Chapter 1
Research Themes in Technology Enhanced Learning

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Introduction

Learning has been influenced by technology at least since prehistoric paintings flickering in the light of burning torches displayed beasts and hunting to the children of cave dwellers. What makes digital systems different from the previous technologies of painting, writing, audio recording and film is that they are interactive. Computers, and more recently mobile devices can not only provide teaching materials through a variety of media, they can also respond to learners by linking between web pages, reacting to queries, and engaging in games and simulations. Technology Enhanced Learning (TEL) harnesses the power of interactivity and has the potential to enhance what is learned, how we learn and how we teach.

This book emerged from the work of STELLAR,[1] a network of excellence in Technology Enhanced Learning funded by the European Union with the aim to provide a strategic direction for TEL research that improves learning and educational systems. STELLAR was formed with the view that breakthroughs in TEL research and development are more likely to occur when people come

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[1]http://www.teleurope.eu/.

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together across the different people-centred and technology-centred disciplines, working as interdisciplinary research teams. From this perspective the multiple and complex differences between different disciplinary perspectives are considered to be essential for innovation and "it is out of the tensions or conflicts between different disciplinary perspectives that innovative approaches and solutions to problems arise" (Sutherland, Eagle, & Joubert, 2012, p. 4).

The broad scope of the STELLAR network is reflected in this compendium of TEL research. Each chapter covers four key papers that lay the foundations for its topic, which are then extended to address current issues in learning with technology. The 15 chapters span the field of TEL, with authors from the fields of Cognitive Science, Computer Science, Education, Educational Technology, Learning Sciences, Learning Technology, Human Computer Interaction and Psychology.

This introductory chapter starts with a brief overview of the history of TEL in order to provide a background to developments in the field. The subsequent sections introduce the chapters in the book, organised into theories of learning with technology, learning as a design science, collaborative and social learning, technology-based learning environments, self-regulation and formative assessment, learning objects and infrastructures, and ending with a discussion of digital divides and social justice in technology-enhanced learning that highlights the risks of taking what is called a techno-determinist perspective on TEL: a belief that technology drives social change.

A Very Brief History of Developments in Technology Enhanced Learning

The origins of Technology Enhanced Learning lie in the experiments of Sidney Pressey in the early 1930s to develop an adaptive teaching machine. Frustrated with lack of official recognition and support for his work, Pressey wrote:

> There must be an 'industrial revolution' in education, in which educational science and the ingenuity of educational technology combine to modernize the grossly inefficient and clumsy procedures of conventional education. Work in the schools of the future will be marvellously though simply organized, so as to adjust almost automatically to individual differences and the characteristics of the learning process. There will be many laborsaving schemes and devices, and even machines – not at all for the mechanizing of education, but for the freeing of teacher and pupil from educational drudgery and incompetence. (Pressey, 1933, pp. 582–583)

During the 1950s, B.F. Skinner again explored the design of teaching machines, based on a theory of "programmed learning" that would allow a learner to progress through teaching materials in small steps, designed to assist correct learning (Skinner, 1968). Thus, some important elements of TEL were established by the late 1950s: learning through technology; design of learning materials; individualized learning; enhancing rather than replacing human teaching.

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Tutor: So now let's think about the switch. Is it a source or a load?

Student: source

Tutor: Why do you say that?

Student: when it is turned off, no energy flows

Tutor: OK, that is true. But does it actually cause electricity to flow?
Or is it merely letting what current was produced by the source flow through
it to the rest of the circuit?
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Fig. 1.1 Brief extract from a dialogue with a computer-based tutoring system from Rosé et al. (2001)

When computer-assisted instruction systems were introduced in the 1960s, they were not based on any deep theory of learning. Such systems responded when a learner typed a number in answer to a multiple choice question by branching to some remedial material (if the answer was wrong) or the next item (if correct). They worked to a limited extent, but to offer more personalised responses that answer a learner's queries or offer help in solving a problem, required educational technologists to investigate how people represent their knowledge to themselves and others, how they express questions and make use of answers, and how they learn individually and together. Thus, the science of learning was founded.

From the 1970s onwards, research into artificial intelligence and education has sought to create computer representations of conceptual knowledge, with the dual aims of modelling human learning and developing computer-based tutoring systems that simulate human tutors. Early tutoring systems attempted to engage a student in a tutorial dialogue using natural language. The example in Fig. 1.1 is from a computer-based tutor of electronics (Rosé, Moore, VanLehn, & Allbritton, 2001). A successful line of applied research has been development of Cognitive Tutors® by Carnegie Learning, based on Anderson's ACT-R theory of human cognition and associative memory. These have been deployed in school classrooms to supplement human teaching by engaging students in carefully managed dialogues to teach topics that have well-structured concepts, such as algebra, geometry or computer programming (Anderson, Corbett, Koedinger, & Pelletier, 1995).

Since then, our understanding of human cognition and learning has grown in tandem with new technologies for teaching and learning. Rather than simply absorbing information, people of all ages are active constructors of knowledge. We relate new information to existing concepts, making connections between old and new ideas. We are able to hold multiple perspectives, for example, to conceive what it would be like to be an immigrant from a foreign country or to walk on the moon, while simultaneously managing our everyday lives. We can think about our own thinking (metacognition), finding ways to learnmore productively. We create

representations of our knowledge in the form of written texts, equations, pictures, and 'mind maps' of our connected ideas. We can engage in collaborative processes of meaning making, exploring different perspectives and reaching joint conclusions. All these ways of learning are being supported by digital tools for connecting, extending, representing, exploring, and sharing knowledge.

A leading example of educational technology that provides an integrated suite of cognitive tools for learning is the Web-based Inquiry Science Environment (WISE) environment from Linn and colleagues.[2] This computer-based environment for science learning has been under development since 1997, accessed by over 100,000 learners worldwide. It guides learners through the process of investigating scientific problems, offering hints, facilities for note-taking and online discussions, as well as software tools for drawing, concept mapping, diagramming, and graphing.[3]

As theories and technologies for learning evolve, there is a continuing need to implement and test the new technology-enabled methods. What started in the early 1960s as small-scale projects in research labs, rapidly extended into large-scale educational systems, notably PLATO and TICCIT (Hagler & Marcy, 2000). These were the forerunners of Virtual Learning Environments, and later Massive Open Online Learning (MOOC) systems that administer and manage learning at large scale. A new Technology Enabled Learning (TEL) industry was born to develop and market these systems and evaluate the learning they enable. From this industry came a need for standards to enable exchange of teaching objects and learner data across systems, and new methods of analysing the progress of large cohorts of learners. Educational data mining and learning analytics draw on techniques from statistics, artificial intelligence, and educational management to determine when to intervene with additional teaching resources, where to assist struggling learners, and how to improve online courses for the future.

Theories of Learning with Technology

Chapter 2, by Crook and Sutherland, considers multiple theories of learning, including behaviourist theories and how they raised the idea of a "teaching machine", cognitive learning theories which led to "intelligent tutoring systems" and also "learning by programming", and social constructivist theories that have informed the design of online environments for collaborative learning. Yet, these grand theories are not in opposition, and a major contribution of the chapter is to show how they can be reconciled to explore new ways to understand and design learning with technology.

One theory of learning that has been widely misunderstood is Constructionism. In Chap. 3, Noss and Hoyles distinguish *constructivism*, which is a theory of how people learn by building mental structures of knowledge, from *constructionism*,

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[2]https://wise.berkeley.edu/.

[3]https://wise.berkeley.edu/pages/features.html.

which is a theory of pedagogy concerned with helping people learn through a process of building and sharing computational entities. These entities may be physical, such as programmable toys, or virtual, such as microworlds—computer environments like where people learn by creating simple shapes or complex music, language, or art. When appropriately designed, these microworlds can allow learners to gain nuggets of knowledge about a topic such as mathematics or linguistics, while making, doing and solving problems.

Learning as a Design Science

The field of TEL is underpinned by a notion of learning as a design science—that environments for learning are designed artefacts, created through human ingenuity, based on accumulated research into how we learn and how to improve the effectiveness of human-technology systems. In Chap. 4, McKenney and Kali describe a dialogue between researchers in the Learning Sciences and Instructional Systems Design. Both fields share a focus on the design of learning environments, ranging from school classrooms and curricula, to online communities of learners. Since all learning now takes place in a technology-enabled world of internet connections, websites and mobile devices, it follows that the technology and the learning must be designed and evaluated as a single system. The method of design-based research (Barab & Squire, 2004) has now been widely adopted in TEL. It involves a sequence of design experiments, each of which starts with a theory of learning and teaching that guides the design of new technology-based interventions in classrooms or online. The technology-enhanced interventions are tested and evaluated with learners and the research findings regarding new ways of learning with technology lead onwards to a new cycle of design, implementation and evaluation.

Collaborative and Social Learning

Two chapters cover aspects of collaborative and social learning. The term Computer-Supported Collaborative Learning (CSCL) was coined in 1989 (see Stahl, Koschmann, & Suthers, 2014) to describe how people learn together with the assistance of computer systems. Since then, there has been growing interest in TEL research on collaborative learning and the idea that knowledge-building is achieved through interaction with others. Early work by Scardamalia and Bereiter developed a computer-supported intentional learning environment (CSILE) which enabled whole classes of students to build knowledge collaboratively through a process of presenting and refining their theories (Scardamalia & Bereiter, 1994).

Chapter 5, by Ludvigsen and Arnseth, indicates three inter-dependent layers of CSCL, which all need to be understood in order to design and analyse collaborative

learning. The first layer is concerned with how people reason, discuss and argue together, the second layer refers to ways that learners, at any point in time, participate in shared activities, and the third layer represents ways that institutions such as schools create conditions for shared participation. The chapter also describes "scaffolding" as an important mechanism in CSCL (and TEL in general) for learners to accomplish tasks that would normally be beyond their ability with the assistance of more knowledgeable helpers. The scaffolding might be offered by other learners, teachers, or computer-based tutoring systems.

As TEL has grown in scale, from classroom systems, through online learning environments, to Massive Scale Open Courses (MOOCs) involving tens of thousands of people in a shared learning activity, so the scope of CSCL has broadened. Chapter 6, by Cress and Fischer, discusses mass collaboration with social software such as wikis and blogs, as well as learning through social networking on Facebook, Twitter and other social media. With massive-scale participation, opportunities arise for "long-tail learning" where groups of learners with niche interests share their knowledge, skill and passion. A connected world creates new learning ecologies where people can become co-creators of shared ideas, knowledge and products. Conversely, people in online social networks need to develop skills of information filtering and strategies to cope with a deluge of time-sapping activity. Research into mass collaboration is starting to identify the social abilities, technical skills and cultural competencies needed for successful participation in mass online learning. It is also exploring innovative pedagogies that can improve with scale, for example by creating conversations for learning among people with differing experiences, perspectives and cultures (Ferguson & Sharples, 2014).

Technology-Based Learning Environments

Recent research in TEL has extended beyond the classroom to explore learning in differing physical and virtual environments. Chapter 7, by Bligh and Crook, considers the material, spatial experience of learning in physical rooms including libraries, labs and classrooms. They suggest that studies of learning spaces can illuminate how learning happens when people interact with technology-enabled settings. Spaces can be seen as unimportant to, impeding, containing, stimulating, associating with, extending, or socially constituting learning. Each of these conceptions of space lead to decisions about how to design for effective learning. For example, seeing spaces as socially constitutive suggests that *community* should be the focus of attention, embracing relationships between the activities of educationalists, architects and estates planners, as well as how learners engage with different spaces to move among communities of practice.

Learning within and across physical spaces is also a concern of research into Mobile Learning, the topic of Chap. 8, by Sharples and Spikol. Here, mobility of learners is a prime concern. Even within a school, children move between classrooms and shift between technologies and resources. Beyond the classroom,

in museums or outdoors, people can create "micro-spaces" for learning out of technologies such as smartphones, their surrounding space and objects, and other people. As mobility and context become more important in education, so research is coming to see learning as an activity extended over time, space and social engagement. A challenge for the future will be to support people over a lifetime of learning, embracing life transitions (such as from school to college, and into workplaces), new technologies, changing societies, and evolving communities and cultures.

New communities will be virtual as well as physical, or hybrids with virtual worlds and information overlaid on the real world. In Chap. 9, Savin-Baden, Falconer, Wimpenny and Callaghan review teaching and learning in virtual worlds. They identify four key themes of socialisation, presence and immersion, collaboration, and participation. Virtual worlds can blur the distinctions between reality and fantasy, evoking uncertainty and disorientation, yet also opportunities to play with identity and to see reality as one option in a space of possibilities.

Chapter 10, by Herder, Sosnovsky and Dimitrova, brings adaptive intelligence into the mix of learning environments. Adaptive Intelligent Learning Environments (AILE) offer personalised learning by building a model of each learner's knowledge and performance, then using that to select learning materials or propose routes through a curriculum to keep learners motivated and engaged. Similar techniques can also drive learning environments that propose Web tools and resources based on learner recommendations and activities, or form learners into affinity groups for collaborative exploration. New methods of learning analytics can provide real-time streams of data from online learning activities, to both inform adaptive teaching and also guide designs of effective teaching materials and curricula.

Self-Regulation and Formative Assessment

A trend in TEL research, shown in mobile, virtual and adaptive learning environments, has been to extend the focus of investigation from classroom to informal settings such as museums, outdoor locations, and online communities. These all require effort by the learners to regulate their learning—to make wise and timely choices about what to learn, where to find materials, and who to collaborate with. Self-Regulated Learning (SRL), the theme of Chap. 11 by Persico and Steffens, is becoming increasingly important in a world of information overload, social change, environmental pressure, and cultural tension. Educational systems worldwide need to support young people in developing skills of goal setting, metacognition, help seeking and self-assessment. Some TEL environments are now helping learners to set and achieve personal goals, measure their progress, and assess their personal progress, but much research and development is needed into how to foster effective and sustained self-regulated learning.

Assessment for learning, covered in Chap. 12, by Perotta and Whitelock, can play an important role in helping people to regulate and track their learning. Methods

of formative assessment provide students with constructive feedback to improve performance. Good feedback on performance can help students to understand where they need to focus attention and overcome weaknesses, and also encourage conversation around learning to explore differences in conception. Even simple technology such as voting systems can prompt conversation—if a teacher sets a question with no single correct answer, then encourages students to talk about their differing responses. More generally, the different ways that we, as educators and researchers, interpret technology enhanced education will have a profound effect on the role and importance of assessment: whether as a means to compare performance on standardised measures across different institutions, countries and technologies; or for assessment to shape, and be shaped by, a multitude of learning practices.

Learning Objects and Infrastructures

The technologies for learning are many and varied. After teaching machines and computer-based instruction, the field has embraced new technologies including interactive videodisks, the internet and worldwide-web, personal and mobile devices, technologies embedded in everyday objects, and virtual and augmented reality.

One central concern from the outset has been how to design, represent, store and distribute pieces of learning content. As Chap. 13, by Boyle and Duval, indicates, definitions of what constitutes a "learning object" vary wildly—from a single image or short piece of teaching text, to a complete course. Nor is there a standard way to describe such objects, or to access and include them in teaching sessions. However, the ALOCoM model makes a major contribution in describing a hierarchy of content units as well as way to aggregate and navigate them, and the Sharable Content Object Reference Model (SCORM) is a widely-adopted set of services to share and reuse learning objects. In parallel to these emerging standards, Open Educational Resources (OER) are teaching materials that can be accessed for free on the worldwide web, though with no common standard or format. Finding a way to create, licence, access, exchange and combine learning content from open courses and from universities and commercial providers is a major challenge for TEL.

Chapter 14 from Ochoa and Ternier extends the discussion of learning objects and their reuse to the design of large scale infrastructures for TEL. The main aim in developing infrastructure standards is to enable interoperability of TEL systems, so that learners can move easily between tools, content, activities and communities provided on different computers by a variety of companies and educational institutions. Metadata standards enable the sharing of learning resources. Content models, such as SCORM and IMS Common Cartridge, allow exchange of educational materials. Learning design patterns provide sharable representations of course structures. Learning process standards provide ways to share tests, questions and results. Other standards are evolving for recording student progress and learning experiences. The journey to develop a standardised TEL infrastructure has been long

and difficult, with many companies and projects competing for recognition of their tools and methods, but also because education is evolving rapidly to embrace open, mobile, and massive-scale systems.

Digital Divides and Social Justice

The final chapter, from Grant and Enyon, addresses a tension within TEL research about the potential of technology to improve education. Such a potential for change can lead to a *technologically determinist* approach that assumes benefits will flow automatically from the introduction of new technology, offering cheap, easy access to learning for disadvantaged people. The authors argue that the digital can reinforce or replicate existing inequalities in society, including censorship and benefits from being fluent in English language. Rather than a single "cyberspace" of seamless interaction, the digital world may be fragmenting into countless small and poorly connected spaces.

Within the STELLAR network we acknowledged that research can often take an overly optimistic and deterministic view of the power of technology to benefit education. We explored areas of tension, with sometimes opposing views of future developments, such as whether new educational technologies will reduce or increase digital divides. Another area of tension relates to understanding why TEL is not being embraced more by schools—perhaps because global competition and high-stakes assessment forces teachers to focus on learning outcomes rather than incorporating learning technologies into their practices. Technology enhanced learning forms part of a broader social, economic and political context, of innovating entrepreneurs, competing companies, political imperatives, and a changing world. New research is needed into how TEL fits into a broader understanding of inequalities in society and how these inequalities can be tackled through programmes of inclusive and empowering education.

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