis and design-refinement was therefore followed by an implementation phase, and subsequently a final phase of evaluation.

### 2.6.1 Relationship to the Literature

As outlined above, DBRC3 was primarily investigative and evaluative in nature, and no new techniques were developed during this cycle. Against this background, as the work of DBRC3 was grounded in literature discussed previously, no major new sources were introduced during this cycle.

## 2.7 Discussion and Conclusions from Case 1

This investigation took a position in the field of educational video and multimedia between those held by Mayer (2001), whose stance is primarily informed by the field of cognitive psychology, and Koumi (2006), whose perspective stems from a background in broadcast production, while also building on Laurillard's (2002) theorisations around the place of dialogue in teaching and learning. In so doing, it contributed to the field of TEL research through the development of a dialogic framework incorporating video-enhancement of learning, assessment and feedback, which is grounded in the context of an empirically-evidenced design-based study conducted within an authentic higher educational setting (McDowell, 2014).

As a practice-based investigation conducted within

this authentic context, this study avoided those criticisms levelled at Mayer's work in connection with experiments conducted in laboratory settings, while also updating and augmenting the CTML through its consideration of the medium of video previously overlooked in his work. The development of an integrated framework in which video facilitates dialogic exchanges between learners and tutors around feedback directly challenged Koumi's view of video as a one-way medium (2006), while also challenging Mayer's insistence on the avoidance of on-screen text (Mayer, 2001).

This integration of both theoretical and practice-derived elements emerging from the work of Mayer (2001), Koumi (2006) and Laurillard (2002) within the dialogic framework for video-enhanced learning, assessment and feedback therefore formed a contribution to knowledge made by this investigation.

### 2.7.1 Summary of contributions to theory and practice

The findings of this investigation concurred with previous research suggesting that students learn better from animation and text than from text alone (Mayer, 2001), that students learn better from animation and spoken text than from animation and on-screen text (Mayer, 2001), and that students learn better where teaching and learning take place within a dialogic framework (Laurillard, 2002).

This research took forward the work on cognitive theorisations around the use of multimedia in learning by extending the use of audio-visual materials within both assessment and feedback. It did so through extending the application of the Cognitive Theory of Multimedia Learning (Mayer, 2001) beyond simply informing the development of learning materials for passive consumption, applying it in an active learning context (Bonwell & Eison, 1991), such that learners become both producers and consumers of video within a conversational framework (Laurillard, 2002).

This research also offered insight in the field of methodological theory, providing comment on the appropriation and repurposing of principles found in software engineering and development models to guide the development of TEL interventions within the broad DBR approach, and on the use of dialogic interviewing (Knight & Saunders, 1999) as a dual-purposed tool to collect qualitative data while simultaneously fostering a participatory form of DBR as the methodological approach.

This case also contributed to ongoing research into asynchronous video (e.g. Collins, Cook-Cottone, Robinson &



Sullivan, 2005; Stannard, 2007; Kerr & McLaughlin, 2008; Griffiths & Graham, 2009; Cheng & Chau, 2009; O'Donoghue & Cochrane, 2010; Jordan, 2012; Mathieson, 2012; Thompson & Lee, 2012; Mathisen, 2012; Crook, Mauchline, Maw, Lawson, Drinkwater, Lundqvist, Orsmond, Gomez & Park, 2012; Séror, 2013) by offering a specific example of an integrated system of video-enhanced learning, assessment and feedback designed for a clearly defined user group.

While the findings of the investigation should not be taken as immediately generalisable to larger sample sizes, to the greater population, or to other subject areas, the range of case studies provided also enabled practitioners to explore these video-enhanced techniques in their own contexts.

Finally, this case formed an example of how an investigation situated within a theoretical framework such as that outlined earlier can bridge the paradigmatic divide, knitting together elements of both cognitive and social theories of learning.

### 3. Navigating the use of multiple, overlapping learning theories within a DBR study

This second case discusses a qualitative investigation into the impact of mobile learning activities designed to promote learner engagement in primary-aged children working on science topics in outdoor settings for three cohorts of pupils at a north-of-England primary school.

Drawing together two research activity streams, a series of mobile learning interventions designed for use in outdoor settings were developed, evaluated and refined over the course of eight research cycles. The *discovery-based* learning activity stream aimed to encourage learners to explore particular themes within an outdoor setting, while the *production-focused* learning stream saw learners generate video-clips and eBooks in response to a directed activity.

Employing qualitative methods, data were collected from a variety of sources, including video-recorded observations, semi-structured interviews with teachers, focus groups with children and learner-generated digital artefacts, while analysis was conducted using thematic analysis and direct interpretation within a grounded theory approach (Glaser & Strauss, 1967).

#### 3.1 The underlying theoretical framework

Adopting a design-based methodological approach, this study responded to calls to address both nature deficit

disorder (Louv, 2009) and the digital disconnect (Erstad & Sefton-Green, 2013), drawing on a theoretical framework which combined learning theories including place-based learning (Zimmerman & Land, 2014), contextualised learning (Rikala & Kankaanranta, 2014), kinaesthetic learning (Pruet, Ang & Farzin, 2016), constructionist learning (Papert, 1980; Zimmerman & Land, 2014), experiential learning (Lai, Yang, Chen, Ho & Chan, 2007), child-centred learning (Dewey, 1938) and cross-contextual learning (Nouri, Cerrat-Pargman, Rossitto & Ramberg, 2014), with theorisations around learner engagement (Fredricks, Blumenfeld & Paris, 2004), flow theory (Csikszentmihalyi, 1997), and Digital Capital (Park, 2017).

#### 3.2 The relationship between theory and practice

Over a period of three years, a series of design-based cycles were conducted in collaboration with 5 teachers and 480 children at a single primary school, with findings from each cycle both driving the refinement of subsequent cycles, whilst also feeding back into theory (Cobb et al., 2003). Given the 'messy' conditions (Brown, 1992) not only of working with children and teachers in a primary school, but also of working with children in an outdoor setting using mobile devices, the capacity for getting swamped by the sheer number of learning theories that might have relevance for the study was immense. While an initial review of the literature uncovered a variety of flavours of mobile learning, it did not uncover a single 'mobile learning theory' that adequately reflected the study's aims. It did, however, expose a number of learning theories of interest, namely:

- *socio-constructivism* - where new ideas or concepts are actively co-constructed by learners based on previous and current knowledge;
- *constructionism* - where learners build knowledge by creating shareable artefacts;
- *experiential learning* - where knowledge is created through the "transformation of experience" (Kolb, 1984, p. 41);
- *contextualised and place-based learning* - where learners learn in authentic settings that have personal meaning;
- *cross-contextual learning* - where learning is on-going and situated across a variety of settings;
- *kinaesthetic learning* - where learning is achieved through physical activity and the use of touch, sight and other senses;

- *flow theory* - where learners are deeply engaged and absorbed in a task that is “intrinsically enjoyable” (Shernoff, Csikszentmihalyi, Shneider & Shernoff, 2003, p. 160).

In keeping with the flexible and emergent nature of DBR, this list was refined and augmented as the study progressed, and also led to consideration of notions relating to: (i) *distributed cognition* (Pea, 1993; Fischer, 2003), which proposes that cognitive processes do not happen in isolation in one individual, but are dispersed amongst other individuals, tools, settings and other resources; (ii) *the learning continuum*, where learners are provided with a “seamless” learning experience (Wong & Looi, 2011, p. 2) that connects learning across contexts (Kuh, 1996); (iii) *the digital disconnect*, where a teacher’s lack of skill, knowledge or confidence in using digital tools to innovate in the delivery of the curriculum can act as a barrier to the adoption of technology in the classroom (Erstad & Sefton-Green, 2013).

Responding to Cobb et al.’s (2003) insistence that the theory “should do real work” in DBR undertakings (p. 10), in addition to feeding into refinement of subsequent DBR cycles, findings from this study fed into *practice*, through informing the drafting of a set of ‘mobile learning’ principles for practitioners, and into *theory*, through extending or building on the work of previous studies.

### 3.3 Using Pilot Studies to determine theories of relevance

Accurately determining which theory might best inform the design of outdoor mobile learning activities (MLAs) for children proved unfeasible at the outset of the study, primarily due to a lack of experience in the field. An early opportunity was therefore taken to design a series of pilot activities to be trialled with a group of 17 Beaver Scouts (6-8-year olds) and a Year 3 class (7-8-year olds) at a local primary school, both to gain experience and to act as a feasibility study. To illustrate how the design of one such activity informed the selection of the dominant learning theories in subsequent DBR cycles, one sample activity from these pilots is summarised below:

#### 3.3.1 Design of Pilot Activity: A QR-code Nature Trail for Beaver Scouts

The pilot activities for the Beaver Scouts were to form part of a ‘sleepover camp’, and were intended to be enjoyable whilst enabling the scouts to demonstrate they had sufficient understanding and skills to earn their Information Technology and Environment badges. Eight iPods were

distributed among seventeen Beaver Scouts (11 boys and 6 girls), working in groups of two or three; the activities took place in a local nature reserve (pseudonymised as ‘Greendale Orchard’), and used two *mifi* devices to provide internet coverage.

A few previous studies have reported on the effective use of Quick Response codes (QR-codes) by children in an outdoor environment (Rikala & Kankaanranta, 2012; Lai, Chang, Wen Shiane, Fan & Wu, 2013; Land & Zimmerman, 2015), with all highlighting the motivational aspects of using this technology. Following a successful trial of the internet coverage provided by the *mifis* in the reserve, and in keeping with the ‘fun’ aspect of the camp, an adaptation of a *treasure hunt* (still widely used as a popular party game with primary-aged children in the U.K.), underpinned the design of the first activity, which took the form of a QR-code Nature Trail. Here, the expectation was that the scouts would work together in groups of 2 or 3, using an iPod to scan a QR-code to reveal a photographic clue of a location in the reserve where they would find their next QR-code.

#### 3.3.2 Evaluation and Findings from the Pilot MLA

Findings from this seemingly simple activity revealed the complexity of issues that can arise when working with groups of children in an outdoor setting, ranging from collaboration problems or a lack of appropriate ‘scaffolding’ of an activity by adult helpers (Reiser & Tabak, 2014), to prevailing weather conditions (Knez, Thorsson, Eliasson & Lindberg, 2009) and the impact of competition on an activity (Wyeth, Fitzpatrick, Good, Smith, Luckin, Underwood, Kher, Walker & Benford, 2008). With this latter, the desire to win overshadowed a fundamental aim of the session, namely to encourage engagement with nature, where a requirement to take photographs as evidence was often neglected in the race to the finish.

While acknowledging that the setting of these pilot activities was less formal than would be found in a school context, such findings guided a further review of the literature and the selection of those learning theories likely to be of value in the design of subsequent activities within the study. Findings from this sample activity, for example, not only acknowledged the key role played by properly-primed adult helpers, but also indicated a need to further explore tenets of child-centred, kinaesthetic, contextualised and collaborative learning, to help support younger children in getting the most out of a learning activity.

### 3.4 Theory informing Design and Practice informing Theory: a trip through an indicative DBR cycle

Following the pilots, and in line with the aim to collaborate closely with teachers to develop and evaluate authentic activities that directly related to the National Curriculum, the initial design of an MLA was guided by those learning objectives highlighted by teachers as key attainment targets; a series of face-to-face and email discussions subsequently resulted in an agreed activity specification, underpinned by a range of theoretical learning approaches considered appropriate for the age group and nature of the task. An illustrative example is described below.

#### 3.4.1 Refinement and Evaluation of the QR-code Nature Trail activity

##### *Theory feeding into Design*

A scoping exercise with two Year 2 (Y2) teachers resulted in some key attainment targets being specified for an MLA for two classes of 30 children aged 6-7 years old, namely map-reading skills, awareness of seasonal changes and the ability to:

- Explore and compare the differences between things that are living, dead, and things that have never been alive;
- Identify and name a variety of plants and animals in their habitats. (Department for Education, 2014, p. 174)

A review of the literature had highlighted two studies of particular interest: (i) a study by Lai et al. (2007), which found that using the *zoom* function of the camera app of a mobile device to focus in on plants heightened observation in 10-11 year old school children, and that taking photographs of plants while outdoors aided recall; and (ii) Zimmerman and Land's (2014) discussion of employing mobile learning initiatives to support science learning in outdoor settings, where they describe three 'empirically-derived' guidelines for the design of such activities:

1. Facilitate participation in disciplinary conversations and practices within personally-relevant places;
2. Amplifying observations to see the disciplinary-relevant aspects of a place;
3. Extending experiences through exploring new perspectives, representations, conversations, or knowledge artifacts. (Zimmerman & Land, 2014, p. 77)

The findings from these studies directly fed into the design of this MLA, particularly in the use of a mobile device's camera app to heighten observation and to aid recall, and the use of context and an authentic setting to promote disciplinary conversations and observations.

It was therefore agreed that 5 or 6 QR-codes would be situated in various locations around one half of the reserve, with a question revealed by scanning the code that related to the physical location of the code (for example, situating the QR-code near a rotting log, with a question asking "Where might you find woodlice? What do you think they eat?"), alongside an instruction to take photographs as evidence, with these latter to be used in a follow-up class activity.

While no previous studies had been found where QR-codes had been used to support map-reading skills, an existing map of the reserve annotated with the locations of the QR-codes (see Figure 2) had been used to good effect in the pilot nature trail activity. A similar approach was therefore adopted for the current MLA within this formal learning context, offering an opportunity to gather empirical evidence that might inform the development and refinement of theory.

**Figure 2. Map of nature reserve annotated with locations of QR-codes**



##### *Empirical Evidence: Practice feeding into Theory*

During the activity, several children were observed demonstrating a growing understanding of how to use the map to locate the QR-codes, for example, one child had been looking intently at the map who then commented excitedly:

**Figure 3. Y2 child showing location of QR-code**



*“So this is .... OK. This one [pointing at the QR-code] is ... this one!” [pointing to the relevant question mark on map] (see Figure 3), and then went off to share his understanding with his group members: “Look! I know where this is! I know where this is!”*

The format of the questions shown by scanning the QR-codes appeared to be appropriate for this age group, and instead of rushing to find the next code, as had happened in the pilots, analysis of the history logs from the scanner app and the photographs taken ‘as evidence’ indicated that all groups had scanned the 6 codes and had taken the time to take at least one photograph in response to the question posed. Some of these included well-focused close-ups and others were responses to the more open questions, for example, relating to seasonal changes (see Figure 4). This suggests that the design of the MLA, and particularly its emphasis on child-centred and kinaesthetic learning, had been effective in promoting learning engagement with the activity.

The questions on the QR-codes often led the children to ask further questions, for example, one child, having just taken a photograph of crocuses, asked what “*the funny little yellow things inside*” were, zooming out the photograph she had taken on the group iPad to illustrate (c.f. Lai et al., 2007); another asked whether birds ate “those red berries” (rosehips); and another commented that the ‘bug hotel’ (a purpose-built structure to house insects during the winter) was rotting, which prompted a discussion between the children that certain insects, like woodlice, actually eat wood.

In line with Zimmerman and Land’s second design guideline that mobile devices can be useful in “*amplifying observations to see the disciplinary-relevant aspects of a place*” (2014, p. 77), these examples all indicate that contextualised QR-code trails can serve as a useful focal point to fire and target this age-group’s curiosity in outdoor settings.

In terms of the general level of environmental knowledge and understanding shown during the activity, it was clear that many children did not know the names of parts of common trees and plants, (for example, catkins, rosehips or ivy), and, echoing Carey’s (1985) findings that young children do not consider plants to be living things, were having difficulty in differentiating between what was living and dead, and what was ‘asleep’. In one group under observation, the

teacher helped scaffold his group’s understanding of this concept by asking them what they thought was different about trees in summer compared to the current season (winter). After a period of thought, one boy excitedly put his hand up to answer: “*They’ve got leaves, they’ve got leaves, and in the winter they don’t have leaves!*” The teacher went on to ask the group if all trees and plants go to sleep in winter and asked them to look around. This particular QR-code had been placed near ivy and holly as well as deciduous trees to help contextualise the question, and the children’s understanding was therefore further scaffolded in heightening their awareness that only some plants and trees are dormant in winter. This echoes Rikala and Kankaanranta’s (2014) findings of the distinct learning opportunities offered by contextualised learning, and serves to illustrate how findings from DBR studies can provide empirical evidence to corroborate previous research.

In his evaluation of the activity, the child’s teacher later contrasted how the children in his class had been “*mildly-interested*” when participating in a map-reading activity using only the paper version of the map, whereas: “*The QR-code one is probably the most enthused I’ve seen them - they were excited about what they were doing, because of the challenge of finding something... it gave more purpose to using the map.*” This highlighted the potential of harnessing the motivational aspects of using QR-codes to promote map-reading skills, and was noted in subsequent iterations of this activity with different classes, different teachers and a different year group of children aged 8-9 years. While it is acknowledged that the activity took place with the same participant school, thereby limiting its generalisability, this replication of findings suggested there was sufficient empirical evidence to feed back into theory.

### 3.5 Summary and Conclusions of Case 2

Design-based research (DBR) justified its selection as the underlying methodological approach to address the research questions in this study, due to its particular emphasis on: (i) maintaining strong collaboration with practitioners in naturalistic settings (e.g. Barab & Squire, 2004); (ii) working in iterative design research cycles to develop, evaluate and refine learning interventions (DBRC, 2003); (iii) its opportunistic, flexible and emergent approach (e.g. Kucirkova, 2017); (iv) enabling the incorporation of a variety of methods and techniques (Looi et al., 2011); and (v) generating theory and practice-informed design principles of use to practitioners (e.g. Wang & Hannafin, 2005).

Situated against a rich and varied theoretical backdrop as detailed in section 3.1, a series of design principles for MLAs



**Figure 4. Photographs taken by Y2 children in response to QR-code questions**

were derived from evidence gathered during eight design-based cycles, where analysis of data led to the identification of relationships between codes and categories (such as correlations between the use of child-centred learning and learner enthusiasm, for example). Any recurring patterns or themes that emerged during the analysis process that demonstrated a high degree of confidence between the theoretical claims made and the evidence collected were fed into the generation of the principles.

Serving to illustrate how DBR studies can also feed back into theory (McDowell, 2018), the DBR cycles in this investigation yielded further evidence and support for both Vygotsky's (1987) and Bruner's (1961) theorisations on the place of language in childhood learning, while also delivering empirical evidence of the effectiveness of mobile learning activities in promoting learner engagement in outdoor settings.

The research also extended the work of: (i) Zimmerman and Land (2014) on the value of constructionism and place-based learning; (ii) Kearney and Schuck (2006) on the motivational aspects of student-generated digital video; and (iii) Kearney (2011) on digital storytelling, by producing empirical evidence of the influence of MLAs that incorporate learner-generated video and eBooks on learner engagement. While acknowledging the value of constructionist learning in deepening children's understanding (Papert, 1980; Zimmerman and Land, 2014), the research also built on Sharples and Pea's (2014) and Nouri et al.'s (2014) theorisations on cross-contextual learning and issues relating to difficulties in conceptual thinking in complex outdoor settings.

In addition, the study built on Rikala and Kankaanranta's (2014), Zimmerman and Land's (2014) and Pruet et al.'s (2016) work on contextualised learning, highlighting that MLAs that are underpinned by child-centred and kinaes-

thetic learning approaches can foster high levels of learner engagement and promote disciplinary conversations in primary-aged children aged 6-8 years. It also supported the work of Brown (1992) and Nouri et al. (2014) in acknowledging the need to balance a child-centred approach with adequate scaffolding.

The research also extended Fredricks et al.'s (2004) work on learner engagement, developing both a coding framework and a relative measure of engagement, the application of which produced empirical evidence that highlighted *enthusiasm* as the primary marker for emotional engagement, being *on-task* for behavioural engagement, and *learner autonomy* and *'focusing in'* for cognitive engagement. As a corollary, the research also supported the work around *flow theory* originally conceived by Csikszentmihalyi (1997), examining this theoretical construct in the novel context of mobile learning within an outdoor setting, while producing empirical evidence which identified flow as emerging through a synergistic convergence of positive emotional, behavioural and cognitive states, highlighting a relationship between the work of Csikszentmihalyi (1997) and Fredricks et al. (2004).

Finally, responding to secondary research questions that emerged relating to the digital disconnect between teachers and technology, the study extended the possibilities of contemporary theorisations around the notion of capital (Bourdieu, 1997), by building on recent work in this area which has seen the development of the concept of digital engagement into a model of *Digital Capital* (Park, 2017). Repurposing the framework through which Bourdieu originally presented the notions of economic, cultural and social capital (1997), this study introduced the concepts of technological and educational capital to encompass the experience of primary-aged children within the domains of *Home*, *School* and *Classmates*, and took steps towards

the development of a model of *Mobile Capital* (McDowell, 2018).

## 4. Conclusion

This tale of two studies has aimed to highlight the crucial role played by methodology in demonstrating the relationship between theory and practice in TEL research, and it is hoped that this discussion has illustrated the symbiotic relationship between theory and practice within design-based research investigations.

As a strongly human-focussed investigative field, it is self-evident that much TEL research necessarily takes place in those messy conditions (Brown, 1992) wherein the very variables which the traditional scientific method seeks to control form that same rich context which practitioners require to understand the applicability of the research to their own environments.

The two cases outlined in this paper have demonstrated how theory has directly and robustly informed the design of a range of TEL interventions, which in turn, through their evaluation and refinement, have generated empirical evidence with which to challenge, corroborate or extend those theories.

While the development of theory in TEL *can* take place in a contextual vacuum, establishing anything beyond the logical and conceptual validity of that theory requires it to be tested and scrutinised against real-world empirical evidence. Where such theory relates to outcomes achieved by learners, the evidence required for corroboration inevitably emerges against a backdrop of those messy conditions which constitute practice, and so it can be argued that the refinement and advancement of theory in the field of TEL is therefore dependent upon the theory-practice nexus.

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## Acknowledgements

This paper draws on research undertaken as part of two doctoral programmes in the Department of Educational Research at Lancaster University.

## About the authors

### Julia A. McDowell



Julia McDowell is an Associate Member of the Centre for Technology Enhanced Learning at Lancaster University, where she completed her PhD through the Department of Educational Research. With over 20 years' experience as a researcher-practitioner in the field of TEL, Julia has previously worked in various capacities at the Universities of Durham and Huddersfield, and with Goldsmiths College, London. In her current role as Senior Research Associate for the Cinema Memory and the Digital Archive project in the Lancaster Institute for the Contemporary Arts, Julia is combining qualitative data analysis with web programming skills to make previous work in the field of 1930s cinemagoing and memory studies accessible to a wider audience.

Julia's research interests focus on the affordances of mobile devices in non-traditional learning spaces, learner engagement, the digital disconnect, and the concept of Mobile Capital.

✉ Email: [j.mcdowell1@lancaster.ac.uk](mailto:j.mcdowell1@lancaster.ac.uk)

ORCID: [0000-0001-5976-0408](https://orcid.org/0000-0001-5976-0408)

### James B. McDowell



James McDowell is an Associate Member of the Centre for Technology Enhanced Learning at Lancaster University, and completed his PhD through the Doctoral Programme in e-Research and Technology Enhanced Learning in the Department of Educational Research. Having previously held senior management roles at the University of Huddersfield as the Director of Teaching and Learning in the School of Computing and Engineering, James is now the Principal of Graduate College at Lancaster, where he also provides leadership around student experience across the Faculty of Arts and Social Sciences.

James's research interests span a range of areas within the field of TEL, encompassing inclusivity for students affected by dyslexia and Asperger's Syndrome, technological enhancement of the assessment and feedback process, and gamification in teaching and learning.

✉ Email: [james.mcdowell@lancaster.ac.uk](mailto:james.mcdowell@lancaster.ac.uk)

ORCID: [0000-0002-1077-3213](https://orcid.org/0000-0002-1077-3213)

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