New Modes of Technology-enhanced Learning: Opportunities and challenges

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A Harnessing Technology research project by the University of Nottingham and Sero Consulting Ltd, in association with Becta

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Executive summary

Between April 2008 and March 2009, the project carried out research, in three iterative phases, into the future of learning with technology. This research will inform the next stage of the Becta Harnessing Technology strategy with respect to learning and teaching.

The research has drawn from, and aims to inform, all UK education sectors: Early Years, schools, 14–19, children's services, higher education and further education, including work-based learning, personal and community development learning and offender learning.

This report synthesises the findings and insight from the research in order to propose a range of new modes of learning with technology that are educationally desirable and which are now, for the first time, becoming feasible for adoption at scale. Based on the evidence collected through the project, we also identify those factors which we suggest need to be addressed by Becta and its partner agencies if wide-scale adoption is to become a reality. We argue that while it is necessary to continue to identify and support innovation and new practices in technology-enhanced learning, at the same time strategies should be formed to enable these new modes of learning to become embedded across the system.

Through the project, we have engaged in a range of evidence-gathering activities including:

- themed 'horizon scanning' led by subject matter experts
- a number of expert reference group events
- action research commissions
- case studies
- 'sandpit' events to investigate particular technologies.

We have also developed a conceptual framework for learning, which describes a range of learning interactions and the circumstances that mediate them, and tested it with our expert groups. This framework can be used to analyse any scenario of learning and also to generate new modes of learning. Through the use of the framework, it is possible to identify the specific ways in which technology can be used to develop new modes and strategies of learning.

We propose four new modes of technology-enabled learning, each of which invokes one of four prevailing perspectives concerning the experience of learning. These perspectives are learning as:

- the private experience of study
- a dialogue involving a more informed other person
- realised through participation in a community

- a situated experience that requires integration across formal and informal settings.

The four proposed new modes of learning interaction that correspond with these perspectives are:

- live reflection: stimulating self-awareness in personal study
- rich feedback: promoting learning dialogue within formative assessment
- learning community trails: expanding and exploiting collective memory
- gaming to learn: subject exploration in massively multi-player games.

The task facing Becta and its partners, however, is not just to imagine new and desirable modes of learning. It is also to develop strategies that can turn new modes of learning into operational reality, by moving beyond the situation where innovation around learning occurs in isolated pockets. The challenge is to identify how such new modes can become widespread and embedded across the education system.

From the evidence collected, we have identified the key strategic issues to address if each of the system outcomes of the Harnessing Technology strategy are to be achieved and new modes of learning adopted at scale and embedded in system-wide educational practice. The strategic issues are as follows:

- Leadership for innovation: specifically, how leaders can become engaged in adopting and embedding innovation in teaching and learning.
- Professional knowledge and fluency: developing the professional understanding that teachers and other enablers of learning need if they are to implement new modes of learning with technology. This goes well beyond technical competence, to embrace understanding of new pedagogical approaches and the new relationships with students, and the new ways of orchestrating learning that these modes embody.
- Digital learning and thinking skills: the need for learners – who are, in many cases, already confident users of digital technology for a limited range of purposes – also to become able and confident users in pursuit of their learning. This requires both a deeper understanding of the technology and also its appropriate use in learning contexts.
- The opportunity cost of safety: the need to ensure that the vital requirement to protect young and vulnerable learners online does not block desirable and increasingly necessary uses of technology in support of learning.
- New assessment strategies: the need to develop not just new ways of assessing using technology, in both formative and summative approaches, but also to design ways of assessing the new learning that a curriculum for the 21st century increasingly demands.

We argue that the conjunction of developments, both within the education system and external to it, provide a unique and vital opportunity to tackle these barriers, and that they must be tackled if innovation is to happen at more than a local scale.

Introduction

Between April 2008 and March 2009, the project carried out research in three iterative phases into the future of learning with technology. This research will inform the next stage of the Becta Harnessing Technology strategy with respect to learning and teaching.

The research has drawn from and aims to inform all UK education sectors: Early Years, schools, 14–19, children's services, higher education (HE) and further education (FE), including work-based learning, personal and community development learning and offender learning.

This report aims to synthesise the findings and insight from this research to propose a range of new modes of learning with technology, and to highlight the areas of policy and practice that need to be addressed if new modes of learning are to extend beyond individual enthusiasts and localised pockets of innovation. Our findings should inform UK policy makers and education leaders in government, Becta, and their strategic partners, as well as leading practitioners in all sectors of education and training.

The first phase of the project, described in our first-term report,[1] identified technological, socio-economic, political and educational trends that are having an impact on the development of technology-enhanced learning and, in particular, on the achievement of the system outcomes set out in the Harnessing Technology performance framework.[2] The analysis of trends and disruptions, which has continued throughout the project, is key to identifying factors that are expected to have an effect on system outcomes.

The second phase focused on discontinuities or interruptions to these trends. It analysed those factors that seem likely, over the three- to five-year time-span of Harnessing Technology, to disrupt the prevailing trends or otherwise to affect, favourably or unfavourably, the desired system outcomes. These factors were set out in our second-term report.[3]

During the final phase for our first year, we used the evidence collected from expert reference group meetings and interviews, case studies, action research commissions and other activities to develop a conceptual framework within which we could develop proposals for new modes of learning. This framework, described later in this report, allows all propositions for new modes and strategies for learning with new technologies to be situated and hence evaluated for desirability and plausibility.

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[1] Chowcat, I., Jones, I., Phillips*, B.* and Popham J. (2008) *Harnessing Technology: Preliminary identification of trends affecting the use of technology for learning*, Becta.
[2] See Becta (2008) *Harnessing Technology: Next generation learning 2008–14*.
[3] Becta (2008) *Discontinuities with current practice which affect the use of technology for learning*.

As outlined in our most recent separate trends analysis report,[4] the objectives of Becta's Harnessing Technology strategy for curriculum and pedagogy are set against the context of a rapidly changing society and technology. Our research identifies six cross-cutting trends that are having an impact on technology-enhanced learning. They are:

- Ubiquitous mobile learning is being continually augmented by the richness of devices and applications available
- The growth of the personal web
- The increasing dependence on cloud computing
- A gathering momentum towards redesign of the curriculum
- Widespread use of personally owned laptops and mobiles in formal education is moving through the sectors from university to FE, and starting to appear in secondary education
- Support for learning design and the orchestration of learning is growing in the HE, FE and adult learning sectors.

This background provides the opportunity for developing new modes of learning that are enabled by technology and are educationally desirable, and which are now, for the first time, becoming feasible for adoption at scale.

We also identify those factors that Becta and its partner agencies need to address if wide-scale adoption is to become a reality. We argue that while it is necessary to continue to identify and support innovation and new practices in technology-enhanced learning, at the same time we need to promote strategies that tackle the key barriers to these new modes of learning becoming embedded across the system.

[4] LSRI/Sero Consulting (March 2009) Trends analysis, unpublished.

Summary of evidence

In this section, we summarise empirical evidence and desk research generated during the first year of the project. We provide an overview of the evidence types and how they were collected, and indicate the key findings and analyses. The diverse forms of evidence and findings are then reviewed in relation to the Harnessing Technology system outcomes.

Overview – how we collected evidence

Figure 1 shows how we collected evidence.

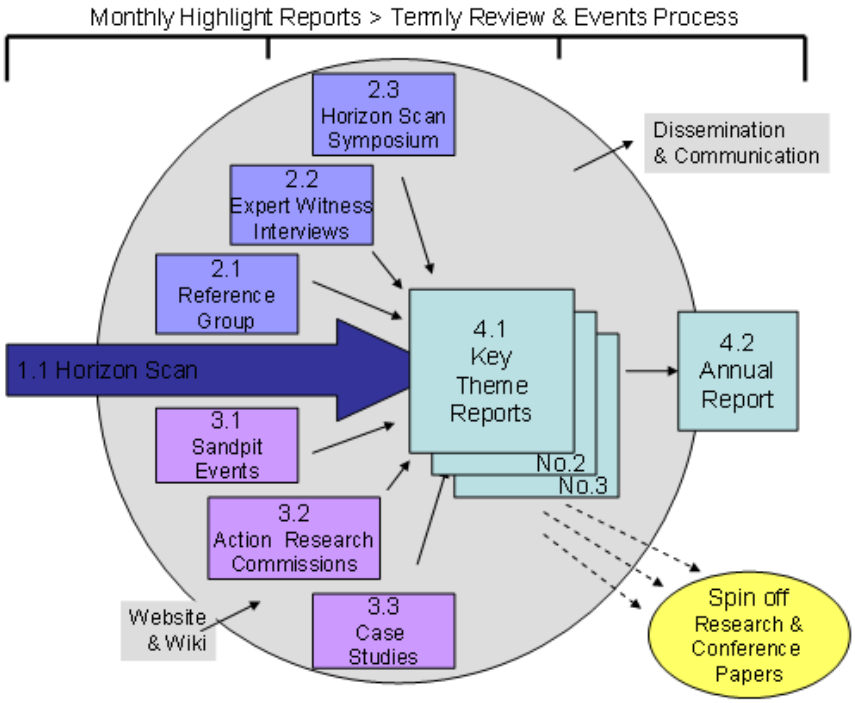

Figure 1: Overview of evidence-collection methodology

The following subsections provide a key to the methodologies shown in Figure 1.

1.1 Horizon scanning

Horizon scanning involved an iterative process of scanning policy, literature (formal and informal) and research programmes across eight 'priorities':

- Disadvantaged learners
- Learning contexts
- Curriculum design and assessment
- Organisational change

- Specialised technologies
- Learning and teaching redesign
- Enablers as learners
- Sustainable personalisation.

2.1 Expert reference group

Twenty-two experts in learning and technology from across the educational sectors convened to propose and discuss disruptions and provide feedback on project findings.

2.2 Expert reference interviews

Individual follow-up interviews with the reference group were held to probe deeper reflections about disruptions and new modes and strategies.

2.3 Horizon scan symposium

A broader group of experts (around 40) met twice to generate new modes and strategies for teaching and learning. These events were developed with the committee of the Association for Learning Technology (ALT).

3.1 Sandpit events

Two one-day workshop events were held with people (different from those in the reference group) who have specific expertise in designing, deploying or evaluating learning technology. The themes were Web 2.0 and personal learning environments, with a further workshop on learning spaces to follow.

3.2 Action research commissions

Practitioners were commissioned to research technology-centred innovations across five sectors:

- An infant (Foundation/Key Stage 1) school
- A primary school
- A secondary school
- An FE college
- HE institutions.

3.3 Case studies

Eighteen case studies[5] were developed to illustrate the potential and practice of the key trends captured in the project activities.

Trends and disruptions

We used two constructs – 'trends' and 'disruptions' – to analyse empirical data and expert opinion.

Trends

Trends were defined, for the purpose of this project, as being persistent patterns of changing practices in a topic area, and in particular those that have significance for the development of the Harnessing Technology strategy as it relates to curriculum and pedagogy. Key attributes of trends are that the patterns exhibit continuity, empirical grounding (they are not hypotheses) and relevance. An example of a trend is the emergence of 'next-generation teachers' who are developing skills in exploiting technology for creativity and social networking. (The Southwark Primary School action research commission[6] exemplifies this trend.)

The horizon scans identified trends across eight priority areas which were defined by Becta at the outset of the project:

- Disadvantaged learners
- Learning contexts
- Curriculum design and assessment
- Organisational change
- Specialised technologies
- Learning and teaching redesign
- Enablers as learners
- Sustainable personalisation.

In total, 24 trends across the first round of scans were identified. The second round of scans mainly focused on major developments identified since the first round. This enabled the processes of change acting on the 'horizons' to be identified in the second horizon scan summary report[7] These processes of change fall into two groups: top-down pressures, and bottom-up (grassroots) movements. For further details see Appendix 3.

[5] The case studies are summarised in Appendix 5 and published in full in *New Modes of Technology-enhanced Learning: Case studies.*
[6] See Jones, I. and Day, C. (2009) *New Modes of Technology-enhanced Learning: Action research*, Becta.
[7] Unpublished.

The horizon scans and other project activities informed two trends analysis reports.[8] These reports distilled six major themes, identified as the:

- the wide-ranging implications for curriculum and pedagogy of Web 2.0 technologies and the behaviours of young people who are incorporating them into their lives
- The longer term impact on curriculum and pedagogy of capital build programmes
- The changing demands of workplace skills
- The extent to which economic, social and technological drivers will lead to a fundamental transformation of the character of education and how it is organised
- The implications for the pedagogical role and professional development of teachers and other enablers of learning
- The implications for education of the development of mobile, ubiquitous and contextual computing.

These cross-cutting themes were also related to the system outcomes of the Harnessing Technology strategy (see the section Harnessing Technology – system outcomes).

Disruptions

Disruptions were defined as emerging issues that have the potential to lead to behaviours that diverge from the trends. Some disruptions may, in time, be absorbed by pre-existing trends, and others may wither, but some will evolve to displace existing trends and become new trends. Key attributes of disruptions are discontinuity, latency or nascence, and impact. An example is 'broadband availability in the UK comes to match that of other countries', which was suggested independently by five experts.

The key sources for disruptions were the first-term report (from which disruptions to the 24 identified trends were identified), and members of the team and the expert reference group, using an adaption of the Delphi method.

In total, almost 200 distinct disruptions were identified and clustered into 12 groups that fall under the cluster headings 'Technology', 'Social', 'Policy' and 'Economic' (see Appendix 4). We conducted follow-up interviews with individual experts to explore the identified disruptions. Illustrative quotes from those interviews are included in Appendix 4.

[8] Unpublished.

Innovation and implementation

The horizon scans provided initial insights into the processes of innovation and implementation (see Appendix 3). Five action research projects offer deeper insights, and are summarised below:

- **Southwark Primary School**:
  Aim: to enhance teaching and learning through ICT.
  Outcome: an uncertain ICT co-ordinator transformed into an innovative practitioner, with the need identified to take further action to spread innovation more widely in the school.
- **Fast Forward Hull** (FE adult literacy):
  Aim: to transfer innovation from one authority to another.
  Outcome: multiple agency support and keen tutors enabled successful transfer.
- **Open educational resources** (Open University):
  Aim: review how academics seek and use open educational resources within their teaching practice.
  Outcome: identified barriers to impactful use, and identified further opportunities.
- **Olney Infant School**:
  Aim: to introduce and assess the impact of a virtual learning environment (VLE) on literacy across the school.
  Outcome: enthusiastic staff and a supportive headteacher enabled a smooth introduction, despite external setbacks to progress.
- **Djanogly Academy** (Key Stage 3):
  Aim: to evaluate and improve the assessment criteria of an innovative curriculum.
  Outcome: a positive impact was made, and a need for further refinement identified.

Two key themes are apparent across the five action research commissions:

- Local enthusiasts and supportive leadership and/or agencies were essential to the success of each project.
  This was particularly notable for the Open University, Olney Infant School and Djanogly Academy, which are institutions with a history of successful innovation.
  Southwark Primary School and Fast Forward Hull provide examples of institutions and practitioners in the earlier stages of becoming innovative.
- The action research commissions themselves enabled the institutions to identify problems and opportunities, and so address them.

In summary, the right people and support, combined with the freedom to innovate and honestly evaluate outcomes (ie take risks) in a reflective and iterative manner, are essential to educational innovation.

Towards new modes and strategies

A principal outcome of the project is the production of new modes and strategies for technology-enhanced learning. The case studies provide an insight into possible approaches for the future, based on current innovations, and are summarised in Appendix 5. The case studies include several examples of how technology can help vulnerable and isolated learners, including older people in the community, teenagers excluded from mainstream education, and HE students who lack the confidence to interact with their lecturers.

The case studies also informed and were used to test the generative framework detailed in the section New modes of learning. For example, the video-conferencing case study offers an example of rich modes of interaction: learners collaborate, engage in inquiry-based activities, design representations to express mathematical ideas, and so on. However, the framework revealed that most of these rich ideas were not directly attributable to the video-conferencing technology itself. The technology made possible the delivery of the enriched mathematics curriculum by a secondary specialist to able Year 6 pupils, but the richness of the modes of engagement was promoted by the teacher. In this way, the framework can help discern what is intrinsic to the technology and what emerges from the ways in which teachers and learners appropriate the technology.

Harnessing Technology – system outcomes

This section summarises what the evidence from the project tells us about how the Becta Harnessing Technology system outcomes are being enacted in relation to curriculum and pedagogy.

- **Confident system leadership and innovation**. The action research commissions demonstrate the importance of leaders of educational organisations understanding how technology supports their priorities, of technology champions possessing leadership knowledge and skills, and of partners buying in to and actively supporting implementation. The Fast Forward Hull project provides an example of how innovation can be encouraged and good practice shared and adopted by institutions. The Eat-a-Metre case study provides another example, in this case with the city learning centre taking the lead.
  However, it is less clear how typical leaders and partners might become supportive of innovation in the first place. The horizon scans suggest that top-down pressures are most notable at the leadership level, and indeed the Minister for Education announced on 16 March 2009 that “great school

leaders must be backed".[9] Disruptive forces, such as the sudden emergence of £99 laptops, may come into play and increase leadership innovation.

- **Technology confident effective providers**. In the case studies and action research commissions, most of the providers achieve well on e-maturity criteria. Case studies such as E-Learn4Life and Wigan Online offer illustrations of provider capability being in place to support home and extended learning, and how this can help reach vulnerable and isolated learners. This is part of the broad trend of Web 2.0 and mobile technologies becoming more accessible, a trend that could, however, be disrupted by a high-profile e-safety incident.
  Overall, technological confidence is a necessary but insufficient condition for ensuring that technology-based tools and resources support effective teaching.
- **Engaged and empowered learners**. Many of the case studies, including E-Learn4Life and InLiving, provide examples of how learner entitlement can be met and vulnerable groups supported. The Fast Forward Hull action research commission provides another example.
  Key to engaged and empowered learners is shifting the context of learning from the institution to the community, so that technology adds value to family and informal learning. The 'community' can range from people who live in a given locality (as in the Silver Surfers case study), to a globally distributed community of practice, as in the open educational resources action research commission.
  However, these advances in learners using technology confidently and safely to support their learning are vulnerable to disruption from high-profile technology issues or e-safety breakdowns (such as those generated around social networking and pictorial street mapping).
- **Enabling infrastructure and processes**. The horizon scans and evidence from some of our expert witnesses show technology supporting multi-agency working through top-down pressures towards systems for learner services becoming fully integrated. This trend is potentially disruptive to institutions and providers who need to ensure there are high quality tailored resources available to all learners.
  Examples of tailored resources are provided by the personalisable memory sticks of the Fast Forward Hull action research commission, and the open educational resources commission, which concluded there was a need to ensure that resources are adaptable if lecturers are to use them in transformative ways. This finding resonates with the Glossy project, Digital Learning Community and Rug Room case studies.

[9] 'Ed Balls says great school leaders must be backed', Teachers TV, http://www.teachers.tv/news/32977

Capital build projects have promised infrastructure designed for efficiency and sustainability, but are being disrupted by the economic downturn.

- **Improved personalised learning experiences**. Our horizon scans and trends analyses highlighted trends towards learners exercising choice among flexible learning options which are enabled by the accessibility of Web 2.0 and ubiquitous communication technologies. Key to this is harnessing the social networking that particularly dominates the private lives of younger learners.
  However, these trends present a disruptive force from the point of view of many institutions. We have noted that tailored and responsive assessment that addresses learners' needs is trailing expectations, and, for example, e-portfolios cannot be expected to have made much impact on the existing high-stakes assessment regime within a five year time-scale. Given the prevalence of 'teaching to the test', so long as the traditional assessment regime stays in place, it is likely that technology-enhanced engaging learning experiences that support deep and higher order learning will continue to be cutting-edge rather than mainstream.

It is worth recalling here that in our first trends analysis report we identified a trend of 'changing IT user skills', which does not neatly align with any of the above system outcomes. This is an aspect of the first cross-cutting trend ('the implications of Web 2.0 technologies and the behaviours of young people' – see the section Trends and disruptions), and relates to the skills of the 'net' or 'Google' generation. On the one hand, education is being disrupted by, and so needs to adapt to, the skills that young people are developing in technology-rich, socially connected, informal environments, and to build on them. On the other hand, the very skills that young people develop in such settings are not necessarily very efficient, consistent or transferable to future roles as citizens in a knowledge-based economy. There is a tension between engaging young people with learning in a way that builds on their experiences of growing up in the modern world and also helps them to identify and overcome the limitations of those experiences.

New modes of learning

The need to describe learning

A central aim of this report is to identify new, potentially effective modes of learning that can be enabled by ICT, and to suggest strategies for achieving them. By 'mode of learning' we mean a description of a type of technology-enabled learning that is sufficiently general that it can apply across subjects, curricula or sites of learning. The mode may involve new forms of learning with technology, or the extension of familiar ways of learning into new settings such as homes, museums or field trips.

To identify these new modes of learning it is important to have a vocabulary that can allow us both to analyse existing forms of learning and to generate new designs for learning. It should offer a 'generative framework' for innovation. Such a framework is outlined here, along with some illustrations of how it can be employed to both analyse and generate modes of learning.

First, however, it is helpful to locate this framework in relation to other, more well-established, descriptions of learning. These tend to come in one of three forms:

- First, there are those vocabularies that aim for completeness and detail. They offer a broad range of terms to cover all aspects of a learning encounter – context, agents, roles, motives, tools, resources, assessment, aims, outcomes, and so on. An interest in the production of learning objects and tagging them with descriptive metadata has recently stimulated the construction of such systems.
  Some systems run to over 100 terms (eg see Conole *et al.*, 2007). Their comprehensive scope makes them useful for producing exhaustive taxonomies, but they are at too fine a level of detail to describe new modes of learning.
- Second, there are systems that indicate the psychological processes involved in an episode of learning (such as 'define', 'hypothesise', 'synthesise'). Bloom's (1956) taxonomy of learning is one highly influential version of such theorising.
  Analysis at this level is important, but it takes place after the work of generating a novel mode of learning has been conceived, rather than being a framework for finding such modes in the first place.
- Thirdly, there are taxonomies of learning situations. These can also suggest a vocabulary of cognitive operations, but at a coarser-grained level of description. A good example (in the domain of e-learning) is the set of 'web-enhanced learning environment strategies' or WELES, described by Grabowski (1996). These taxonomies identify a number of learning situations or scenarios. Each has some pedigree in relation to psychological theories of how best to organise educational practice, for instance 'collaborative learning', 'expository learning', 'anchored

instruction', and so on. These are closer to where we feel a framework for learning should be if it is to be 'generative'. However, they describe relatively undifferentiated global scenarios for learning – sets of circumstances that have been designed to foster just one particular type of activity.

Supporting innovative thinking about learning

New digital technologies can support effective learning, but innovation in learning should not start from technology. Certainly, it is easy to notice some functionality in a piece of hardware or software and then move on to ask how this might enable good learning. But this should come after deciding what experience we want the learner to have: what kind of engagements with the world will best bring about learning? (We saw an example of this process in action in our Eat-a-Metre case study.)

This direction of thinking about how we innovate has been well developed by the educationalist Richard Clark (1983, 1994). Clark starts by saying that we should relate learning technologies to learning innovation, declaring that 'media will never influence learning'. According to Clark, it is the practice that counts, not the particular technology that is adopted into it. Where practices are well conceived, effective learning will be supported and new understanding will arise.

Technologies remain significant because they mediate the exchanges between learners and the objects, symbols and other people that comprise a setting for learning. If we want to claim that media do influence learning, then it may be by noting that some means of mediation (some technologies) may prove more efficient, more economic or more convivial than others when they are designed into an established educational practice. But it is the educational practice itself that matters. Technologies offer choices as to how a particular practice is managed and supported. However, it is also important to acknowledge both the positive and negative mediating forces that affect individuals' and organisations' capacity to change.

A generative framework specified

Put simply, the framework for learning that might best reflect the perspective described above should be built around two broad sets of terms:

- one set of terms that refer to the learning practice – characterised here as 'interaction'; its proposed elements help us identify distinct varieties of learning practice
- one set that deals with the mediation of learning – these terms allow us to specify design choices for resourcing that practice.

In Table 1 below, the interactions of learning are represented as the 16 categories listed in the left-hand column. These interactions are mediated by circumstances defined in the remaining three columns.

Table 1: The vocabulary of a generative framework for new modes of learning

Learning practice	**Mediating circumstances**		
Interaction	**Context**	**Technology**	**Agents**
Exposition	Setting: Workplace Classroom Home…	Time: Synchronous Asynchronous	Peers
Reflective			Teachers
Performative			Mentors
Networked		Place: Contained Co-located Distributed Virtual	Technicians
Community	Process: Scripted Open		Supporters: Parents Siblings Carers…
Collaborative			
Tutorial			
Assessing	Curriculum: 21st century Nuffield Basics…	Instrument: Representation Augmentation Simulation Construction site Recording Computation Communication	
Browsing			
Cross-contextual			
Cross-conceptual			
Case-based	Subject: Maths ICT...		
Problem-solving			
Inquiry-driven			
Ludic			
Construction			

The term ‘interaction’ indicates a basic concern for how a learner acts – a description of some exchange the learner has with the world. The focus on activity should not imply a narrow behavioural definition of learning. The different forms of interaction are distinguished by their purpose.

For any given interaction, the purpose is an outcome of some implicit learning design. For example, design may determine that an interaction is ‘expository’ (the first item in ‘Interaction’ column of Table 1). The case is interesting because some might argue that the exposition of knowledge (as in a lecture) is not a learning

'interaction' at all – and may criticise it for that reason. However, an effective exposition is one that prompts the learner into a private, mental dialogue (an interaction, therefore), which may bring about useful cognitive reorganisation.

A 'reflective' interaction elicits another kind of useful cognitive construction: one in which learners distance themselves from acquired knowledge in a manner that permits them new levels of meta-cognition. A 'collaborative' interaction is different again: it stimulates the possibility of building a structure of shared knowledge – something that creates a distinctive platform for further cognitive investigations.

The psychological significance of each of the 16 forms of interaction is discussed in more detail in Appendix 1. The point of creating a taxonomy of learning interactions in this way is to acknowledge that there are a wide range of interaction designs that can be provided for the learner. Each of these offers a distinctive cognitive or motivational possibility for learning.

Educational practice involves making strategic choices with respect to the options for interaction. Once a choice has been made – about whether to promote exposition, reflection, collaboration or whatever – then there are further decisions to be made about how this interaction is mediated. These decisions are covered by the other columns in Table 1. The interactions of exposition, reflection and collaboration, and so on are configured by how contexts, agents and technologies are recruited into those interactions. Again, the elements constituting these categories are elaborated in Appendix 1. One element to highlight here is the category of most concern for this report: technology.

A technology can determine how a learning interaction is configured in particular places and how it is organised in time. So, it may determine that events are spatially contained or distributed in various ways, and it may dictate whether events happen synchronously or asynchronously. Most powerfully, a technology can configure how the learning situation is constructed and instrumented. For example, in relation to a curriculum topic such as physical geography or ancient history, technology may enable the manipulation of topic-relevant representations – it may augment their properties. In some cases, technology may offer a computer simulation of topic-relevant events, a construction space for learners to be inventive with domain material, or devices for recording events, computing processes in the domain, or communicating with others.

Exercising the generative framework

One value of a generative framework is that it can support the activity of finding new modes of learning. For example, selecting terms that may not at first seem to fit together (such as 'ludic', 'assessing' and 'problem-solving') may suggest a potentially interesting scenario for learning (eg a game-based approach to the assessment of problem-solving abilities) that could be appropriate to a particular context (such as

workplace learning). While this approach can be provocative, it is not enough to generate new modes of learning by simply putting together elements in the system in a random fashion to see what surprises are created. Nor is it likely that novelty will come from adding new elements to a basic list of learning interactions. As Clark (1983) suggests, there are simply a limited set of teaching and learning practices implied by our current understanding of how people learn.

Instead, we suggest a more structured way to generate and analyse new modes of technology-enabled learning: we propose three broad ways in which interactions can be combined to enable effective learning. Then the framework can be explored to see which combinations will work with new technologies. The three productive combinations are: integration, embedding and accessibility.

- **New integrations**: Technology can enable learning interactions to be linked into a new learning 'journey'. For instance, a sequence of 'constructive' interactions (eg using a camera to create video clips) can be linked into a 'performative' interaction such as a video diary that can be made visible to others.
- **New embeddings**: Technology can enrich one form of learning interaction by allowing another to be embedded within it. For instance, a computer toolkit to carry out 'cross-contextual' science inquiries (such as data logging on field trips) may have embedded tools for 'collaborative' interaction that allow students to share and compare data.
- **New extensions**: A learning interaction could be extended to make it more accessible or pervasive: for example, it may become available to new parts of the curriculum, become more attractive to learners who had previously rejected it, or become easier to afford or organise in learning contexts. For instance, mobile devices can make instruments for 'recording' or 'constructing' attractive and accessible both in the classroom and outside. Similarly, simulation software can offer compelling case-based interactions for workplace learning.

Such innovations are likely to alter existing ways of learning: the new interactions may be at the expense of others, or they may alter the power relations between teachers and learners. Such changes of balance will need to be monitored.

So we arrive at a structured process for proposing and exploring new modes of learning. First, interactions from the framework in Table 1 can be chosen and combined to form new integrations, embeddings or accessibilities of technology-enabled learning. Then items from the remaining columns of Table 1 can be selected to show which context, technologies and agents may match the interactions, to form new modes of learning. These combinations can be systematically explored, for example by describing and assessing particular scenarios of learning as exemplars of the new modes.

Illustrative new modes of technology-enabled learning

From our expert workshops, team discussions and analysis of the studies we have carried out, we propose four modes of technology-enabled learning. Each is pitched at a level that allows some claim to generic status. In terms of the distinctions made in the previous sections, the new mode may involve integration, embedding or extension of familiar learning interactions. It may involve any or all of these developments applied to novel contexts (subjects, curricula, sites of learning, etc), or it may involve new agents (parents, mentors, practitioners, etc).

The new modes have been chosen with some care from the set of possibilities generated by the framework. They illustrate new or emerging modes of learning that have already been demonstrated on a small scale (in research projects or by innovative practitioners), and which show promise for being more widely adopted. The novelty of the new modes arises from the manner in which technology allows new ways of learning to combine and enact the interactions captured in Table 1.

The four modes that we propose, each of which invokes one of four prevailing perspectives concerning the experience of learning, are learning as:

- the private experience of 'study'
- a dialogue involving a more informed other person
- realised through participation in a community
- a situated experience that requires integration across formal and informal settings.

Proposed new forms of learning interaction central to these four perspectives are described below.

Live reflection: stimulating self-awareness in personal study

A great deal of learning has always taken place in the form of unsupervised individual study. Moreover, much current policy in this area stresses the importance of learner autonomy and independence. Technology has supported learners to be independent through the manner in which it has made resources for study more accessible, more readily navigable, and richer in representational format. However, there is now an opportunity to empower private study by incorporating more opportunities for learners to engage in active reflection around the ongoing experience of their interaction with those resources. Such reflection would position learners to record personal reactions to the ongoing effectiveness, direction or challenge of their study.

It has been widely argued by leading educational theorists (eg Brown, 1987; Mayer, 2001) that effective learning depends on students' ability to stand back from their own activity, appraising its progress with a strategic attitude. Such metacognition lies

at the root of current interest in stimulating 'learning to learn': metacognition may be regarded as the mental skill base for effective lifelong learning. There is current interest in e-portfolios, which represent one technology format for stimulating learner reflection. Yet it is widely accepted that maintaining regular engagement with personal e-portfolios is difficult – at least when that engagement is not linked to some form of summative assessment. Thus, existing technology continues to make only a modest impact on this important dimension of effective learning.

A new learning mode based around live reflection works at designing a closer link between the activities of learning and those of reflection. At present, reflection is decoupled from the activities of learning by the imperative that it takes place at a different time and, typically, using different tools: reflection is something that is done later and somewhere else. Live reflection is based upon designing the act of reflection as an opportunity that is integral to the learning resource context. As materials for study are increasingly encountered in digital format, so their construction can include vehicles for learner input in the form of reflection and review. These opportunities may be formally scaffolded as explicit requirements within the learning material or they may be ready to hand as design affordances to be exploited as the learner chooses. Digital media and infrastructures allow this live reflecting to occur in various representational formats (visual, text, speech) but also allow the individual reflections to be organised into a central learner portfolio. This, in turn, may be made available to peers, tutors and/or mentors.

For example, students on a field trip can be assisted by mobile technology to engage in cycles of action and reflection: collecting data, analysing it at the location, reflecting, and proposing further collection activities. Alternatively, a digital text encountered on, say, a VLE can include prompts for reflection. These live self-reviews can be located on the VLE in a manner that supports later access by the learner and others.

We expect that technology will continue to evolve in ways that encourage the design of study materials and environments to include live reflection as an increasingly prominent mode of learning.

Rich feedback: promoting learning dialogue within formative assessment

Despite the contemporary emphasis on learner independence and autonomy – as outlined in the first example mode – 'Live reflection: stimulating self-awareness in personal study' – above, it remains accepted that dialogue with teachers is an important part of the learner's experience. Yet the opportunities for that dialogue may be undergoing some degree of erosion. For example, student–staff ratios in higher education have doubled over the last 15 years (University and College Union, 2007), constraining the possibilities for tutorial discussion centred on students' work. Elsewhere in education, the emphasis on high-stakes summative assessment may

have been at the expense of assessment for learning, with its emphasis on supportive forms of teacher feedback (Black and Wiliam, 1998).

This second mode of learning assumes new designs that embed commentary from teachers (or peers) into the submitted work of students. Moreover, digital technologies allow new forms of dialogue that can be built around such commentary. For instance, students' reports can be annotated with multimedia and web-based conversation. These reports can then be re-circulated in a networked environment and developed further as dialogues. The use of social networking tools such as blogs for formative assessment are the first steps in this direction. The facility to add feedback is readily extended in ways that will ease the task of a reader inserting textual, visual and oral commentary directly into submitted work.

We expect the elaboration of such rich feedback will become a significant new mode of learning. There are signs of such methods being pursued and acknowledged by the educational community (JISC, 2008).

Learning community trails: expanding and exploiting collective memory

While learning is readily seen as both a private experience of study (as in 'Live reflection: stimulating self-awareness in personal study' above) and a tutorial exchange (as in 'Rich feedback: promoting learning dialogue within formative assessment' above), it is increasingly acknowledged that understandings also evolve within the dynamic created by groups of people. This has given rise to a significant interest in the corporate nature of learning and, in particular, the idea that learning happens best within a community of practice (Lave and Wenger, 1991). A key psychological element within such learning settings is the notion of membership. Learners are regarded as needing to develop their understandings through strong ties within the social groups that are making knowledge available to them as 'peripheral participants' (Kimble and Hildreth, 2008).

The value of social contexts has been stressed in other ways, notably through an emphasis on the shared discourses that are maintained in such groups of learners. Thus Edwards and Mercer (1987) highlight the importance of teachers working to create a sense of common knowledge within the classes that they co-ordinate. However, Edwards and Mercer (and others since) have tended to frame that enterprise as a rather local and short-term one – perhaps describing how a topic for learning is discursively unfolded over a number of lessons, or how broader patterns of common understanding are shaped over the course of natural academic periods such as the school year. The learning mode proposed here as 'community trails' is one that constructs a sense of common knowledge beyond the shorter term life of a single community or classroom. It does this by strengthening the collective remembering of such transient communities while, at the same time, extending it. This is brought about by referencing the experiences and achievements of the transient communities that have gone before.

What we therefore propose is a mode of learning that invites the student to orient towards the 'trails' that have been left by students who have come before. Those predecessors will have added to an archive of reflections and learning artefacts that reflect their own personal struggles towards understanding. Such corporate archiving has been explored with technology at the level of the class project (cf. Bereiter and Scardamalia, 2003). We propose here that the success of ventures at this fine-grained level of collective memory will be extended by the capabilities of new technology to capture, integrate and disseminate class activity into 'community trails'. Teachers will be positioned to anchor discussion to this history, and contemporary students will be invited to contribute to its evolution.

Gaming to learn: subject exploration in massively multi-player games

The three modes of learning sketched above imply strong links into formal modes of educational practice – forms of engagement that are likely to be teacher directed, tied to a distinct curriculum, and orchestrated at a particular institutional site. Yet there are high expectations of new technology for realising more loosely structured experiences of learning. This final proposed mode explores the potential of computer gaming, and its apparent recreational appeal, as a context within which new learning experiences can be structured (Shaffer, 2007).

The richest and most technically evolved genre of computer-based games is that in which large groups of players engage in an ongoing networked venture, which calls upon co-operation, collaboration, knowledge building and reflection. Existing versions of such games dwell on familiar recreational themes – notably warfare (*World of Warcraft*), science fiction scenarios (*The Matrix Online*) and role playing (*Neverwinter Nights*). The expectation associated with the proposed 'gaming to learn' mode is that these designs can be recruited to represent topics which are closer to the traditional curricula of formal education and skills.

Through multi-player online gaming, learners can become involved in constructing their own interpretations of a complex environment such as protecting an animal habitat, positioning a wind farm or designing a school. This approach would involve managing assessment through the typical penalties, rewards and social commentaries of a multi-player game. It could also allow the trajectory of learning to be more open and, potentially, lifelong.

Taking a generative framework forwards

We have indicated how a vocabulary for discussing learning can be organised as a generative framework. Our fieldwork and expert panel feedback suggest that the framework is valid and robust as a means to analyse and generate modes of learning. We have illustrated how the framework can be employed to conceive new modes of learning. One way forward is to identify how such modes of learning can

be evaluated and promoted. The framework also provides a way of keeping a general watch on the appropriation of new technologies into learning.

Each of the 16 interactions, identified in Table 1, can define a reference point for tracking research and development around learning innovations. For each form of interaction it will be instructive to trace how technology is allowing the form of that interaction to be re-mediated by new technology. Such a comprehensive audit will also allow a detection of new learning modes as well as stimulating an imagination for constructing them.

However, the task facing Becta and its partners is not just of imagining new and desirable modes of learning. It is also to develop strategies that can turn new modes of learning into operational reality, moving beyond the situation where innovation around learning occurs in isolated pockets. The challenge is to identify how these new modes can be spread beneficially across the education system and embedded as permanent features of learning and teaching.

For the new modes of learning suggested above to be adopted at a system-wide scale there can be a need for a certain sort of technical infrastructure to be in place, and for teachers and other enablers of learning to be confident in using the technology. Much effort and investment has been put into such factors, and yet we are not yet near the point where we can say that technology-enhanced learning has become embedded in education.

If we look at what is involved in each of the new modes of learning proposed above, it is evident that each requires new forms of engagement by and between students and teachers, and therefore a willingness and ability on the part of teachers to rethink how they construct, orchestrate and manage learning situations. Part of the challenge here is to support students in becoming not only confident users of technology, which many already are in their social and leisure-time lives, but also confident and effective learners in contexts that are rich in technology. This requires a range of academic skills, including the ability to make appropriate use of technology (and sometimes to put it aside).

For such new modes to become more than the property of individual innovators will take support and facilitation from leadership teams at institutional and system-wide level. It also needs an educational system that accommodates new modes of learning by ensuring that assessment methods – one of the major drivers in shaping the overall character of education – and methods of learning and teaching are mutually reinforcing.

Lastly, we need to ensure that the duty of care we owe to younger and vulnerable learners in keeping them safe online is discharged without crippling the educational opportunities we can offer. Clearly some of the new modes of learning we have described present a challenge in that regard.

This analysis of the broader system issues that are implicit in adopting new modes of learning at scale therefore defines the challenges we face in moving towards the full adoption and embedding of technology-enhanced learning across the system. These challenges are set out in more detail in the next section.

Conclusion

In the section New modes of learning, we propose a framework that can be employed to both analyse learning innovations and to construct new modes of learning. Although all the basic learning interactions in the framework have been tried before, digital technologies enable them to be combined, embedded and extended in novel ways, some of which may have a significant impact within and across sectors. The framework provides both the means to evaluate the innovative force of technology in learning and a tool to generate and examine modes of learning.

In this report, we have proposed four new modes of learning that are mediated by technology. They span different perspectives on the learning experience, and each new mode of learning is a candidate for being more widely adopted across the education system and in different sectors of education. However, it is not sufficient simply to propose that innovations in technology-enhanced learning should be adopted more widely. As we have argued, we also need to know how such adoption can be fostered and enabled. At this point, we can draw upon the empirical evidence we have gathered, summarised in Summary of evidence above, to reach conclusions about how to move from piecemeal innovation to system-wide change. We also argue that the changing context of education provides opportunities for adoption of these new modes of learning across the education system, while also making their necessity more pressing.

The challenges facing education

The research highlights that the potential for harnessing technology to enhance 21st century learning is dependent on complex interrelated factors both within and outside the education system:

- Outside education:
  - Technology – the fast pace of growth in digital technologies, and their tendency to transform a growing number of daily interactions throughout all spheres of life, setting the social and economic context for education and providing new opportunities and challenges for teaching and learning
  - Learner experience – learners come to education accustomed to using digital technology as a commonplace feature of their daily lives; they are not just used to adopting new tools, but also to interacting with others and with sources of information and knowledge in different ways from those used by many of their teachers

- Within education:
  - Curriculum – the need for curriculum change to adequately prepare students for working and living in a world where digital technologies are pervasive
  - Process – changes in the organisation and administration of learning and in methods of education to produce the desired learning outcomes
  - Teacher and learner – changes in the learning and in teacher–learner relationships.

The possibilities for new modes of learning and teaching, building on the potential of digital technology to deliver enhanced personalised learning experiences, are increasingly dependent on the interface between the education system and the outside world. Figure 2 illustrates this relationship.

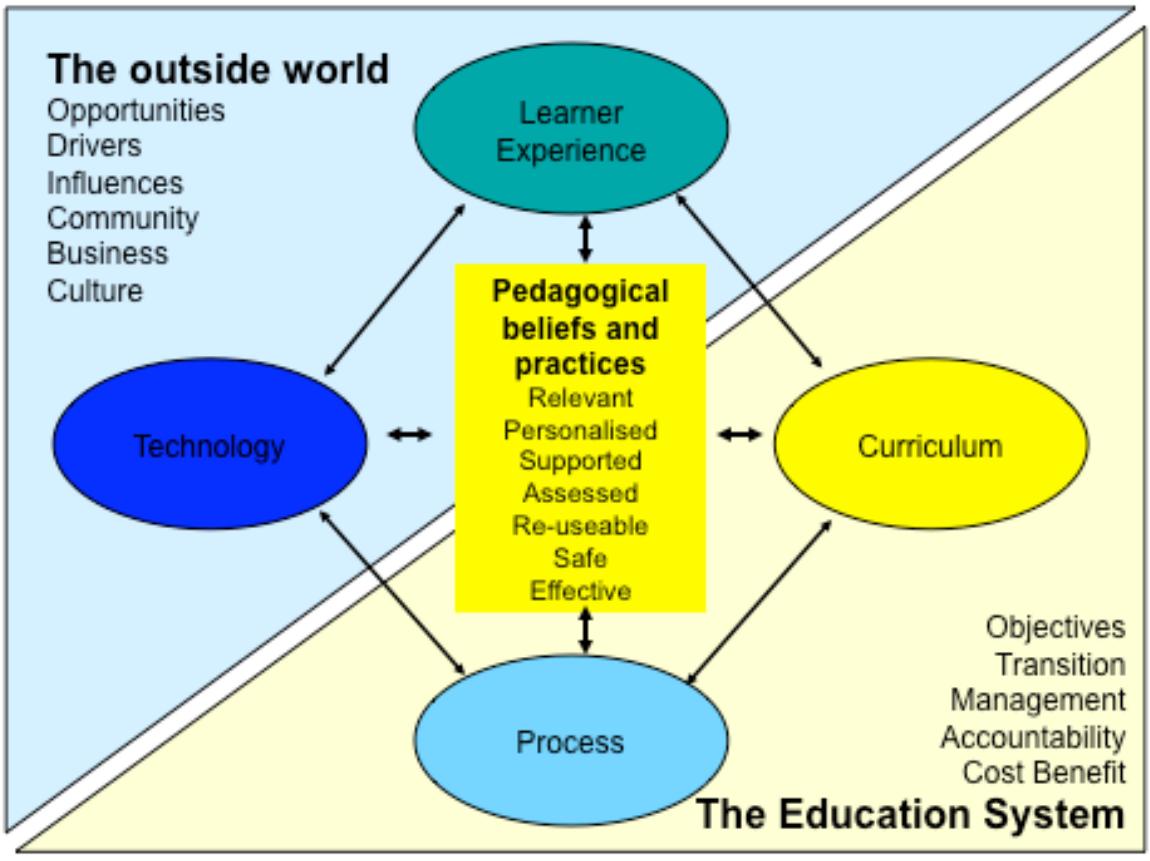

Figure 2: Illustration of the interface between the education system and the outside world

For example, the 'Gaming to learn' mode proposed in the section New modes of learning will depend on compatible education processes and structures for curriculum and assessment if it is to exploit current and emerging technologies and draw on the experiences of 'digital born' learners.

Our investigation of trends and disruptions[10] indicated that the rate of adoption of technology-enhanced learning is perhaps more subject to factors within the education system than it is challenged by drivers from without.

When considering local, regional and national exemplars of outstanding success and achievement, illustrated by the case studies and action research commissions, we are struck by the:

- dependency on individuals and organisations with exceptional commitment
- slow speed of technology adoption in education compared with other fields such as retail
- inherent barriers to wider replication.

If the problem does not lie in a lack of outstanding individuals or ideas, it is proposed that key blockages are likely to be systemic – within the individual institution and across the accountable bodies and the national system.

The glass ceiling

Closer investigation of the evidence base suggests specific blockages within the system that represent causes for concern above and beyond the challenges of new and ever-evolving technologies.

The UK education system, particularly secondary and primary schools, may have reached a critical point at which the adoption of technology for learning and teaching is in the balance. It is suggested that incremental development driven by outstanding localised practice, typically practitioner-inspired and curriculum-specific and often dependent on fragile funding, has hit a glass ceiling or ‘adoption gap’ at a relatively low level of adoption and embedding (Figure 3). If the UK is to accrue tangible and multi-scalar benefits from new modes of learning, individual excellence must work in tandem with institutional and national enablers.

[10] Becta (2008) *Discontinuities with current practice which affect the use of technology for learning*.

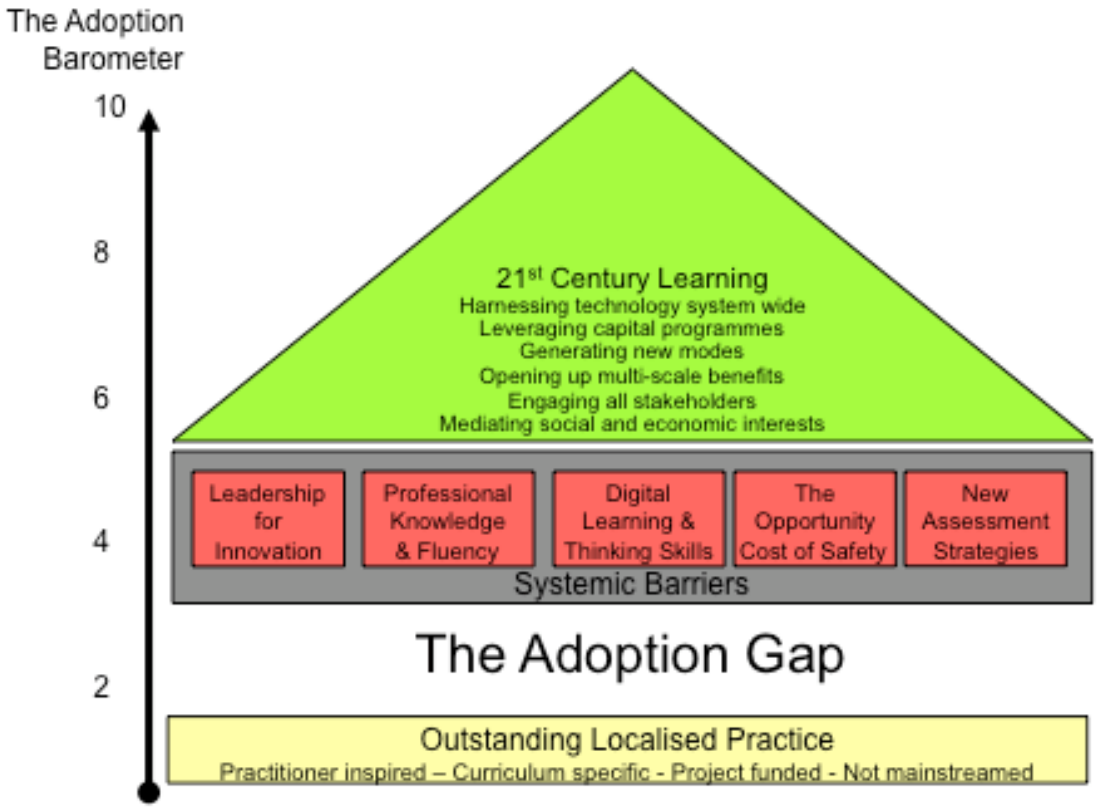

Figure 3: Illustration of the 'adoption gap' and barriers within the education system

It is possible that the UK system can progress little further towards the desired Harnessing Technology system outcomes on this basis, despite the efforts of leading practitioners who will continue to inspire students, engage like-minded colleagues and transform through pockets of outstanding local practice. This adoption gap, which will continue to block step change, is a function of barriers within the education system itself.

Critical blockages

The research identified five areas where there is a need to overcome barriers of strategic importance:

- Leadership for innovation
- Professional knowledge and fluency
- Digital learning and thinking skills
- The opportunity cost of safety
- New assessment strategies.

It is significant that these issues can be mapped onto the five Harnessing Technology system outcomes shown in Table 2 below.

Table 2: Mapping of system outcomes and critical blockages

System outcomes	Critical blockages
Confident system leadership and innovation	Leadership for innovation
Technology confident effective providers	Professional knowledge and fluency
Engaged and empowered learners	Digital learning and thinking skills
Enabling infrastructure and processes	The opportunity cost of safety
Improved personalised learning experiences	New assessment strategies

The barriers are discussed in the following subsections.

Leadership for innovation

Our research reinforces the view that leadership support is key if innovation is to move from individual enthusiasm to institution-wide adoption or beyond. We have also identified a growing wave of practitioner-led innovation with technology, but this cannot in itself achieve systematic change in education unless the support of leaders is engaged. The specific issue we have identified, therefore, and on which more knowledge is needed, is that of how leadership teams can become engaged in support of innovation.

Leadership from the very top, starting at ministerial level, has a role to play, but clearly cannot be the full story. Education leaders have many competing pressures on them, and many will support innovation only if it does not jeopardise their existing success, judged by standardised measures of institutional performance, or can reasonably guarantee improved attainment outcomes. It would be easy but trite and unproductive to suggest that the solution lies in changing the measures of overall educational success. Rather, our analysis above suggests that the issue for leaders is how to maintain success in the light of the changing external drivers for education.

Our latest analysis of trends (March 2009) suggests that curriculum reform measures and initiatives around assessment are becoming increasingly important; it is in these areas – aspects of education that have the most impact for leaders and managers – that the impact of the changing external environment on education is first felt. It therefore becomes crucial to develop measures by which leaders can become more aware of the need for innovation in support of such developments, grasp the scope of the innovation that is needed, and be supported in the opportunities and challenges that innovation poses.

Professional knowledge and fluency

It is too often the case that innovation in the field of technology-enhanced learning is seen as predominantly an issue of mastering the technology; among teachers for whom such skills are new, this issue becomes uppermost in their minds. However,

as we have argued in the section New modes of learning, the new modes of learning that need to develop are not primarily about technologies, but about developing the range and depth of the learning experience.

Our research evidence shows that technical confidence is a necessary but not sufficient condition for success in innovating with educational technology. New modes of learning imply new modes of teaching and the need to rethink aspects of professional practice accordingly. More active engagement by learners in new sorts of activities implies the need for teachers to develop new methods and relationships with learners, both in formal educational settings and beyond, to acquire new skills in inculcating the growth of knowledge, and to manage more formative processes of assessment.

In short, for technology-enhanced learning to become embedded requires new developments in professional knowledge and competence, without which adoption of new modes of learning will be stifled. It is our view that the scope of what is required in this regard has so far been insufficiently recognised.

Digital learning and thinking skills

As noted in our first trends analysis report,[11] it has become commonplace to refer to the digital skills of younger people using terms such as 'digital natives'. While the merits of various terms can be debated, what seems indisputable is that the learners who are now in schools, colleges and universities have grown up in a world where interactions through digital technology are taken for granted. However, it has become equally evident that competence with digital technology for a limited range of purposes does not automatically translate into a deep understanding of technology, or into a wider range of necessary learning and thinking skills. This was the subject of a well-publicised report in 2008[12] and is recognised by the inclusion of personal learning and thinking skills in the 14–19 curriculum reforms.

At the same time, recent government policy in abolishing GCSE coursework as a reaction to evidence of internet plagiarism sends out a mixed message, recognising the issue about learners' academic skills while seeing the answer as lying in a retreat from engagement with the internet. Moreover, this goes against other areas of policy where online engagement is advocated.

The relevance for Harnessing Technology is that the use of terms such as 'digital natives' can mislead if they are taken to mean that learners who are confident users of digital technology for a range of social and personal purposes outside of education are also confident and competent in the full range of educational purposes for which

[11] Chowcat, I., Jones, I., Phillips B. and Popham J. (2008) *Harnessing Technology: Preliminary identification of trends affecting the use of technology for learning*, Becta.
[12] UCL (2008) *Information Behaviour of the Researcher of the Future*. http://www.jisc.ac.uk/media/documents/programmes/reppres/gg_final_keynote_11012008.pdf

they might use digital technology. This is far from the case, and the Harnessing Technology strategy needs to recognise and constructively address this gap.

The opportunity cost of safety

Harnessing Technology recognises the importance of ensuring that learners are safe online, and that the potential cost of a failure of online safety, not only to the individuals concerned but to the prospects of the strategy overall, are considerable. However, many of the technical solutions being implemented to address the problem of safety do nothing to tackle the issue of developing safe behaviours, and can act as a block to the development of new modes of learning.

One of our case studies (the PlymKids e-safety project at South West Grid for Learning) illustrates how safety issues can be tackled as an issue for learning, through questioning and studying behaviours around technology rather than removing access to technology. If the emerging recommendations of the Rose review of the primary curriculum are implemented, then this issue will be posed very sharply.

New assessment strategies

The need for flexible personalised assessment as an integral component of personalised learning experiences is rightly highlighted in Harnessing Technology, yet we persistently find the assessment regime being highlighted as one of the key brakes on innovation and reform. The need for a less monolithic, more modular assessment regime, embracing both formative and summative assessment in all phases of education, poses a major challenge. While the use of technology to support and enable formative assessment (assessment for learning) is becoming more widespread, this should not obscure the major issue of how summative assessment should be reformed to reflect the new learning needs of the digital world.

The recent global assessment initiative undertaken by major industry players and with support from the Organisation for Economic Co-operation and Development (OECD) may be an important development, but its implications for national education policy, if any, are not immediate. Of more current significance may be developments in how new curricula can be assessed, whether this is through the development of the 14–19 reforms or by taking initiatives such as the RSA's Open Minds curriculum into Key Stage 4, both developments still being in their early days. Issues are raised about both what we assess and how we assess it.

Links to new modes

An examination of the new modes of learning illustrated in the section New modes of learning predicts critical dependencies of each new mode on the removal of the following barriers (shown in Table 3):

- First-order dependencies relating to introduction
- Second-order dependencies relating to embedding and scaling.

Table 3: Barrier-removal critical dependencies

	New mode 1	New mode 2	New mode 3	New mode 4
	Live reflection	Rich feedback	Learning community trials	Gaming to learn
Leadership for innovation				
Professional knowledge and fluency				
Digital learning and thinking skills				
Opportunity cost of safety				
New assessment strategies				

Although this high level analysis suggests that leadership for innovation may be less explicitly significant than other factors, it should be recognised that permission, reward and positive value chains (all the prerogatives of leadership), lie at the heart of most personal, collective and corporate change models.

We would argue that this situation is endemic rather than localised, and that the glass ceiling (see Figure 3) represents a fundamental barrier to transformative technology-enhanced 21st century learning within the UK system.

The UK system may currently be faced with an opportunity for step change, which arises from the combination of drivers including:

- capital build programmes in schools and colleges
- the universal Home Access initiative
- the review of the primary curriculum
- the reform of 14–19 provision, including the introduction of the 14–19 Diplomas.

Furthermore, crucial and systemic shortfalls in current capabilities have been highlighted in recent reports (which complement our own observations), including the:

- proposal for the global assessment initiative, Assessment and Teaching of 21st Century Skills[13]
- Ofsted report *The Importance of ICT: Information and communication technology in primary and secondary schools, 2005/2008*.[14]

There is no inevitability to change happening on the scale needed, and it may not happen without the right sort of interventions to capitalise on the opportunity the conjuncture of circumstances presents.

We therefore conclude that our evidence (ranging from expert opinion to case studies, from desk to action research) shows that in each area of the system outcomes, barriers exist to new technology-enabled modes of learning becoming shared and embedded and so leading to systemic change. However, we also observe that convergent and interrelated drivers are at play in the current UK system, from primary to higher education and lifelong learning, which together provide a reason to focus on the adoption gap and the particular systemic 'pain points' singled out here. These must be tackled if the opportunities for new modes of learning that scale beyond the local are to be grasped. It is therefore essential that Becta tackles these issues with its strategic partners. This perspective will provide the focus for our next phase of work.

[13] http://www.atc21s.org
[14] http://www.ofsted.gov.uk/Ofsted-home/Publications-and-research/Browse-all-by/Documents-by-type/Thematic-reports/The-importance-of-ICT-information-and-communication-technology-in-primary-and-secondary-schools-2005-2008

Appendix 1: The generative framework

This appendix gives further detail on the characteristics of the generative framework proposed in the main text of this document.

Learning interactions of the generative framework

A learning interaction is an exchange between learners and objects, symbols or other people in their immediate world. It brings about activity at a mental (psychological) level: that is, effects of a cognitive, motivational or personal kind that underpin the changes we identify as successful learning. The classifications, articulated in Table 1 and expanded here, reflect the fact that these interactions are always located in some structure of meaning or purpose. This structure determines the nature of the mental effects arising from the interactions.

The varieties of possible structure of meaning or purpose are described here as 16 forms of learning interaction. Broadly, they are organised from relatively private activities through to activities with an increasingly intense social core, towards activities that are more centrally investigative.

Exposition

A structure of interaction that arranges circumstances that allow available and relevant information to be presented to a learner in a narrative form.

Theory: Where the presentation of information takes the form of direct instructional interaction with a tutor, there remains a strong defence of such relationships in learning (Kirschner *et al*., 2006; Schwartz and Bransford, 1998), The more learner-centred version of delivered interactions has long been promoted within the tradition of resource-based learning (Beswick, 1977).

ICT example: A VLE can manage such delivery of organised pathways through course material.

Reflective

A structure of interaction arranging circumstances that create and encourage opportunities for reflective examination of the learner's own evolving activities.

Theory: The value of such interactive opportunities in learning is celebrated by the work of Schon (1987) on practitioner learning. It finds support also in relation to the cultivation of a metacognitive attitude in the learner (Hartman, 2001).

ICT example: Use of an e-portfolio to capture key examples of a learner's output and reflections by the learner on his or her learning, with possible teacher feedback and perhaps using multimedia, can support this form of interaction.

Networked

A structure of interaction arranging circumstances whereby individual learners can be put into intermittent but productive contact with others for conversations or data co-ordinations that are separated in time and space.

Theory: Learning interactions of this kind are most commonly associated with the co-ordinating tools and frameworks of Web 2.0. The theoretical grounding of such exchanges is illustrated by essays in Steeples and Jones (2002).

ICT example: A Ning website can support learning interactions among children distributed over several schools.

Community

A structure of interaction arranging circumstances that foster integration among a group of individuals with an evolving history of shared understanding and practice, and a motive to work towards elaborating this.

Theory: Lave and Wenger (1991) argued that learning interactions should be directed towards cultivating communities of practice. The work of Bereiter (2002) illustrates the gains arising from creating communities of practice at classroom level.

ICT example: A VLE discussion space can mediate this form of interaction in the interests of a classroom of learners.

Performative

A structure of interaction arranging circumstances for learners to publish the outcome of an activity.

Theory: The significance of outlets for the expressive dimension of learning, and the significance of audience has been demonstrated in initiatives such as the Knowledge Forum (Bereiter and Scardamalia, 2003).

ICT example: A blog can productively mediate between a learning episode and a reading audience.

Collaborative

A structure of interaction arranging circumstances to allow a small group of learners to deliberately engage to construct a shared understanding.

Theory: This form of learning interaction is widely endorsed in disciplinary cultures (Brufee, 1983), outcome studies of classroom organisation (Johnson and Johnson, 1989) and laboratory-style investigations (Dillenbourg, 1999).

ICT example: Web-based tools to produce shared documents can be used to support such collaborative interaction among pairs of learners.

Tutorial

A structure of interaction arranging a dialogue for the learner.

Theory: This form of inter-subjective exchange characterises interactions in which one partner is more knowledgeable, but it also includes less stratified social partnerships. Its potency is elaborated by a number of authors, notably Pask (1975) and, more recently, Laurillard (1993).

ICT example: A learner can converse with a tutor in an online chat system.

Assessing

A structure of interaction arranging circumstances that optimise the opportunities for effective feedback on an activity.

Theory: The significance of regular formative feedback has been widely acknowledged in the success of assessment for learning programmes (Black and Wiliam, 1996).

ICT example: A screen-casting technology can enable tutors to offer audio-visual feedback on a piece of written work.

Browsing

A structure of interaction arranging opportunities for the learner to interact with domain-relevant information through self-managed exploration.

Theory: Where the structure or linking of such information is rich, interactions that allow browsing exploration can make the structure visible and thereby create the basis for cognitive schemata. This view is well developed in cognitive flexibility theory with its special interest in

hyperlinking information resources (Spiro and Jehng, 1990).

ICT example: The internet offers a variety of navigational tools and architectures that permit learner-driven navigation of information.

Cross-contextual

A structure of interaction arranging circumstances requiring learners to integrate and manage their activities over more than one context.

Theory: Challenges to the necessity of institutionally based learning invite consideration of how far learning can be organised to use contexts outside the classroom (Freire, 1996). Guile (2006) and Sharples *et al*. (2007) articulate perspectives on learning that incorporate such institutional spaces but illustrate how interactions can be shaped in which such varying contexts can be productively integrated.

ICT example: A digital handheld toolkit can integrate data gathering over more than one context. It might thus be a cross-contextual learning interaction within an (overall) inquiry learning experience.

Cross-conceptual

A structure of interaction arranging circumstances whereby learners can create productive continuities between conceptual systems that differ in how familiar they are to learners, but which have significant commonalities.

Theory: Bransford *et al*. (2001) highlight how learners are helped by building new cognitive schema through continuities with those that they already understand. Examples of the success of such integration are particularly well illustrated in science learning (eg Schauble *et al*. 1995).

ICT example: A malleable representation display allows the learner to explore structural correspondences between a familiar and situated activity system and one that is more abstract.

Case-based

A structure of interaction arranging circumstances that allows learners to build new understandings arising from the scrutiny and investigation of individual cases.

Theory: Some cognitive theory (eg Schank, 1982) stresses the case-based nature of much human intuitive thinking. This has been extended to the structuring of learning interactions (eg Kolodner, 1993), with a degree of practical success (Collins *et al*., 1989).

ICT example: A computer simulation can construct a model system that can be actively explored with suitable adjustment of parameters to observe effects.

Problem solving

A structure of interaction arranging a set of domain-relevant problems for the learner to solve.

Theory: Such interactions are commonly associated with the 'practice' requirements demanded by the skills associated with a domain. Although relegated to a low level in systems of learning, it is prominent in the widely-invoked Bloom (1956). It finds a more sophisticated realisation in the tradition of problem-based learning, whereby whole programmes are based around higher level problem solving (eg Dolmans, 1994) with some degree of success (Albanese and Mitchell, 1993).

ICT example: Desktop computers can be programmed to present a series of discrete problems. The software design can provide tools for solving the problems as well as feedback on answers.

Inquiry driven

A structure of interaction arranging circumstances that position learners systematically to investigate authentic problems.

Theory: This approach is commonly derived from the work of Dewey (1938), and its effectiveness is well illustrated by contemporary approaches to science education (Grandy and Duschi, 2007).

ICT example: A digital probe can support the collection of data that forms part of an empirical inquiry.

Ludic

A structure of interaction arranging learning material into a game-like engagement in which a rule structure guides activity, with the reward of positive effect.

Theory:	The rich learning of early years is often located in playful routines. This has been extensively explored in the influential work of Bruner (1986) and its in-class relevance pursued by many others subsequently (eg Wassermann, 1992).
ICT example:	A teacher can use an interactive whiteboard and handheld voting system in a game-show-style plenary.

Construction

A structure of interaction arranging for the learner to engage in some form of activity that supports building artefacts, knowledge or representations.

Theory:	This approach to learning is often derived from the developmental writings of Piaget (1936/1953) as elaborated by Bruner (1960) and related to technology through the seminal work of Papert (1980).
ICT example:	Software can supply a set of graphic tools that allow the construction of pictorial images or animations in the course of which the learners must engage with domain-relevant principles (such as geometry and arithmetic).

Mediational factors in the generative framework

The particular experience arising from a given learning interaction depends upon the circumstances of its configuration. This is discussed in terms of the ‘mediation’ of that interaction. Mediation can be described in terms of the context within which the interaction is organised, the role taken by other people supporting the interaction, or the properties of various technologies that can be employed by the learner.

Context

Items in this category describe varieties of constraint that may be imposed on how a learning interaction happens. For example, the interaction may happen in a location with particular public, private or institutional characteristics. Descriptors (‘classroom’, ‘workplace’, etc) are thus chosen to suggest the range of constraining and affording features that are likely to be shaping the interaction.

In addition, the design of technologies mediating the interaction may constrain the route that the dynamic of an interaction can take – perhaps limiting or directing choices. The preferred choice of interaction may be dictated by the overarching concern of a particular curriculum, while the specific content will be dictated by the

demands of learning particular subject matter (mathematics, ICT, etc). These constraints are captured through the elements of the following four categories of 'condition':

- Setting: A learning interaction will be arranged to occur within a particular cultural setting. Examples are a classroom, workplace or the learner's family home. The designs and practices characteristic of the setting may shape the possibilities for interaction.
- Process: A learning interaction may be guided and shaped (to varying degrees) by the scaffolding design of the software. This may offer no particular prescription or it may offer a more scripted route in which progress depends on the completion of steps in a particular order.
- Curriculum: A learning interaction should be chosen that is consistent with the design principles of a curriculum – that is, a particular academic portfolio of study material.
- Subject: A learning interaction will present content that supports the development of expertise in a particular subject domain.

Technology

Items in this category describe how the design properties of a technology constrain the terms of an interaction between learner and subject matter. This constraint applies to matters of temporal organisation, spatial organisation, and the instrumentality of the technology.

- Synchronisation: The organisation and management of time. Thus, a technology may demand that interaction between two or more parties takes place simultaneously, or it may allow that interaction is spread in sequence across time.
- Distribution: The organisation and management of the spatial dimension of activity. Thus a technology may require that an interaction is contained at a particular place (the setting of the physical device), or it may support the distribution of activity over more than one site. In the case of joint activity, it may allow that partners can be co-located.
- Instrument: The functional properties of the technology in structuring the learner–world interaction. A technology may:
    - mediate a learning interaction by offering novel representations that may be scrutinised and/or manipulated as part of the learner's interaction with some domain; such representations may be built into a full-blown simulation which will allow the learner to interact with a model system from within a domain
    - elaborate the meaning of objects or events by augmenting their properties

- reproduce a version of the context for some domain activity through simulation, and thereby allow relatively authentic experiences to take place
- offer the learner a space in which constructive activity relevant to a domain can be achieved
- serve as an externalised memory through allowing the recording of domain-relevant events or observations
- externalise and support the execution of computations relevant to domain activity
- permit communication of ideas between agents acting in a domain.

Agents

Items in this category specify the actors involved in the learning intervention. These agents may be particularly important in determining the depth of learner engagement with the designs that shape a learning interaction. In particular, useful learning depends on whether the interaction is processed to a suitable cognitive depth – whether meaning is fully extracted. This processing may be underpinned by the activities and input of supportive others around the interaction (peers, teachers, technicians, etc).

Appendix 2: References

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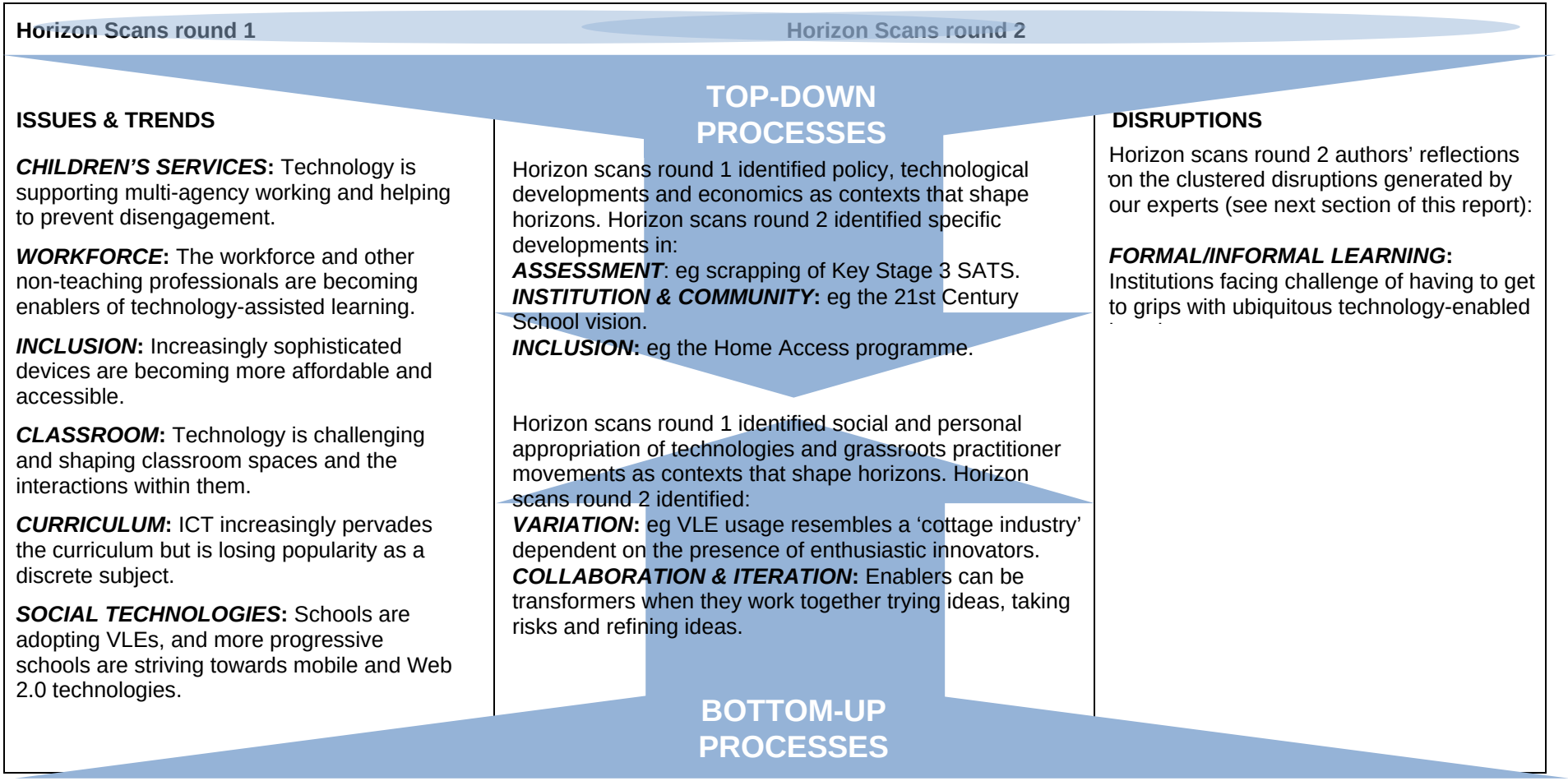
Appendix 3: Horizon scans overview



Appendix 4: 'Disruptions' overview

	Cluster	Example disruption	Illustrative quotations
Technology	New technologies offer new opportunities/ problems	Broadband availability in the UK comes to match that in some other countries	"Technology-enhanced learning can actually change the way in which knowledge is represented and can help... in terms of understanding" – academic "Technology is not simply a tool about access to content, it's also a tool about communicating with other learners... groups coming together from lots of different classrooms, be they one authority or far wider" – primary headteacher
	Existing technologies get used in unanticipated ways	Very small PC devices become the normal ownership and exist on students' desks all the time	
	Internet regulation	All content becomes available globally and is free, so institutions rely on 'cloud services' for more of their critical functions	
	Internet business models	A technology company such as Google starts an online university	

Social	A critical educational/ research incident	An e-security incident disrupts personal and social learning or results in an urgent need for added security around young people using technology or social software	"I think what will happen is there will emerge networks that are child-friendly, you know, like the OU's social project for instance, where [e-safety] measures will be put into it" – consultant "The things that drive [technology] are a sense that we need to keep up with other people who are doing it... a competitive aspect" – academic
	Restructuring/cultural shifts within teaching	Learners and teachers become prime collaborative creators of digital content	
	Changes in popular public perceptions of ICT	Significant learner resistance to more technology-enhanced learning encroachment on home and personal technologies	
	Demographic changes	Professional-class parents learn to turn home–school links to their advantage, exacerbating the digital divide	
Policy	Educational policy	SATs are swept away, freeing teachers to use ICT in more innovative ways, including formative assessment	"We're able to use technology, but the inhibitor is when you come to the exam, you have to sit here and write it" – community college headteacher
	Social policy	Environment studies are prioritised as eco-education becomes more important	
Economic	National perspectives	Industry invents ways of using e-portfolios for the evaluation of potential employees, possibly rendering academic accreditation unnecessary	"I don't buy any form of DVD-ROM that requires any form of installation, because then if you try and lend it out to anybody they are making copies and under licensing it's illegal" – college head of e-learning
	National and global perspectives	Global competition from emerging economies kills the high-skilled, high-paid knowledge economy in the UK	

Appendix 5: Case studies overview

The case studies are published in full in *New Modes of Technology-enhanced Learning: Case studies*.

Case study	Lead organisation	Sector(s)	Keywords
Booxpace	Mount Carmel RC Technology College for Girls	Secondary	Literacy, VLE, social network/forum
Cube	Sheffield South City Learning Centre	14–19	Gifted and Talented, literacy, media literacies, vocational/work-related, Diplomas, city learning centre
Digital Learning Community	East Riding of Yorkshire Council	Primary	Enablers, CPD, SEN/LDD inclusion, Gifted and Talented, cross-curricular, distance learning
E-assessment	Shell Centre, University of Nottingham	Secondary	Numeracy, e-assessment
Eat-a-Metre	i-City Learning Centre, Bristol	Mainly primary (Early Years to Key Stage 4)	Re-engagement/inclusion, cross-curricular, data handling, parental engagement, city learning centre
E-Learn4Life	Doncaster North City Learning Centre	ACL	Family learning, re-engagement/inclusion, home access, multi-agency
Enhancing library catalogues	University of Huddersfield library	HE	Data sharing, personalisation, student voice
Glossy project on mobile learning	Gloucester College	FE	Mobile, VLE, digital video/audio, personally owned devices
InLiving	Kirklees Neighbourhood Housing	14–19	SEN/LDD inclusion, mobile, co-creation, independent living, multi-agency, informal learning

Case study	Lead organisation	Sector(s)	Keywords
Laureate	University of Liverpool	HE	Postgraduates, work-based learners, learning platform, distance learning
PlymKids e-safety project	South West Grid for Learning	Primary, secondary	E-safety/media literacies, digital video/audio
Rug Room	City College Norwich	FE	SEN/LDD inclusion, social network/forum, e-safety/media literacies, co-creation, reconfigured learning spaces, ASD
Silver Surfers	Ealing City Learning Centre	ACL	Re-engagement/inclusion, SEN/LDD inclusion, EAL, ICT, City Learning Centre
Text messaging in undergraduate lectures	University of Nottingham	HE	Mobile, SMS/texting, personalisation, data sharing, student voice
Talking Tactile Technology (T3)	The Royal National College for the Blind	FE, all sectors	SEN/LDD inclusion, cross-curricular, visual impairment
Video conferencing	Finham Park School	Primary, secondary	Transition, video conferencing, mathematics
Whole-school creative digital media	St Helen's Catholic Primary School	Primary	Enablers, CPD, digital video/audio, literacy, cross-curricular, city learning centre
Wigan Online	Wigan Council	14–16	Re-engagement/inclusion, learning platform, NEET, home access, personalisation

ASD, autistic spectrum disorder; CPD, continuing professional development; EAL, English as an additional language; LDD, learning difficulties and disabilities; NEET, not in employment, education or training; SEN, special educational needs.