A Grand Challenge for Computing: 

Learning for Life

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Introduction

With the emergence of mobile and ubiquitous computing, the semantic web and the development of an e-Research infrastructure, new possibilities open up for e-learning and learning for life that take us beyond what has been conceived in this area before. Indeed, to a large extent, the challenge here is to even conceptualise how learning environments and opportunities will manifest, how people will engage with learning events, and what learning for life will be like.

These new possibilities need to be understood in the context of our developing understanding of the co-evolutionary nature of learning and computing systems, so we ensure that the full potential of learning for life is realised. The future will involve much more than incrementally extending current models of teaching and learning: rather something of the order of a paradigm shift is required to halt the accretion of tools and environments that do little more than replicate face-to-face assumptions about teaching and learning, and which do very little to recognise the nature of learning for life.

In order to do this we need to promote a strong interdisciplinary research agenda that brings together a broad range of previously disparate research traditions. This has already been recognised in the US, with the establishment of dedicated e-learning research centres and NSF support for the “A tutor for every learner” Grand Challenge. Similarly, the UK needs to develop and promote a dedicated Grand Challenge in learning for life that exploits the significant capacity within the UK to tackle the emerging research issues within this area.

This document has come together as a result of a nationwide consultation on research issues for this area, supported by a workshop attended by 50 contributors. We are therefore confident that it represents an area of work which a large number of researchers are committed. The work will also be supported by funding in a forthcoming joint call from EPSRC and ESRC.

The Challenge

Research into e-learning is inherently multidisciplinary, requiring partnerships between those who develop technology and a broad range of social science researchers who seek to understand the nature of learning and the interaction and organisational effects of technology. This combines perspectives, methods and theories from the technical domains (e.g. Computer Science, Technology, Artificial Intelligence); design disciplines (e.g. Design, HCI); the learning sciences (e.g. Educational Technology, Psychology, Education) and the disciplines studying communication, communities and discourse (i.e. Social Sciences, Linguistics). Establishing and maintaining these multidisciplinary research teams is essential for successful e-learning research, particularly given the longitudinal nature of the research involved, and requires us to move forward in a coordinated manner in order to build effective e-learning environments in the future.

The development of new forms of e-learning environment and the effective use of new e-learning tools and facilities require us to consider a variety of distinct research challenges, including four main themes in particular:

- **Modelling and Dynamic evaluation**: How do we best model and represent learners within e-learning facilities and how might we assess these over time?

- **Informal and Lifelong Learning**: how might we develop facilities that support learning outside formal educational settings over a learner’s lifetime?

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1 Such as the Stanford Institute for Learning Sciences and Technologies (SILST)
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- **Creativity and Problem Solving**: How might we encourage and support creativity and problem solving with and through e-learning facilities?

- **Inclusion and Accessibility**: How do we ensure that learning for life is a viable option for all, and that the facilities provided reflect the diversity of learners?

Underpinning these themes are **two multidisciplinary challenges** in e-learning:

- **Technological challenges**: How do we exploit the potential that emerges from new technological advances to best support learning for life?

- **Economic, Social and Cultural Challenges for learning for life**: How do we ensure that the benefits to emerge from e-learning are exploited to their best potential and how do we best understand and manage the social and cultural impact of e-learning research and practice?

Tackling the research questions to emerge from these themes and challenges outlines a Grand Challenge on learning for life that will require significant progress to be made in terms of the technologies, theories and methods of e-learning. This will have significant benefits including:

- Enhancing the effectiveness of learning and the quality of the learning experience by providing a better fit between the needs of learners at a particular time and the learning facilities provided.

- Increasing the scope of learning facilities, infrastructure and opportunities to promote lifelong learning, increasing the skills of the UK workforce in a knowledge intensive world economy.

- Developing flexibility within learners by promoting and encouraging creativity and problem solving as part of the core learning experience.

- Increasing access to learning opportunities in the UK by broadening the set of e-learning facilities available to learners.

- Developing new technologies and facilities to support learning for life that exploit emerging technologies.

- Developing appropriate models and policies that support and encourage the uptake of learning facilities.

- Developing an understanding of the social and cultural issues within e-learning and the development of approaches to the management these issues.

In the rest of this document we outline the four key learning for life research themes and the two multidisciplinary challenges that need to be tackled to ensure that the vision of learning for life becomes an everyday reality for those who wish to exploit the benefits it offers.

**Theme 1 - Modeling and dynamic evaluation**

Researchers engaged in creating computer systems that adapt to the needs of their users have developed the community’s understanding of the theoretical and practical issues that impact upon the process of modelling the learner, the construction and exploitation of user and system models, and the application of this knowledge to an ever increasing range of technologies, from interface agents and on-line help systems to broader use of ubiquitous computing approaches within the learning context. Those involved in the development of intelligent and adaptive educational technologies have been concerned with individualizing the experience of learners and groups of learners and supporting a range of representations and reifications of either the domain being explored or the learning process. Likewise, those involved in the evaluation of learning technologies collect process data via automatically generated logs that reflect the ways that learners interact with technology in and across different learning contexts. This has led to novel methodologies for the representation and analysis of this information as well as increasing our understanding about how learners use their technology.

Ubiquitous networked technology offers the potential to create a more complete picture of each learner that includes information about their learning activities across multiple contexts and over time. Pervasive sensing technology enables us to collect and integrate information about learners’ cognitive, physical and emotional behaviours. This rich picture, whilst created through human activity, is
represented, maintained and made available through technology. In consulting the UK research community, a number of research questions emerged of specific relevance to these issues of modelling and dynamic evaluation:

- How can we build models for all learners and teachers as individuals and as group members that can be distributed across different devices and contexts accessed as and when needed in a secure manner that provides the appropriate level of privacy?
- Learner models can vary in timescales from 10 seconds to 10 years – how do our theories and methods address these differing timescales? How can we share our data?
- Research into computer gaming has the potential to inform our understanding of, for example, the nature of ‘engagement’ and ‘flow’. How can these be deployed for the benefit of lifelong learners?

**Theme 2: Informal, Lifelong and Workplace Learning**

The growing availability of information through digital technologies allows access to learning to broaden from traditional approaches to become part of our everyday life. Simultaneously, researchers and policy makers are mapping out a new landscape of informal, lifelong and workplace learning. This everyday learning need not be in competition with traditional classroom teaching or workplace training, but can complement it. The defining features of everyday learning are that:

- Formal education cannot provide people with all the knowledge and skills they need to prosper throughout a lifetime, so people will need continually to enhance their abilities, in order to address immediate problems and to participate in a process of continuing vocational and professional development;
- It is not confined to pre-specified times or places, but may happen whenever there is a break in the flow of routine daily performance and a person reflects on the current situation, resolves to address a problem, to share an idea, or to gain an understanding;
- It is fundamentally mobile, in that it can occur at any time of the day or night, in any location, and that a learning episode may continue across contexts and on the move, for example on a train or flight;
- It is mediated by a variety of personal technologies, including mobile phones and portable computers.

A consequence of this re-conceptualisation of learning is that the environments where learning occurs cannot be pre-specified, but are created through the activity. Nor can the environment be decomposed into elements that are independent of the learner, but instead are dynamically constructed by learners interacting with their social and physical surroundings. This poses considerable challenges for the analysis of everyday learning and the design of technologies and practices to support it.

- For technology designers, a central question is how can we develop personal technologies that support a person through a lifetime of learning?

This requires a deep understanding of: the development of learning abilities; the role of technology in mediating learning for different ages and contexts; learning across life transitions such as the transition from college to workplace; the design of engaging technology for mobile and ambient learning; the design of technology to support opportunistic learning and ad hoc collaboration; the implications for policy and practice of introducing personal technologies into schools and workplaces.

- For educators, a central question is how can we understand the dialectical relationship between personal technology and everyday learning?

The appropriation of a technological tool such as a mobile phone offers new possibilities for learning, and the new contexts of learning create conflicts with existing technology and offer opportunities for further technologies and services. We lack a coherent theory of everyday learning that can guide the
design of new learning technologies and environments. We need to develop new methods to analyse the appropriation and adaptation of technology for learning and to study the detailed practices of technology-mediated everyday learning.

**Theme 3: Creativity and Problem Solving**

IT support for creativity has been characterised as having several requirements such as supporting easy exploration and experimentation, support for engagement with content to promote active learning and discovery, support for search retrieval and classification, support for instructive mistakes.

- **How do we develop systems which provide these opportunities for learners?**

One important aspect of many forms of creative problem solving is the ability to visualize data relevant to the problem and to visualize potential problem solutions. One important theoretical concept has been the notion of using various forms of representation as a means of cognitive offloading – allowing the external representation of the problem to free up the learner to consider problem solutions and not need to keep track of the various elements of the problem and their interactions. This work has emerged from many internationally leading UK researchers on the role of visualisation in education and training.

- **How can e-learning use new forms of visualizations that allow learners to explore problem spaces in new ways and to develop creative solutions?**

This theme could draw on work on 3D interactive models, immersive and collaborative virtual environments, mixed reality where the real and the virtual are merging, and new forms of augmented reality. All of these techniques can be harnessed to allow learners the space to explore and be playful and creative. The opportunities offered by new forms of user interface including adaptive, haptic and direct brain interfaces, all offer new opportunities to devise engaging and flexible learning environments which could be tailored to users’ preferences or learning styles or to support their creative interactions with technologies and problem domains.

These new forms of user interface also offer considerable opportunities in support of creative activities in variety of domains from visual arts such as painting to music. For example, Lin et al (2004) recently described one way in which new forms of interface can be used in visual arts - in their research a 3D haptic brush provides an intuitive method for artists to engage in virtual painting. The opportunities to develop such novel technologies for education and training in the creative arts are considerable but many research questions remain to be addressed.

- **What are the challenges that education in the creative arts present to HCI?**

- **How can new developments in interface technologies be exploited to support training in artistic composition?**

**Theme 4: Inclusion and Accessibility**

If information technology is to have a wide spread educational impact then research questions around inclusion and accessibility must be addressed. The US Grand Challenges for Computing Science highlighted this as one of their key topics in their ‘A Teacher for Every Learner’ theme in which they stated their 20 year vision as encompassing ‘information technology which enables all learners to participate’ and in which ‘the learning environment continuously assesses and adapts to each learner’s needs’.

In the UK, we are internationally leading in the widespread use of IT in mainstream and special education, as well as having leading researchers active in research and design IT inclusion and accessibility. The problem has been that it has been very challenging to move beyond research prototypes which encompass well-designed and accessible IT tools and resources, to wide-spread evaluation and deployment in classrooms or other learning contexts.

In consulting the UK research community, important research questions around accessibility and inclusion emerged. For example:
How do we develop models of individual learners which encompass the widely varying timescale over which different sorts of learning occur form the very immediate to the very long term?

Notions of stable individual learning styles are no longer thought to be useful for the design of IT educational systems. Instead the goal is how can we design and support context-bound, domain-dependent characteristics of the learning task and of the learning relationships influencing the individual learner?

Inclusive accessible learner-centred design presents challenges to Human Computer Interaction. For example how do we support learners with limited literacy, language or cognitive skills to access meaningful learning resources and experiences? How do we design systems that enable such learners to collaborate with their peers? Can the design solutions for such learners lead us to truly intuitive, empathetic means of interaction in the era of the disappearing computer?

How do we develop intelligent pedagogical agents that can be tailored by the learner to their needs? What degree of personalisation is necessary to achieve digital inclusion for all learners – and how is this balanced against developmental effort and complexity?

How do we capture key features of user semantics? Can we then use these to pull together ontologically appropriate content to enable the effective use of the educational semantic web?

Technological challenges in e-learning

The realisation of future technology enhanced learning environments raises a number of significant technological research challenges that need to be addressed if we are to consider the development of e-learning facilities that meet the needs of users. These can be considered in terms of two key technological research areas.

Developing New Forms of Interactive Learning and Learning community

Interaction, cooperation and community play a central role in the support for learning. The development of future e-learning environments allow us the opportunity to provide new forms of interactive learning experience and new relationships between computer and learner and the formation of new forms of learning community. Key challenges that need to be addressed include:

- New forms of naturalistic and multimodal interface to support learning whether it takes place across a distance supported by a variety of different interaction devices or in a co-located manner.

- New techniques and metaphors to understand and support learning communities that combine both human and computational agents including new models of computer based learning and new forms of augmented cognition.

- The development of new techniques for the design, development and assessment of systems to support distributed, transient and mobile communities of learners.

- New forms of support for community memories that ensure the consolidation and preservation of learning along with its originating provenance.

- Personalisation techniques that allow users to tailor the learning facilities to meet their individual needs and current activity.

- Techniques to support and promote interaction across and between learning communities including the discovery of new communities.

Developing New Knowledge Facilities for e-learning

Lying at the core of e-learning is the discovery of new knowledge. Indeed the generation, support and maintenance of knowledge provides the foundation of e-learning. The rapid increase in the volume and
variety of data available electronically means that learning facilities need to be supported by appropriate semantic services. These services must be able to generate a surrounding semantic context in which learning can be supported. Fundamental research on knowledge systems and services is needed to allow us to develop a powerful set of knowledge services for e-learning. Research that needs to take place includes work on:

- New theories and techniques to allow learning and reasoning over uncertain and incomplete knowledge.
- Tools, methods and techniques to support the design, development and deployment of large-scale learning facilities.
- Support for collaboration and sharing across different learning facilities at varying scales including working across personalised learning structures and larger organisational and disciplinary structures.
- Support for semantic directed knowledge discovery as part of a dynamic learning process.
- The development of lightweight and incidental knowledge capture techniques to promote in-situ and lifelong learning.
- Development of learning support services that can be tailored to meet the demands of different domains and users.

Many of these issues are shared with the growing knowledge research agendas underpinning the Semantic Web and Semantic Grid initiatives.

**Maturity of the Grand Challenge**

- **It arises from scientific curiosity about the foundation, the nature or the limits of a scientific discipline.**

The Challenge certainly recognizes the limits of the discipline as it has been carried out so far. The term ‘e-learning’ inherits problems stemming from superficial responses to specific educational problems which, although they may be important, do not constitute a revolutionary approach to the understanding of people engaged in learning. This has led to the perception that computing solutions to educational problems have promised much and delivered little – and that this may be just another phase in that cycle. Such a view ignores the great progress that is being made in computing systems at the present time, which are not confined to the ‘one system fits all’ approach. We have the opportunity to break this cycle.

- **It gives scope for engineering ambition to build something that has never been seen before.**

What we are aiming for certainly has never been seen before. We are not proposing to simply extend what we currently know, and to that extent we are not sure what the dimensions of our proposal actually are. All we know is that current approaches are not sufficient. This will only happen if the computing community engages with the challenge.

- **It has enthusiastic support from (almost) the entire research community, even those who do not participate and do not benefit from it.**

As noted earlier, this document is the product of a UK-wide consultation and represents the research concerns of over 200 researchers.

- **It has international scope: participation would increase the research profile of a nation.**
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The UK has a small margin of worldwide lead in this area at present, but we run the serious risk of being overtaken unless we devote our undoubted talented pool of researchers to this topic. This point has been noted by the research councils, hence the funding programme.

- It is generally comprehensible, and captures the imagination of the general public, as well as the esteem of scientists in other disciplines.

Most people would be relieved to see e-learning mature to such an extent that they do not have to even consider the systems which underpin their learning activities, whether these are self determined, or whether they are part of a formal learning activity. At the moment, too many hitches and glitches bedevil the learner, who often retires frustrated by the fractured experience of today’s learning environments.

- It promises to go beyond what is initially possible, and requires development of understanding, techniques and tools unknown at the start of the project.

We feel that this is the case, which makes it difficult to ascertain how ‘it will be obvious how far and when the challenge has been met (or not)’.

- It decomposes into identified intermediate research goals, whose achievement brings scientific or economic benefit, even if the project as a whole fails.

The themes we have identified illustrate how the overall goal could be decomposed, and each of these represents a significant contribution to the field. Scientific and economic benefit would result.

- It will lead to radical paradigm shift, breaking free from the dead hand of legacy.

The key point is to get a community to break from the dead hand of legacy when many members don’t even recognize that the hand is dead. The paradigm shift is required to deconstruct some of the complacent thinking that has characterized this field for so long. The commercialization of e-learning has had a detrimental effect, leading to claims that certain companies have ‘solved all the research issues’. Unfortunately, nothing could be further from the truth.

Relation to other Research Challenges

This challenge shares some common ground with the Memories for Life Grand Challenge, in that learners, like another other user, will need to have methods, systems and tools to preserve and manipulate what they know to create new knowledge and further learning. However, in reading the Memories for Life document, we felt that much of the specific detail pertaining to research for e-learning and learning for life is absent. We would therefore proposed that this challenge be a sister challenge to Memories for Life. Consultation has taken place with the Memories for Life Grand Challenge participants, some of whom are supporting this proposal.