Erik Duval · Mike Sharples
Rosamund Sutherland *Editors*

Technology Enhanced Learning

Research Themes

Springer

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Preface

This book provides an introduction to research in learning with technology in classrooms, online and outdoors. Written by leading international researchers, it covers foundational theories and methods as well as recent research into learning in virtual worlds and in social networks. It also discusses social issues and implications such as whether widening access to digital technologies will decrease or increase inequality in education.

Each chapter in the book covers one theme in technology-enhanced learning (TEL), discussing and expanding on four foundational research papers in that theme. The chapters, plus the introduction chapter, can be read as a primer for people new to the field of TEL (also called "e-learning", "educational technology" or "cyber-learning"). Or a chapter can be a route to exploring the theme in more depth, through reading and discussing the selected papers guided by the chapter commentary. Inevitably, we have had to be selective in coverage, and some areas of TEL are not discussed in the depth they deserve, including evaluation of TEL systems, learning through simulations, orchestration of learning with technology and technology-enhanced learning in subject areas including science, technology, arts and languages. In this book, you will find pointers to further reading in these and other related areas.

The idea for this book came from Erik Duval, and he guided its production. Erik was a leader in the STELLAR Network of Excellence in Technology Enhanced Learning, a stimulating nexus of people and ideas from education, computing, psychology and the social sciences. Other outcomes from STELLAR include a Vision and Strategy report and a set of Grand Challenges in Technology Enhanced Learning.[1]

Erik Duval died on 12 March 2016 after two years of illness with leukaemia. Erik's blog[2] starts in 2003 with entries that mix his research interests with commentaries on technology and culture. As his illness takes hold, the blog charts

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

[2] erikduval.wordpress.com

in poignant detail his fears and hopes. The last entry from the 4th of January ends with typical optimism: “For now, I’m mostly hopeful and confident: I wish you all a hopeful and confident 2016 too!”.

Erik’s work exemplified the interdisciplinarity and continuing innovation of TEL. He researched and developed the core enabling technologies of learning objects and educational metadata and helped to establish learning analytics as a field of international research. As a teacher, he embraced open and social technologies, using his blog and Twitter to share ideas and communicate with students, and also led practice-based courses where students worked together, guided and inspired by Erik. Erik initiated this compendium of research in technology-enhanced learning, as he did many projects, with passion and commitment. In his name, we dedicate this book to all scholars of technology-enhanced learning who share a devotion to helping others learn.

Leuven, Belgium — Erik Duval
Milton Keynes, UK — Mike Sharples
Bristol, UK — Rosamund Sutherland

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About the Editors and Authors

Editors

Erik Duval was full professor at the Katholieke Universiteit Leuven where he chaired the Informatics Section of the Computer Science Department and also chaired the Research Unit on Human-Computer Interaction. His research was situated in the long-standing quest to augment the human intellect, with a scope that included technology-enhanced learning and learning analytics, science 2.0, digital humanities, personal health and data journalism. He died on 12 March 2016.

Mike Sharples is professor of educational technology in the Institute of Educational Technology at The Open University, UK. He also has a post as academic lead for the FutureLearn company. His research involves human-centred design of new technologies and environments for learning. He inaugurated the mLearn conference series and was founding president of the International Association for Mobile Learning. He is associate editor-in-chief of *IEEE Transactions on Learning Technologies*. He is author of over 300 papers in the areas of educational technology, science education, human-centred design of personal technologies, artificial intelligence and cognitive science.

Rosamund Sutherland is professor of education at the University of Bristol and was formerly head of the Graduate School of Education. Her research is concerned with teaching and learning with ICT, young people's use of digital technologies outside school and mathematics education. She recently published the book *Education and Social Justice in a Digital Age*, and nowadays she uses her research to inform her work as governor of Merchants' Academy in South Bristol.

Authors

Hans Christian Arnseth is an associate professor in the Department of Education at the University of Oslo. He holds a PhD in the educational sciences in the field of technology-enhanced learning and specialises in how and what students learn in subjects in school and in their leisure time. His main contributions are in the field of computer-supported collaborative learning. Based on a sociocultural stance, he contributes with studies within themes like games and simulations, learning and identity, science education, learning across sites and methodological issues related to discourse and interaction analysis. He is a member of the editorial board of the the International Journal of Computer-Supported Learning (IJCSCL).

Brett Bligh is a lecturer in the Department of Educational Research at Lancaster University. He conducts research into the connections between our material surroundings, the technologies that permeate them and the ways we act, think and learn. Part of that research involves studying uses of technology in complex institutional settings and attendant approaches to organisational change. Brett uses activity theory to underpin his empirical work and also investigates that theory as a research object in its own right. His current work focusses on academic collaboration in the design of technology-rich university learning spaces.

Tom Boyle is emeritus professor at London Metropolitan University and former director of its Learning Technology Research Institute (LTRI) from 2000 to 2012. He championed the role of learning design in the learning objects movement as a complement to the predominantly technical emphasis on metadata and packaging. Professor Boyle led several projects that used ICT to significantly improve the quality of the learning experience for students, as measured both by student evaluation and improved pass rates. He has published widely on technology-enhanced learning both on theory and practical guides to development. The learning objects for Java that he designed won an EASA (European Academic Software Award) in 2004.

Michael Callaghan is a reader at Ulster University. His research interests include serious games, virtual worlds, remote experimentation/laboratories and e-learning. He is a fellow of the Higher Education Academy, is a distinguished fellow of the university, is an editor of the *International Journal of Online Engineering*, serves on the Scientific Advisory Board of the International Association of Online Engineering and is a reviewer for a number of IEEE journals and funding bodies including the AHRC, HEA and EU in his areas of expertise. He has been a grant holder on funded projects from the AHRC, DETI, INVESTNI, JISC and Higher Education Academy.

Ulrike Cress studied psychology and completed her PhD with a dissertation about self-regulated learning. She is the director of the Leibniz-Institut für Wissensmedien (IWM) and a full professor at the University of Tübingen in the Department of Psychology. In her lab Knowledge Construction, she researches social and cognitive processes that are relevant for the joint construction and usage of knowledge. Her research foci include computer-supported collaborative learning (CSCL), mass collaboration, social software, knowledge management, embodied interaction as well as design and evaluation of media-supported learning and working environments.

Charles Crook is professor of education at the University of Nottingham and director of its Learning Sciences Research Institute. He has held posts at Brown, Strathclyde, Durham and Loughborough Universities. His main interest is in the psychology of human development, with special concern for young people's use of new social media. He has authored a number of papers developing a cultural psychological approach to educational practice and has published empirical papers in most of the major journals of developmental psychology. His current work is focussing on the integration of voice and image in young people's multimodal compositions.

Vania Dimitrova is an associate professor at the School of Computing, University of Leeds, UK. She is a member of the Knowledge Representation and Reasoning Group where she leads the research activity on user modelling and adaptive systems. Vania's research focuses on developing intelligent systems that adapt to individuals, groups and communities. Her research interests include learner/user modelling, dialogic interaction, knowledge capture, meta-cognitive skills, community adaptation, ontological modelling and reasoning.

Rebecca Eynon is an associate professor and senior research fellow at the University of Oxford. She holds a joint academic post between the Oxford Internet Institute (OII) and the Department of Education. Her research examines the relationships between technology, learning and inequalities, and she has carried out projects in a range of settings (higher education, schools and the home) and life stages (childhood, adolescence and late adulthood). She is co-author of *Teenagers and Technology* (Routledge, 2013) and *Education and Technology: Major Themes* (Routledge, 2015). Rebecca is co-editor of *Learning, Media and Technology*.

Liz Falconer is professor of technology-enhanced learning and director of the Education Innovation Centre at the University of the West of England, Bristol, UK. She is a chartered manager and member of the CMI and is a principal fellow of the Higher Education Academy. Her current area of research is in learning in immersive virtual environments and virtual worlds. She publishes in national and international journals and speaks at international conferences on subjects related to technology-enhanced learning, majoring upon situated and contextual learning in immersive virtual environments to support simulation and practice-based learning.

Gerhard Fischer is a professor adjunct and professor emeritus of computer science, a fellow of the Institute of Cognitive Science and the director of the Center for Lifelong Learning and Design (L3D) at the University of Colorado at Boulder. He is a member of the Computer-Human Interaction Academy, a fellow of the Association for Computing Machinery and a recipient of the RIGO Award of ACM-SIGDOC. In 2015, he was awarded an honorary doctorate from the University of Gothenburg, Sweden. His research has focused on new conceptual frameworks and new media for learning, working and collaborating, human-centred computing and design.

Lyndsay Grant is a doctoral researcher at the University of Bristol. She has worked as a researcher in education, technology and society for over 10 years at the University of Bristol and previously at the independent educational technology research lab, Futurelab. Her research has explored social justice and digital inclusion, connections between learning in and outside schools with digital technologies and participatory approaches to the design of educational interventions using technologies. Her doctoral research focuses on the use of data technologies in schools.

Eelco Herder works as a senior researcher at the L3S Research Center in Hannover, Germany. His main research interests include Web personalisation, user modelling, usability and HCI in general. Other research topics include Web usage analysis and the development of tools for personal information management. He is board member of the SIG User Modeling Inc. and served as chair of ABIS, the German SIG on adaptive systems, between 2007 and 2015. Eelco served as programme, workshop, poster, publicity and local chair at various conferences, among which are Hypertext 2016, IUI 2015, Hypertext 2014, CHI 2012, UMAP 2010–2013 and Adaptive Hypermedia 2008.

Celia Hoyles is professor of mathematics education at the UCL Institute of Education. She holds a first class honours degree in mathematics and a master's and doctorate in mathematics education. Before moving into higher education, she taught in London secondary schools. An enduring research interest has been the design of computer environments to engage students in learning mathematics. She was the first recipient of the International Commission of Mathematics Instruction (ICMI) Hans Freudenthal Medal in 2004 and the Royal Society Kavli Education Medal in 2011. She was awarded foreign fellow of the Union of Bulgarian Mathematicians. She was the UK government's chief adviser for mathematics (2004–2007) and the director of the National Centre for Excellence in the Teaching of Mathematics (2007–2013). She was president of the Institute of Mathematics and Its Applications (IMA) (2014–2015). Celia was awarded an OBE in 2004 and made a dame commander of the Order of the British Empire in 2014 for services to mathematics and mathematics education.

Yael Kali is an associate professor of technology-enhanced learning in the Department of Learning, Instruction and Teacher Education at the University of Haifa. She is also the director of the Learning in a Networked Society (LINKS) of the Israeli Centers for Research Excellence (I-CORE). Using a design-based research approach, she explores technology-enhanced learning and teaching at various levels from junior high school to higher education and is especially interested in the role of design and design principles for supporting computer-supported collaborative learning (CSCL) and teacher professional development, in a teachers as designers (TaD) approach.

Sten Ludvigsen Professor Sten Ludvigsen holds a PhD in educational sciences (education psychology, from the University of Oslo, 1998). He led the Kaleidoscope European Network of Excellence (NoE) (Programme: Technology Enhanced Learning) from 2007 to 2008. He was director of InterMedia (2004–2009) and scientific leader of NATED: the National Research School in Educational Science (2008–2012) and now leads the research group Mediate at the Faculty of Education (2013–present). He leads the public committee that in 2015 delivered a report to the Norwegian government about the future of the Norwegian school system (K-12). He is the editor-in-chief for the *International Journal of Computer-Supported Collaborative Learning* (IJCSCL).

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Carlo Perrotta is academic fellow in digital learning at the University of Leeds. He is interested in educational technology, and his background is in social psychology, sociology and cultural theory. He has carried out research about innovation in assessment, teacher beliefs, the datafication of education and the use of video games in schools.

Donatella Persico is senior researcher at the Institute for Educational Technology (ITD) of the Italian National Research Council (CNR). Her major research interests concern technology-enhanced learning and, specifically, learning design, e-learning, self-regulated learning, teacher training and digital scholarship. She has been lecturer of educational technology in several teacher training initiatives of the University of Genoa and presently sits on the board of the doctoral school of the Cà Foscari University of Venice. She is author of educational material and scientific publications of various kinds, including books, educational software, multimedia material and research papers concerning various aspects of educational technology. She is editor of the Italian journal *TD Tecnologie Didattiche*.

Maggi Savin-Baden is professor of education at the University of Worcester. Over the last 20 years, she has pioneered work on the use of problem-based learning nationally and internationally. To date she has published 13 books and over 50 research publications as well as gaining external funding to research and evaluate staff and student experience of learning. Her recent research is into cyber-influence. She has just completed her next book on *Research Methods for Education in the Digital Age* (with Gemma Tombs). In her spare time, she bakes, runs, rock-climbs, skis and attempts triathlons.

Sergey Sosnovsky is a group leader at the Center for e-Learning Technology (CeLTech), German Center for Artificial Intelligence (DFKI), and a principal researcher at the School of Education, Saarland University. He holds an MSc degree in information systems from Kazan State Technological University (Kazan, Russia) and a PhD degree in information sciences from the University of Pittsburgh (Pittsburgh, PA, USA). He is a receiver of the Marie Curie International Incoming Senior Fellowship and an author of about 100 peer-reviewed publications on various topics related to adaptive and intelligent educational systems. His research interests lie at the intersection of technology-enhanced learning, personalisation and semantic web technologies.

Daniel Spikol is assistant professor of media technology at the Faculty of Science and Technology, Malmö University, Sweden. His main research interests are in the design and development of mobile and ubiquitous environments that explore different modes of collaboration that foster formal and informal inquiry-based learning and play. Spikol is interested in expanding the role of design to support understanding how people can navigate across physical and virtual spaces in active and creative ways.

Karl Steffens is psychologist and senior researcher at the University of Cologne, Germany. He obtained his PhD from the University of Bonn and has been working at the Universities of Bonn, Cologne, Frankfurt, Erfurt and Barcelona (Spain). At the University of Barcelona, he conducted research in the field of ICT for a year with a grant from the European Commission. Since then, he participated in a number of European research projects and networks of excellence on technology-enhanced learning and on intercultural communication, with a focus on self-regulated learning in technology-enhanced learning environments. In his teaching, he focuses on learning and instruction, technology-enhanced learning, motivation, emotion and personality development, competences and assessment.

Stefaan Ternier is an assistant professor at the Welten Institute of The Open University of the Netherlands. From 2000 till 2008, Stefaan worked in the group of Erik Duval, as technical architect for the ARIADNE Foundation. His current areas of research include mobile learning, metadata management, architectures for learning object repositories and learning analytics. Stefaan was a member of the CEN/ISSS Workshop on Learning Technologies (WS/LT). At this workshop, he coordinated the developments of the Simple Publishing Interface (SPI) and contributed to several other standardisation initiatives (including SQI). Furthermore, he was involved in several European projects that had an impact.

Denise Whitelock is professor of technology-enhanced assessment and learning in the Institute of Educational Technology at The Open University. Her main research interests are concerned with automatic feedback systems that promote assessment for learning. She has been involved in a number of multidisciplinary collaborations. These are generating new thinking about modelling automatic socio-emotive feedback, which, combined with automated constructive cognitive comments, can enhance both student learning and motivation.

Katherine Wimpenny is co-lead for research in the Disruptive Media Learning Lab at Coventry University where she researches pedagogic development in new and disruptive spaces using methodologies including arts-related research, interactive documentary, qualitative research synthesis and evaluation research. Katherine works on a range of (inter)national projects enhancing the research capacity of the lab and its funding base, focusing on methodological and pedagogical creativity, open education practices and visual and experiential learning. She has over 40 publications including peer-reviewed research papers, scholarly reports, book chapters and a book on arts-related research. Katherine supervises three PhD students and has five completions.

Chapter 1
Research Themes in Technology Enhanced Learning

Erik Duval, Mike Sharples, and Rosamund Sutherland

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

[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.

```
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*,

[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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Chapter 2
Technology and Theories of Learning

Charles Crook and Rosamund Sutherland

Introduction

> Humans are irrepressible theorisers. We can't help but note similarities among diverse experiences, to see relationships among events and to develop theories that explain these relationships (and that predict others).[1]

Establishing a principled understanding of human learning should be the starting point for any design and research ambitions involving educational technology. Innovation is too difficult—and its implementation too fragile—to risk basing it upon informal and intuitive theories of the learning process. Having declared this, we recognise that it will be difficult to do justice to such concerns in a short essay. Nevertheless, the relevance of learning theories to the further development of educational technology will be outlined here. In what follows, the history of such theorising will be sketched in broad terms: with the ambition of allowing it to be linked to shifting design, research and practice around technology-enhanced learning (TEL).

The Section "From Behaviourism to Information Processing" below starts the discussion with behaviourism and its significance for raising the idea of a "teaching machine". This is followed by a discussion of how TEL became increasingly influenced by cognitive psychology, with its conceptualisation of learning in terms

[1]Davis et al. (2000, p. 52).

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of information processing. Around the time that "cognition" began to displace "behaviour" as the central concern of theory, a "constructivist" perspective on learning was emerging. This is addressed in the Section "The Rise of Constructivism". From that perspective, we will describe how the field developed with a more explicit focus on learners *actively* interrogating their world.

However, within constructivist theorising the learner's world tends to appear as a rather lonely place. Accordingly, discussion will move in the Section "A Turn to the Social and the Cultural" towards acknowledging the significance of a social context for learning: one that has encouraged the development of "*social* constructivist" theories. Yet within both constructivist and social constructivist perspectives the focus is still very much on the individual: in short, an exploratory agent, actively making sense of an external world. Such a perspective has been gradually re-calibrated within those theories of learning termed "sociocultural". Therefore, the Section "A Turn to the Social and the Cultural" will also consider the "cultural" sense of this term as well as (the more widely noted) "social".

The path sketched above offers up four approaches to learning; which we might term behaviourist, cognitivist, constructivist and social constructivist. This structure risks implying that they are in some sort of simple competition. Therefore the Section "Which Theory? Reconciling Differences" considers the sense in which they address the phenomena of learning at different levels. These four core perspectives we refer to as "grand theories" of the field. Yet it will be argued that they are better thought of as "frameworks" rather than theories. As such, they are generative of other perspectives, some of which are closer to having the characteristics of formal theories—although they are narrower in the span of their concerns. In the Section "Some Emerging Diversity of Theoretical Frameworks" we will review some of these "subsidiary theories": not with the intention of furnishing a comprehensive collection, more in the spirit of indicating the direction of evolution the overarching frameworks are inspiring. We finish the chapter (the Section "From Learning to Knowledge Building") with some reflections on the work of Bereiter and his colleagues—not least because it brings "theorising" into the domain of the learner's own knowledge construction activity.

From Behaviourism to Information Processing

The discipline of Psychology makes a strong claim to be the natural home for theorising learning. And for much of the twentieth century the host for that theorising within Psychology was behaviourism. Simply put, the behaviourist conception of learning was in terms of changes brought about through the formation of two sorts of *association*. That is, learners would link events in the world ("stimuli") to each other (as Pavlov's dogs showed learning by linking the stimulus of a bell that predicted the subsequent arrival of food). Or, alternatively, learners would link stimuli to their own actions (their "responses" as in how the response of B.F. Skinner's rat would lead to food).

Although these Pavlovian stimulus–stimulus (S-S or bell-food) associations were regarded as important and known as “classical conditioning”, the dominant organising principle of learning became Skinner’s reinforced response, whereby behaviour that is rewarded, or reinforced, tends to be repeated. This process became known as “operant conditioning”, and this formulation had a natural appeal: it was simple, elegant, and seemed to map onto common sense: a feeling that what we learn is a function of the consequences of what we have done.

Undoubtedly, the principle of association is an important one. Moreover, and arising from it, how consequences are managed—that is, the various *contingencies* of association—can offer a useful perspective on the practicalities of instructional design. For example, learned response associations are stronger under conditions of more intermittent or irregular reinforcement. This especially applies to the design of instructional interactions that are mediated by digital technology. Indeed, the very first instructional methods deploying such technology drew heavily on this associative reasoning of behaviourism for their design, notably through the influence of B.F. Skinner’s (1968) reflections on education and his construction of mechanical machines for teaching based on principles of operant conditioning. So, one legacy of behaviourism has been the recurring vision of “machines-that-teach”.

Behaviourism suggested an engine for such machines in the form of “programmed instruction” (Keller, 1968). Such designs comprised a logically defined sequence of tasks presented to learners, whose responses were then given immediate and tailored feedback. Such a method reflected two central tenets of behaviourism. First, that coming to know something was a matter of attaining a complex response capability through a “bottom up” process of sequential construction involving simpler task constituents. Second that success in the steps of such a (response) sequence was reinforced with suitable contingent feedback. Yet, as theorising goes, this associationist perspective on educational practice was not a rich one. It captured the popular imagination but it reinforced positivistic views of knowledge and reductive approaches to instruction. Accordingly, whatever one’s preferences in debates about epistemology or methodology, in the end behaviourism has not proved sufficiently versatile or generative of innovation to sustain a dominant influence within the mainstream of Psychology.

Arguably, it was the very emergence of digital technology that inspired an alternative to behaviourism as a cornerstone of the discipline. Psychology began to borrow the vocabulary emerging through the description of this new digital technology: this language encouraged conceptualising human experience in terms of *information* (Crook, 2013; Gleick, 2011). Moreover, practical designs around this technology demonstrated ways of effectively *engineering* that information—and doing so in ways that often suggested “smart” mechanisms and, so, a mechanical conception of “intelligence”. The emergence of cognitive psychology (later “cognitive science”) in the latter third of the twentieth century was a response to the engineering successes of information theory and the novel and richer computational vocabulary it offered for theorising human mentality (Shannon, 1948). In this way of thinking, the learner became an “information processing system” (Miller, 1956) and the behaviourist’s stimulus-response (S-R) associations were displaced by the "Test-Operate-Test-Exit" (TOTE) cycle of mental processing. These defined iterative routines in which the learner would create (test) a problem representation, act in some way in relation to it (operate), test the outcome and then exit or refresh the TOTE. This new formulation became a key analytic unit for understanding learning interactions (Miller, Galanter, & Pribram, 1960): one that seemed to position the learner with a greater reflective and interpretative role.

However, compared to behaviourism, the vocabulary of human cognition that emerged from this metaphor of computation seemed less well suited to the educational practitioner's concerns. This new vocabulary was less centred on learning and more about perceiving, selecting, filtering, processing, testing and operating (Attneave, 1959; Broadbent, 1958). Accordingly, the "cognitive" view of human mentality seemed to foreground a language of attending (input) and remembering (storage). A danger of this focus is that it can render theories of learning as mere subsidiaries to theories of memory. This may thereby encourage conceptions of educational practice that place students within relatively passive encounters. Learning risks becoming the narrow process of recruiting these cognitive processes into sequences of: input selection, registration, encoding and long term storage—as opposed to the active processes of exploration, interrogation and inquiry.

Nevertheless, although the TOTE conception has rather faded from view, the basic "information processing" discourse of cognitive psychology has certainly been an influential force and examples of that influence will be noted within the Section below "Which Theory? Reconciling Differences". A useful one to highlight here is work by Richard Mayer (2001) and his associates. This is the first of our selected papers and it serves to illustrate how a discourse of information processing has influenced the effective design of technology-enhanced learning materials: particularly those that offer the learner multimedia interactions. Three central principles of Mayer's cognitive theory of learning are: (1) humans possess separate channels for processing auditory and visual information, (2) there is a limit to how much information can be processed within a channel, and (3) humans engage in active learning by organising incoming information into coherent mental representations. The recruitment of a computational metaphor is apparent. The practical implementation of such theorising might then involve designing learning materials that "fit" constraints inherent to this human information processing system. For instance, designers of such learning environments would take into account the parameters that define finite capacities of attending to information or recovering it. Such an approach to optimising the environment for learning is well illustrated by research that stresses managing the "cognitive load" generated within the design of resources for learning (Artino, 2008).

The Rise of Constructivism

However, behaviourism was not displaced single-handedly by cognitive psychology; because at the same time, constructivism was also exerting a powerful influence on the theorising of learning, not least through the influence of Piaget's writing on developmental psychology (Piaget & Inhelder, 1969) and Bruner's application of it to education (Bruner, 1960). Constructivism resists positivistic notions of knowledge and resists passive models of its acquisition by learners. It insists that knowledge is not something in the world to be "acquired" but a state of understanding to be discovered afresh by the learner through their own exploratory (and constructing) actions. This was a theoretical perspective that excited many TEL practitioners for its potential to re-cast technology from being the learner's "tutor" to becoming the learner's "tutee". In other words, to conceptualise technology as an arena for exploration. But, more specifically, to conceptualise it as a device that, in some sense, was to be "tutored", a resource for the learner's design experiments with knowledge. The Logo programming language (Papert, 1980) is an example of such a TEL environment, in which the student learns from programming or "tutoring" the computer.[2]

Yet the cognitivist theoretical vocabulary cannot be said to have everywhere neglected such agency in the learner: cognitive psychology did manage to harmonise with more constructivist perspectives. So, in tune with the growth of constructivist thinking, "schema" theories of knowledge (Anderson, Spiro, & Anderson, 1978; Rummelhart, 1980) became popular within cognitive psychology. These mental constructs offered a perspective on knowledge structures that accepted learners as occupying an active and exploratory role: having them build and elaborate personal cognitive tools for reasoning and sense-making (i.e., knowledge schemata) in a manner that harmonised with constructivist thinking.

However, it has been hard to dispose completely of the passive actor in conceptions of learning. Certainly, the learner became more typically cast as an (active) interrogator of the world. But that world is too often itself a rather static (passive) place: a place of fixed or unresponsive learning materials: for example, textbooks and worksheets—even if designed for optimal information processing. Of course resources that are multimodal in design do imply opportunities for a richer form of interaction. Yet surely the most dynamic form of engagement the learner could experience would be engagement with other *people*—where those others also become "learning materials" in some sense. Accordingly, various forms of "*social* constructivism" have come to dominate the present effort to theorise learning.

Such theories can be considered to take a more participative approach to understanding learning. Changes associated with learning come about by virtue of the learner participating in thinking routines that coordinate private, mental activity with an external world of tools and people. Learning is thereby understood as a process of internalisation: practices of joint reasoning are abstracted by learners from their (shared) role within contexts of social exchange—particularly where such joint thinking functions to coordinate expert (teacher) with novice (learner). So,

[2]The development of Logo was strongly influenced by the theory of constructivism. However as Noss and Hoyles discuss in their chapter "Constructionism and Microworlds", Paper has developed a new 'framework for action' called constructionism with its emphasis on the construction of shared physical or virtual entities.

increasingly the researcher of learning now asks not only "what's inside the head?" but also "what is the head inside of?" It is surely the case that interaction-with-others is one circumstance in the world that human beings are relentlessly "inside of"—certainly they are in early infancy and childhood but, thereafter, they experience this social presence during occasions of guidance, apprenticeship, or teaching. However, in what terms can this awareness of the socially-mediated nature of learning be still more deeply theorised?

A Turn to the Social and the Cultural

In the second of our selected papers Bailey (2003) summarises the sort of theoretical perspective that is needed to appreciate the potency of social experience in learning. It will put stress on what might be a uniquely human capacity: namely, our capacity for diagnosing that other human beings have a private mental life—and that the beliefs and desires within it are the principal determiners of how they act. Moreover, human beings seem to enjoy a strong motivation for endeavouring to "read" those minds of others. Insofar as one person recognises, for instance, the attitudes, beliefs, desires, ambitions, and predications of another, so that person is able to enter into well-calibrated and well-monitored interactions with them. Such interactions may then establish and grow powerful resources of shared understanding, either in the format of collaborating or in the format of instructing. This all reflects the distinctive human capacity for "intersubjective engagement with the mental and intentional lives of other people" (Bailey, 2003, p. 177).

Sociocultural theory addresses more than the interpersonal: it considers the role of artefacts and tools as mediators of human activity. In this respect learning from a sociocultural perspective, is the *appropriation* and mastering of symbolic and technical cultural *tools* within social practices. This appropriation is a process characterised by increasing co-ordination between tools and the user(s) of those tools: from an initial encounter and exploration towards the tools becoming transparent to the user. In the third of our selected papers Säljö (2010) points out that:

> We cannot look for human competences solely in our minds and bodies. Instead, our knowledge is expressed in our abilities to merge and collaborate with external tools, and to integrate them into the flow of our doings, whether these are intellectual, physical or mixed. (p. 62)

Such accounts build on the work of a range of authors: notably, Vygotsky (1978), Bruner (1960) and Cole (1996).

Thus, sociocultural theory emphasises the role of physical and psychological tools (sometimes called "meditational means") in structuring and supporting learning activity. Within sociocultural thinking the individual and the world are considered to be inextricably linked from the outset, such that the external environment is not simply viewed as a "context" to the human mind but intrinsic to the way in which mentality is actually constituted. Moreover, the culture inherited by learners is seen as having both people and tools as central constituents. The formative place of cultural history is thereby acknowledged in terms of how it specifies a heritage of spaces, rituals, practices, institutions and technologies (which, of course, includes digital technologies) that mediate the experience of learning.

Sociocultural theory thus has been embraced by many researchers interested in technology enhanced learning. For example, Carroll (2001) has observed that sociocultural theory is becoming the standard theory-base within the field of Human Computer Interaction (HCI). However, the label "sociocultural" does not stand for a unified theory but rather a framework: a perspective encompassing a range of theoretical accounts of learning and knowing, for example situated cognition (Brown, Collins, & Duguid, 1989), situated action (Suchman, 1987), cultural psychology (Cole, 1996), distributed cognition (Hutchins, 1991) and activity theory (Leontiev, 1978). In particular, activity theory has been used to develop conceptual tools for design and evaluation of user interaction experiences within the field of HCI research (Kaptelinin & Nardi, 2006).

Säljö (2010) argues that digital technologies do not only support learning but also transform both how we learn and how we interpret learning. The written text is an example of how artefacts are used as a form of social and collective memory, becoming "partners in thinking and remembering across a range of activities" (p. 57). Säljö notes that the institutional traditions of schooling are inextricably linked to the printed text; he argues that developments of multimedia digital texts are changing literacy practices from a focus on interpretation to a focus on "reading as design". This calls for the "performative turn in the interpretation of learning". A major contribution to this performative turn is the performance capabilities of digital artefacts such as calculators, global positioning systems and statistical packages, where the algorithmic aspects of problem solving are carried out (performed) by the technology. Säljö suggests that the performative perspective on learning challenges both the nature of educational institutions and traditions of research on learning.

Which Theory? Reconciling Differences

The sections above outline four traditions for theorising human learning and thereby guiding TEL designs. These traditions are the ones that are most commonly distinguished in reviews of the present kind: namely, theories that are behaviourist, cognitive, constructivist, and socio-cultural. Readers of such reviews might often be left wondering "do I have to make a choice?" Certainly, there are choices that can be made and both practitioners and researchers often line up firmly behind one or other of these "grand theories". But although they are often felt to be distinct, there are reconciliations to be made between them. So, it would be misleading to imply that they were essentially incompatible with each other. There are a number of ways in which reconciliation might be approached (cf. Engeström, 2014; Greeno & Engeström, 2014), the present sections considers one particular way involving different "levels" of explanation.

Arguably, referring to each of these positions as a "theory" is imprecise and unhelpful. They do not have the principled construction typical of theories elsewhere in science. Their form does not render them inevitably in competition and, ultimately, awaiting exposure to testing that would lead to their individual acceptance or dismissal. It would be wiser to think of these "theories" as "conceptual frameworks", or umbrellas under which a variety of research and design priorities can be meaningfully organized. How we select among such frameworks will depend upon a variety of factors: namely, the circumstances that arise when addressing particular learning situations. Framework decisions (say, for TEL design) will be related to the detailed context of such situations, the identity of the learners, and the nature of what it is to be learned. We will return to such decision making in the next section.

Meanwhile, one way of taming this conceptual diversity is to admit the need for different explanatory "layers" in accounting for learning. Most simply, such a need can be expressed in terms of different choices made with respect to "micro" or "macro" levels of explanation. Let us consider first an understanding of learning that is pitched at the micro level.

Users of digital technology will surely be among the most keenly aware of how accounts of the human nervous system invoke a digital description: they refer to on-off patterns of neural activation. Moreover, the densely-wired and inter-connected nature of the brain encourages a particular understanding of this physical substrate of mentality: namely, one that stresses *networks* of (neural) *associations*. Accordingly, theorising learning at the micro-level readily invites accounts based upon appreciating the growth, elaboration and topography of such associative structures. The approaches to learning inspired by these ideas are generally regarded as only remotely related to the associationist thinking of behaviorism. (Although some commentators do see close links and not always flattering ones—"behaviourism in computer's clothing" (Papert, 1988, p. 9)). Certainly these "connectionist" accounts do not offer the narrow behavioral language of "stimuli" and "responses". Instead, they are typically discussed at a neural level of description through a language of thresholds, connection weights, spreading activation, and feed-forward loops[3] (Hebb, 1949; Kelso, 1995). Yet they may also be discussed at a cognitive level of description, through a parallel language of schema, learning rules, assimilation, and assemblages (Rumelhart & McClelland, 1986; Shallice, 1988). Such alternative (but post-behaviourist) vocabularies of associative learning are complementary to one another: that is, cognitive levels of system description are believed to harmonise with system descriptions at the neural level. Indeed this is a very appealing feature of connectionist theorising. It furnishes an agreeably integrated account of learning. But connectionism is firmly an account pitched at the micro-level.

This is not to imply that the micro-layer of such connectionist thinking cannot furnish frameworks to help design technologies for learning. Indeed, this has

[3]Connectionism should not be confused with Connectivism. The latter is discussed briefly later in this chapter.

been happening in relation to the development of instructional systems that are intelligently adaptive to learners' activity, as well as student learning environments that reflect the implicit structures of how connectionist systems learn (e.g., Xhafa, Caballé, Abraham, Daradoumis, & Juan, 2012). However, it would be unwise to suppose, for example, that how a technology is best built to conduct some reasoning operation provides a model for how humans do the same thing (e.g., calculators and humans compute multiplication in very different ways). This lack of a simple operational harmony between a well-designed digital machine and a well-developed digital brain is salutary for our thinking about learning. It requires us to theorise at a different level of granularity: to recognise ways in which the frameworks of connectionist and networked modelling have to be extended to fully embrace a theorising of human learning.

One way of characterising the nature of this extension is to start from an observation made by Clark about human intelligence: "good at Frisbee, bad at logic" (1998, p. 60). This judgment celebrates an extraordinary human capacity to (for instance) accurately anticipate the position of a fast moving object and then act in order to optimise catching it—an achievement that reflects the rapid, pattern-completing capability of the human brain. Yet while such a capability may be *well* matched to the ancient demands of hunting, escape, and capture (and Frisbee), the parallel processing architecture of the brain seems a *poor* design for the serial demands of much deliberate planning, reasoning, or logic.

Yet, in the end, our presentation of the "grand theories" (behaviorist, constructivist, cognitivist, and socio-cultural) renders them too singular: we are not respecting the diversity of current theoretical thinking around the topic of learning. Moreover, our presentation does not do justice to the range of inspiration thereby available for design and research around technology-enhanced learning. The designer and researcher working with technology will be curious about how these central theoretical traditions are generative of distinctive pathways for innovative practice. In the next section, we will briefly sketch examples of theorising that is subsumed in this sense: projections of the grand theories that have a particular focus (relevant to technology and learning).

Some Emerging Diversity of Theoretical Frameworks

In exploring how mainstream theoretical traditions are specialising and diversifying, we highlight two groups: one linked by its affinity to cognitive themes, and one that derives more from social constructivism. We then offer a short third section below that acknowledges theoretical perspectives that take as their starting point not shared and universal processes, but individual differences. This acknowledges a tradition of theorising that refers to those dimensions of distinct personal identity that the individual brings to learning situations. Inevitably, this is only a partial sampling. Yet it indicates provocative perspectives for guiding design and research within technology enhanced learning.

Cognitive Theoretical Themes

Cognitive psychology has furnished rich explanatory systems to account for the detailed mechanisms of attending, reasoning, remembering and other aspects of human thought. Therefore, it is not surprising to find that such systems are invoked when characterising the ideal conditions for learning and, from there, to help define methods of instruction and optimal designs for the spaces and tools that support instruction. Some examples of such theorising are sketched here: hopefully in each case there is just enough detail to convey the aspects of theory that have stimulated the design of technologies and technology-enhanced learning spaces.

The computational metaphor in cognitive psychology naturally encourages consideration of performance constraints arising from limits in cognitive storage space and processing speed. *Cognitive Load Theory* (Sweller, 1988) attempts to define ideal designs for teaching and learning that take these limits into account. The approach centres on working memory as the focal point of constraint and identifies three sources of cognitive load that can arise in a typical learning situation. Two of these (germane and extraneous) can be influenced by the design of instructional materials or routines. Indeed the theory has been very influential among designers of multi-media learning materials (e.g., Mayer, 2001). Although influential, the theory is not without critics (de Jong, 2010).

However, space and speed are not the only features of cognitive system functioning that can be theorised in relation to learning. Theory can also refer to the representational formats of the material which is processed and the functional organisation that can arise from these demands. An example would be Pavio's *Dual Coding Theory* (Paivio, 1986) based around a key distinction between verbal and non-verbal processing and carrying implications for how multi-modal material is most efficiently presented for learning (Clark & Paivio, 1991).

As a species of cognitive theory, dual coding may be said to be about the "architecture" of cognition. A more elaborated version of theorising at this level is *ACT-R*. This is a tradition of theorising associated with Anderson and his colleagues and has been unfolding since the early 1970s (Anderson, 1983; Anderson et al., 2004). Although ACT follows an established tradition of proposing functional modules of cognition, it does also strive to give a more holistic or integrated account of the human mind. Central to its architectural description is the distinction between declarative and procedural memory: the former being concerned with what we might term "factual knowledge" and the latter with "productions" or ways of going about acting on that knowledge. Fundamental to its method is the implementation of this cognitive model in a computer language. This, in turn, provides the link from theory to instructional design. It does so because ACT-R can simulate the cognitive actions of learners, including their mistakes and how to address these, and thereby provide teaching that responds to learners' errors and misunderstandings. This has led to the design of "cognitive tutors" (Koedinger & Corbett, 2006): that is, intelligent tutoring systems that are "adaptive" to student activity such that they provide effective feedback based on modelling the student's apparent understanding of the knowledge domain under instruction (see Chap. 10).

Social Constructivist Themes

Some theories about learning locate an important opportunity for influence and innovation within the interpersonal context of learning. This may be defined at the level of one-to-one social interaction and its structure. Or it may be defined in terms of the broader community level of social organization. Accordingly, such theorising offers advice to TEL based around either the management of dialogue or the management of macro-social organization.

An early approach that dwells on the structure of learner-other dialogue is that of Pask and *conversation theory* (Pask, 1975). In this theory, differences in perspectives relating to some domain (such as might exist between a student and a teacher) are explored and reconciled through a process of language exchange. The trail of these exchanges may be captured as an "entailment mesh". These may afford representations of understanding that resource further conversation. For Pask the "teachback" was a crucial conversational extension: one in which the learners teach what they have learned to a fresh novice. These ideas have been most vigorously applied to TEL through the work of Laurillard (2002). Here the ideal learning situation is defined in terms of a media rich simulation which is experienced as the ground for a tutorial conversation, the structure of which is articulated in a formal diagram of organized social exchange.

A related theory based upon the management of tutorial conversation is that of *contingent teaching*. This is an account of learning that dwells upon disparities of understanding within an interaction (such as might exist between teacher and student) and the strategic application of feedback as the student's actions are monitored. This approach attracted much attention through recruiting the compelling metaphor of "scaffolding" to characterize the nature of such exchanges (Wood, Bruner, & Ross, 1976). Instructional designers have subsequently borrowed this model of feedback to design TEL environments (e.g., Luckin & du Boulay, 1999).

Social themes within theories of learning need not exist only at the interpersonal or micro-communicational level. The term "social" also refers to events at the level of learning community. This is captured in Lave and Wenger's writing on *communities of practice* (Wenger, 1998). As a theoretical perspective this enjoys influence at a very general level. It is a perspective that identifies learning as taking place through processes of participation as this occurs within organized groups of individuals with shared goals. The influence on design for TEL is likely to take place through the design and implementation of communication systems within such organisations in order to protect and cultivate the participatory experience of membership.

The theoretical perspective of connectivism (Siemens, 2005) has more recently inspired such communication infrastructures. This is a position that identifies learning with immersion in networks of connected nodes—learning is not simply a consequence of such connections, it is defined to *be* this. Moreover, the nodes that are connected are commonly other people but will be in the external world of the learner, as well as in some private cognitive system—although their existence may be modelled in terms of underpinning neural representations. What the learner comes to know emerges in the form of patterned connections. This is a perspective not without critics (e.g., Clarà & Barberà, 2014), yet its influence on TEL has been far-ranging, not least as a framework for conceptualizing Massive Open Online Courses (MOOCs) (Kop, 2011). The key driver for that influence is, again, the need for courses to work from a communication infrastructure that optimizes the creation of networks.

Acknowledging Individual Differences

Students do not enter situations of learning as blank slates. They bring with them different resources of existing knowledge and also different histories of involvement with learning as a cultural practice—some will be idiosyncratic, some will reflect the influence of cultural and institutional traditions of education. Students also bring other personal characteristics that may influence their readiness, or enthusiasm, or understanding of situations where learning is intended to occur.

Evidently, learners bring to their tasks differences in ability or intelligence. The form of such cognitive diversity that has attracted most interest is that which is organized around proposed differences in how individuals *prefer* to learn. One way in which such preferences have been theorized is in terms of *multiple intelligences* (Gardner, 1993). Gardner describes seven: each one refers to the individual's focus on one particular representational system (e.g., language, music, spatial). The significance of such differences for teaching and learning lies in the resulting attention that is given to such a dimension of individual difference and the need to cultivate it. A similar consequence is associated with the second major way in which individual dispositional differences have been theorized: namely, variation in *learning style*. There are a very large number of theories associated with the idea of differences in learning style, although the significance of such differences have been questioned (Pashler, McDaniel, Rohrer, & Bjork, 2008). Even if they do have psychological reality, it is not clear whether instruction and teaching materials should be adapted to meet the learner's "style" by harmonizing with it, or whether instruction should be in conflict with a learning style—and thereby be more useful in terms of cultivating learner versatility. Certainly, TEL design is frequently driven by this dimension of difference, as developers seek to construct learning systems that offer either this harmony or this challenge.

From Learning to Knowledge Building

In the early sections of this chapter we identified grand theoretical traditions and in the section above we extended this by noting a variety of secondary theories that are variously embedded within them. At the heart of this overview is an evolutionary trajectory that passes from a focus on responses and stimuli (behaviourism), to a focus on the mind (cognitive science), to a focus on the individual as a constructive agent of learning (constructivism), to a recognition of the social and intersubjective nature of learning, to a focus on the role of culture and technological tools as constituting learning (sociocultural theory). Yet these grand theoretical perspectives have been criticised by Scardamalia and Bereiter (2014) (our fourth selected paper) for not adequately engaging with the relationship between learning and knowledge.

Interestingly, given the emphasis within education on "knowledge" and the focus in current economic theory on the "knowledge economy", there is very little conceptual weight given to its role within theories of learning. Bereiter (1997) challenges this neglect and, together with Scardamalia, has developed a knowledge-building conception of mind—designing a technology infrastructure to explicitly support such knowledge-building. They draw on Popper (1972) in order to differentiate between objects in the physical world (World 1), conceptual objects of the mind (World 2) and the world of knowledge objects (World 3). Bereiter (1997) argues that: "Learning is activity directed towards World 2. It is doing something to alter the state of your mind to achieve a gain in personal knowledge or competence" (p. 255). By contrast, knowledge-building is activity directed towards World 3, the world of knowledge objects which are objects of inquiry, created by humans and made accessible so that they can be discussed, revised or replaced.

Bereiter suggests that as knowledge is the focus of school education, learning theories need to focus on World 3 knowledge objects as well as World 2 conceptual objects of the mind, and that the focus of school education, and classroom activity should shift from improving students' minds to improving their theorical (academic) knowledge. Bereiter's theory of knowledge-building focuses on classrooms as knowledge-building communities, shifting from individual learning to the collective building of knowledge. From this perspective, knowledge is considered to be socially constructed and the focus is on the inter-relatedness of concepts within a complex conceptual field. Bereiter's theory has some resonance with Vygotsky's sociocultural theory mentioned in Section "A Turn to the Social and the Cultural".

Bereiter and Scardamalia developed the "Knowledge Forum" as a digital toolkit that can support students to develop knowledge-building communities. The Knowledge Forum centres around a multimedia database, accessible by all students who are engaged in knowledge building. Nowadays Web 2.0 software such as wikis could be used for collective knowledge building although TEL research in this area tends to emphasise the potential of Web 2.0 technology for collaboration paying little attention to the role of knowledge in such collaborative activity.

Focusing on knowledge as a key aspect of learning in education is often criticised by those who believe that education should be emphasising what are called twenty-first Century Skills and the strongest advocates for such a skills-based approach to learning are often strong supporters of TEL (for example Leadbeater, 2006). In order to move the often polarised debate between what is considered to be a backward-looking focus on knowledge and a more forward-looking focus on skills, Michael Young (2013) distinguishes between what he calls "powerful knowledge" from "knowledge of the powerful". For Young "powerful knowledge" is socially constructed theoretical knowledge (similar to Vygotsky's academic knowledge and Bereiter's world 3 knowledge) and from this perspective the emphasis is on what this knowledge can do, how it is organised for the production of new knowledge and the boundaries between everyday and academic knowledge. We are straying here into polemic as opposed to academic discussion, but developments in TEL tend to be accompanied by hype and polemic which often makes it difficult for a principled understanding of human learning to become the starting point for design ambitions involving educational technology (for a fuller discussion of these issues see Sutherland, 2013).

Concluding Remarks

Säljö (2010) argues that there is a tendency for those working in the area of TEL to view technology as a positive good, with teachers and schools often regarded in negative and deficit terms: that is, being slow to take up the potential of digital technologies for learning. It is beyond the scope of this chapter to engage with the debate about the role of schools, but we agree with Bereiter that schools are best thought of as "knowledge institutions", and that from this perspective theories of learning should take into account the role of socially constructed "academic" knowledge. Theories of learning inspired by constructivism often do not adequately take into account the role of the teacher or more knowledgeable other in supporting students to shift from everyday to academic knowledge. Moreover, Vygotsky's theorising about everyday and academic knowledge is often not emphasised when sociocultural theory is used to influence the design and research of TEL environments. As discussed in the section above, Bereiter's theorising explicitly focuses on knowledge construction and distinguishes between an individual's construction of knowledge (World 2) and socially constructed knowledge (World 3) and in so doing acknowledges the role of institutions such as schools and universities in knowledge-building. In general, theories of learning are influenced by psychology and as such cannot adequately take into account the more sociological aspects of institutional-based learning. Olson (2003) has provocatively suggested that:

> A major blindspot in the attempt to create a psychology for education, is the reluctance or inability to grasp, how social institutions structure the social relations between teacher and student as well as the learning and thinking (p. 48)

This opens up a new interdisciplinary challenge for those who are concerned with technology enhanced learning and paying attention to the more sociological and political aspects of learning helps to explain why TEL is not always enthusiastically embraced by schools and universities (Selwyn, 2011).

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Chapter 3
Constructionism and Microworlds

Richard Noss and Celia Hoyles

What is Constructionism?

Seymour Papert launched the notion of *constructionism* in the mid-1980s. The central idea, expressed in the first of the selected papers (Papert, 1991), is that a powerful way for learners to build knowledge structures in their mind is to build with external representations, to construct physical or virtual entities that can be reflected on, edited and shared:

> Constructionism [. . .] shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Harel & Papert, 1991, p. 1)

Constructionism therefore seeks, unlike *constructivism*, to inform a theory of pedagogy, by directly addressing the question of how best to help learners learn. By contrast, constructivism is a theory of how people learn, irrespective of the circumstances of that learning, or whether teaching is involved at all (for an introduction to constructivism, see for example, von Glasersfeld, 1989). As Papert goes on to put it, "the *n*-word", constructionism rather than "the *v*-word", constructivism, is aimed at trying to theorise strategies that align the way people learn with the ways it makes sense to help them learn, especially through the design of suitable artefacts. The word "especially" is crucial here, as it focuses attention on design: on the *design* of constructionist environments leading to the notion of a *microworld*, which we discuss later.

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A classic example of a constructionist environment is the work centred around Logo, the computer programming language derived from the artificial intelligence language, LISP (Harvey, 1997). Logo was, and still is in its various incarnations, a fully-fledged programming language by which people—including young children—can and do program anything they can imagine. Logo included a very powerful property, the *turtle*, a robot or a programmable screen object that could, in a straightforward way, be controlled through Logo. The presence of this manipulable ‘concrete’ object opened up three distinct but closely related affordances for the learner.

First, the constructionist environment represents a compelling medium in which to explore and learn from feedback (in different forms), much as one can master a foreign language by living in the appropriate country. Second, in the environment, the learner can adopt a construction-based approach to learning in which there is some ownership by learners of the construction process, and which, potentially at least, leads to their engagement, confidence and empowerment. Third, exploration through building enables the learner to encounter “powerful ideas” or intellectual nuggets, while ostensibly constructing something else, say, geometrical shapes on the screen in the case of turtle geometry, Lego robots, or music. The key notion of “powerful ideas” tries to capture the notion of engagement with intellectual tools, ways of thinking that afford the learner access to concepts and strategies that confront and build on intuitive knowledge. For a comprehensive view of the role of tools in the learning of mathematics (see Monaghan, Trouche, & Borwein, 2016).

Constructionist tools should be expressive: they can be shaped by their users to construct new entities (geometric shapes, linguistic structures, artistic creations), in ways that emerge in activity. At the same time, tools like this constrain and shape what learners can do, think and learn. In the second selected paper (Noss & Hoyles, 1996), we discuss this reciprocity between the ways learners shape the tools they use and the ways that the tools shape learning, manifested in personalised conceptions that we term situated abstractions. (See also the debate around the notions of situated abstraction, instrumental genesis and orchestration in Hoyles, Noss, & Kent 2004.)

The three affordances of Logo above, allow us to generalise the idea of constructionism beyond the case of Logo and its descendants. As Logo has evolved, and as the ambient digital space around it has evolved alongside (Logo was invented some 30 years before the web!), the theory of constructionism has acquired more form and detail, inspiring designers to build more technologies that support its key objectives: Boxer, Scratch,[1] NetLogo,[2] ToonTalk,[3] and most recently hardware that finally is ubiquitous like the Raspberry Pi and the BBC Micro:bit. In addition, numerous knowledge-focussed environments have now potentially at least entered the constructionist arena, with similar visions for learning, such as the dynamic geometry systems in mathematics (Sinclair & Crespo, 2006) or *Impromptu* in music

[1] http://scratch.mit.edu/.

[2] http://ccl.northwestern.edu/netlogo/.

[3] http://www.toontalk.com/.

(Bamberger & Hernandez, 1999). Eisenberg (2003) has also added to this mix through his descriptions of environments that blend traditional and computational material. Over the years, constructionism has also provided the framework for a fertile strand of research detailing trajectories of learning with the tools, which range widely over topics from topology to musical composition.

The discussion above illustrates that, as Papert was at pains to point out, constructionism seeks to develop knowledge structures in the mind alongside physical or virtual structures external to the mind, and as such is as much a theory of epistemology as of pedagogy (see Harel & Papert, 1991). Papert explains that the distinction between *instructionism* and *constructionism*, is also about epistemology and not merely about two ways of thinking about the transmission of knowledge. Rather, the distinction "goes beyond the acquisition of knowledge to touch on the nature of knowledge and the nature of knowing" (Papert, 1993, p. 8). In other words, constructionism involves choosing or designing representations, engaging artefacts and suitably oriented pedagogies that together can bring about fundamental change in *how* to learn and, if successful, will ultimately change *what* is learned.

A thought-provoking discussion of this epistemological shift has been explored by Wilensky and Papert who argue that constructionism has:

> shifted the focus from the means to the object of learning ... how the structure and properties of knowledge affect its learnability and the power that it affords to individuals and groups. (Wilensky & Papert, 2010, p. 1).

The name they give to this process is *restructuration*,

> ... the encoding of the knowledge in a domain as a function of the representational infrastructure used to express the knowledge. A change from one structuration of a domain to another resulting from such a change in representational infrastructure we call a restructuration. (ibid. pp. 2–3)

The example they give (Papert, 2006) is the shift (though not, of course, made for educational purposes) from Roman to Arabic numerals, a shift that made it possible for nearly everyone to calculate in ways that were hitherto obscure. Our challenge is to think beyond this example, and seek to identify where the computer presence has shifted not only how knowledge is spread and developed, but the nature of knowledge itself, in scientific, social-scientific and humanities disciplines (see, for example, Resnick, 1995).

One of the persistent challenges of realising the constructionist vision, is the tension between aiming to teach specific content of, say, mathematics or music, and *at the same time* affording the learner the experience of constructing, making, doing and problem solving. These two aims are, of course, not antithetical, but neither is it obvious how to align them for pedagogical purposes. One solution that has evolved has been to design "microworlds", insulated and accessible islands of activity in which nuggets of relevant knowledge are encountered in a natural way—or at least, in which the chance of meeting the nuggets is designed to be as high as possible.

From Constructionism to Microworlds

Hoyles (1993) describes the evolution of the *microworld* idea from its genesis in the artificial intelligence community, in which it was used to describe a relatively simple and constrained domain where computational systems could solve problems, to a more broadly conceived environment that served as a concrete embodiment of a knowledge domain or structure. The structure comprises tools that are extensible (so tools and objects can be combined to build new ones), but also transparent so their workings are visible, and rich in different representations. Edwards (1998), in the third selected paper, contrasts this "structural" view of a microworld with a "functional" view, which prioritises its features as they become apparent in use, as learners explore, build and learn from feedback. Kafai (2006) adds a further discussion of constructionism and microworlds in the fourth selected paper.

This functional view points to the importance of the way that knowledge actually grows in the learner. As diSessa (2006) points out, traditional instruction fails to engage with how knowledge is actually built, piece by piece, and layer upon layer. There is a duality here: a successful microworld is both an epistemological and an emotional universe, a place where powerful (mathematical, or scientific, or artistic) ideas can be explored; but explored "in safety", acting as an incubator both in the sense of fostering conceptual growth, and a place where it is safe to make mistakes and show ignorance. And, centrally these days, it is a place where ideas can be effortlessly shared, remixed and improved. (For an earlier discussion of these twin aspects of engaging through building and sharing (see Noss & Hoyles, 2006).

Thus the emotional component is more than incidental to the microworld idea: building and sharing things is not much use for learning if learners do not care about what they are building and sharing. Papert's famous example in the preface to his book, Mindstorms (Papert, 1980), tells a story that is not just about how much he learned about mathematics by playing with gears, but is about how he "fell in love" with gears, an intimate and consuming knowledge that he used as a model for future learning of mathematics. There are, of course, contexts other than mathematics and science that have been subject to the constructionist analysis: see discussion related to drawing and painting, in Clayson (2008) and Gargarian(1993).

But as well as an intellectual challenge for authentic engagement, there are issues that are fundamental to general goals of learning. Confrey and her colleagues put it, in relation to mathematics, thus:

> The importance of tapping into youth culture should not be underestimated in motivating and sustaining student educational progress. This is especially true for subjects like science and mathematics, which carry considerable social capital yet are easy for students to dismiss as irrelevant, boring and hard in a world of digital images, animations, easy information retrieval and communication. We need engaging environments, in which the mathematics is actually needed for students to achieve goals that they find compelling, and made visible to students and expressed in a language with which they can connect. (Confrey et al., 2010, p. 20)

Outstanding Challenges

In this concluding section, we point to some outstanding challenges to the constructionist/microworld agenda from a theoretical point of view.

First, we need to pin down more precisely what kind of a thing constructionism is. While the constructionist project might seem like a theory, it is perhaps best thought of as not so much a theory, but as a principle or even a manifesto. As diSessa and Cobb (2004) remark, constructionism presents more a "framework for action" than a theory, providing "some focus and direction to the design of learning environments with much left implicit and open to diverse interpretation" (p. 82). Nonetheless, they underline the point made earlier: that the idea of students learning through design is compelling since it combines affective and cognitive properties (see also diSessa (1995) for elaboration of the relationship between epistemology and system design).

The second challenge is that although microworlds are intended to orient students towards a way of thinking carefully structured by the designer, learners must also gain some autonomy. This means, of course, that learning will not occur precisely as planned. Thus, an inevitable challenge arises: how to balance self-motivated activity while maximising the opportunity to encounter the planned powerful ideas (see the 'Play Paradox', Noss & Hoyles, 1996). Indeed, some of the papers cited have, over time, treated this paradox as solved—but better, perhaps, to think of it as a paradox-in-resolution: the challenge of designing engaging, compelling, and intellectually powerful learning environments is one that will surely never be totally resolved.

The third challenge is to understand the extent to which ideas developed within a given medium "transfer" (whatever that means) to knowledge independent of that medium? How does the knowledge gained within a microworld extend beyond the context of its genesis? (see Pratt & Noss, 2002 for a contribution on this theme).

The answer may necessitate looking beyond the notion of an individual constructing his or her own knowledge towards a consideration of the social framework within which activities take place and how social interaction transcends and transforms individual conceptual structures. It is these active encounters in which knowledge is co-constructed through experimentation and social engagement that might form the engine of transfer.

At the same time, the momentum of technological change will raise delicate challenges for constructionist design. As the opportunities for collaborative learning, seamless and flexible interaction and access to information increase, there is no guarantee that these will enhance learning. To take just one example: the "App" culture is not necessarily supportive of the constructionist project. However, App Inventor,[4] which allows students to program *their own* Apps, could certainly do so. The focus here is on the creation of engaging *culturally resonant* artefacts, which simultaneously afford learners the opportunity to encounter *powerful computational ideas*.

[4] http://appinventor.mit.edu/.

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Chapter 4
Design Methods for TEL

Susan McKenney and Yael Kali

Background: Key Fields Informing TEL Development

About a decade ago, Hoadley and Carr-Chellman edited a special issue in *Educational Technology* (44(3), 2004), that sought to begin a dialogue between two substantive fields of research that are concerned with TEL design and evaluation. Despite their many overlapping interests, according to Hoadley and Carr-Chellman, these two fields, Learning Sciences (LS) and Instructional Systems Design (ISD), had very little interaction and cross fertilization. Both fields have had common interests such as cognitive psychology, educational psychology, situated cognition, educational technology, constructivist learning environments, computer-supported collaborative learning and computer-supported collaborative work. However, citation analyses conducted by researchers who took part in writing the aforementioned special issue showed that the literature identified within these two fields has very little overlap. Some of the authors described the two research areas as "parallel" and even "colliding universes".

In this chapter, we revisit the dialogue that began at this time to present current trends in design and evaluation methods for TEL. Through this lens, we can still see some of this parallelism, which we view as productive, representing unique directions that each of the fields has continued to develop, but we also find emerging trajectories which demonstrate that these perspectives are far less isolated than

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previously. The remainder of this chapter contains three sections. First, attention is given to literature concerning “design” and “evaluate” as verbs; this section focuses on the processes of design and evaluation and draws particularly from ISD literature. Second, attention is given to design and evaluation as nouns, hereby focusing on the products of design and evaluation activity and being heavily influenced by LS literature where such products are often regarded as a means for exploring learning theory. Finally, the third section discusses two approaches through which TEL, ISD and LS have overlapping and often complementary elements: Patterned and Principled Design (PPD), and Design-Based Research (DBR). After a brief mention of Learning Design (LD) as a new area of research that has embraced these approaches, the chapter concludes with emerging directions that we view as fruitful for further research in design and evaluation of TEL.

Informing Processes of Design and Evaluation

Few fields have contributed as much to articulating the processes of designing and evaluating TEL environments, tools and/or instruction as that of ISD. Though not always written exclusively for TEL, such literature is particularly useful for the developer (team) and generally informs both the planning and execution of design and evaluation processes. This section briefly addresses: (a) instructional development models, which provide a bird’s eye view of the overall process, as well as specific sources that offer in-depth information related to (b) designing and (c) evaluating, respectively.

Instructional Systems Design Models

Many instructional systems design (ISD) models have been developed to portray or even steer the design and evaluation of instruction and instructional resources. A particularly informative analysis of ISD models, which we include as our first selected publication for this chapter, was conducted by Gustafson and Branch (1997) (see also Gustafson & Branch, (1981) for a more comprehensive survey). They conclude that the core elements of most instructional development processes include the need to: analyze, design, develop, implement and evaluate (ADDIE). Models that incorporate these processes have come to be known as ADDIE models. (Note that it is a common misconception that ADDIE is a process model. ADDIE itself represents no specific indication of how to shape development; ADDIE is merely a characterization used to describe common elements in some instructional development models.) In this article, Gustafson and Branch (1997) offer an overview of ISD models as well as commentary on how different models suit various design situations. Additional literature concerning overall processes attends less to stages (like the five ADDIE stages), and more to other forms of design knowledge, that influence how each stage is executed. For example, the work of Hoadley and Cox (2009) emphasizes design values and roles (e.g., the notion that we should examine our designs from different perspectives, such as that of the user, the implementer and the critic), which commonly shape the overall process, while Visscher-Voerman and Gustafson (2004) describe how individual designer 'paradigms' (e.g. concerning how designers help users cultivate their ownership of designed products) influence decision-making during the development process.

The Process of Design

Much of the literature concerning processes for the design of (technology enhanced) learning is concerned with what is necessary to yield products that exhibit characteristics which are considered to be salient. Specific product features rarely emerge on their own. Rather, they are more present and robust when explicit attention is given to them; such is the case with the work of Kirschner and van Merriënboer (2008). They describe ten steps needed to create instruction that attends to four interrelated components—learning tasks, supportive information, just in time information and part-task practice—which are considered essential for learning complex skills (and developing the relevant knowledge base). These steps are described in more detail in their book on the same topic (van Merriënboer & Kirschner, 2007) and include: design learning tasks; sequence task classes; set performance objectives; design supportive information; analyze cognitive strategies; analyze mental models; design procedural information; analyze cognitive rules; analyze prerequisite knowledge; and design part-task practice. They specifically address how to conduct task/content analysis and design.

The Process of Evaluation

Evaluation is generally accepted as a continuous process in the development of TEL, with the most common distinctions being made between formative (improvement) and summative (judgment) goals. Phillips, Kennedy, and Mcnaught (2012) view the "lifecycle" of e-learning projects as consisting of seven (0–6) stages: analyze problem; design e-learning artefact; prototype e-learning artefact; design e-learning environment and conduct pilot study; refine e-learning environment and conduct full trial; conduct revaluation research on mature system; and carry out repeated evaluation research on the mature system. Their article also connects each stage to development activity (e.g. documenting the problem); evaluation (e.g. baseline analysis); research (e.g. effectiveness of learning); and the connections between theory development and design principles (e.g. specifying and refining principles of e-learning). More detailed guidance for TEL evaluation processes can be found in their book (Phillips et al., 2011) and in that of Reeves and Hedberg (2003). A fresh look at evaluation processes (though not specifically written for the TEL community) is also available by the renowned evaluation expert, Patton (2011) who draws on complexity theory to describe ‘developmental evaluation’ processes which support innovation and use through partnerships with program decision makers. This approach is particularly useful in evaluation situations involving complex dynamic systems and uncertainty, as well as to understand and respond to designs as they emerge.

Informing Products of Design and Evaluation

Over the years, a line of research has developed, especially among LS researchers, which views TEL design and evaluation as a means for developing and testing theory (Hoadley, 2004). Consequently the design products: (a) are driven heuristically by what is already known about how people learn, (b) are viewed holistically, with technology as a component in social contexts, and (c) are driven by domain specific insights. Each of these is described in the remainder of this section.

Heuristics to Guide Design Solutions

An example of a heuristic approach is Collins’ (1996) “cost-benefit” approach to design, in which decisions regarding various issues, including fine grain details of the design, are made by weighing affordances against tradeoffs. Taking into account learning and motivation, as well as constraints such as time, money, and effort, this approach does not conclude with prescribed solutions, and rather, is guided by more fluid rules of thumb. For instance, in weighing the trade-offs between having students perform whole tasks that require integration of a variety of skills, versus having them perform simplified tasks that focus on particular subskills, Collins suggests “to start by scaffolding students in whole tasks, and then go to component tasks when they seem appropriate” (p. 350). Another example of product heuristics that serve design is embodied in Merrill’s (2002, pp. 44–45) first principles of instruction. These are prescriptive principles for shaping learning, (e.g. “learning is promoted when existing knowledge is activated as a foundation for new knowledge”) which are common across most instructional theories, though they can be enacted in different ways. Similar theories and heuristics can be found in Reigeluth and Carr-Chellman (2009).

Technology as a Component in Social Context

Our second selected publication for this chapter is Bielaczyc's (2006) social infrastructure framework. Bielaczyc claims that when designing TEL, technology should be considered as one component in a holistic endeavor, which should include other, socially driven design elements in four critical dimensions: "(a) cultural beliefs of the people who are to use the designed product, (b) their practices in engaging in both online and offline activities, (c) the socio-techno-spatial relations (d) their interaction with the 'outside world'." (p. 301). For each dimension she describes design considerations and example questions that need to be answered to design a socially sensitive design product. For instance, in the cultural beliefs dimension, one design consideration is "how a student's social identity is understood" (p. 314). A question that can guide this consideration is "How are students meant to view each other—as learning resources, as team members, as competitors?" (p. 314). The reason we decided to include Bielaczyc's social infrastructure framework as a selected publication is that it demonstrates the kinds of fine-grained design considerations that learning scientists have developed to explore learning in social contexts.

Domain-Specific Design

In addition to the heuristic and holistic approaches described above, it is important to note that design products are also driven by domain-specific insights. For instance, in science education, a most influential design approach was developed by the US Technology Enhanced Learning in Science (TELS) Center, namely, the Knowledge Integration framework (Linn, Lee, Tinker, Husic, & Chiu, 2006). At the heart of this framework are four main processes that need to be supported to help students develop deep understanding of complex scientific phenomena: (a) elicit their current ideas, (b) add new ideas, (c) assist them to develop criteria for evaluating ideas, and (d) support them in sorting out ideas. Consequently, TELS modules "help students act like scientists, comparing viewpoints, generating criteria for selecting fruitful ideas, fitting ideas together in arguments, gathering evidence for their own views, and critiquing the arguments generated by their peers" (p. 1050).

Cross-Cutting Themes and Future Directions

Over the past decade, since the Hoadley and Carr-Chellman special issue (Hoadley, 2004) has been published, a productive dialogue between the two fields of LS and ISD has led to the emergence of new trajectories that cut across the fields. Before we present these trajectories, we first provide brief descriptions of these fields, as they are defined from within the respective research communities. In the mission statement of the International Society of the Learning Sciences, the field is described as follows: "Learning Sciences (LS) investigations include fundamental inquiries on how people learn alone and in collaborative ways, as well as on how learning may be effectively facilitated by different social and organizational settings and new learning environment designs, particularly those incorporating information and communication technologies (ICT), as in computer supported collaborative learning (CSCL)" (International Society of the Learning Sciences, 2016, p. 1). In their report, commissioned by the AECT (Association for Educational Communications and Technology), Seels and Richey (1994) defined the field of ISD as follows:

> Instructional Technology is the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning . . . The words Instructional Technology in the definition mean a discipline devoted to techniques or ways to make learning more efficient based on theory . . . Theory consists of concepts, constructs, principles, and propositions that serve as the body of knowledge. Practice is the application of that knowledge to solve problems . . . The purpose of instructional technology is to affect and effect learning. (pp. 1–9)

The productive dialogue between LS and ISD continues, building on research informing processes, as well as products of TEL design and evaluation. Key themes in those discussions are described below.

Principled and Patterned Design

The heuristic approach to design has served as a basis for the development of another TEL design approach, which can relate to the design process and/or the designed products, namely, principled (e.g. Kali, 2008) and patterned (Goodyear & Retalis, 2010) design. The principled and patterned approach is concerned with general guidelines for designing TEL, that coalesce the wisdom gained by researchers, designers and practitioners who study, design, and enact innovative curricular units in various contexts. Research in the area of design principles and patterns typically explores means for teachers and curriculum designers to publicly share and accumulate their tacit knowledge about designing technology-enhanced learning, and to synthesize and abstract the combined knowledge into generalized guidelines.

Design-Based Research

The principled and patterned approach has developed in the past decade in conjunction with Design-Based Research (DBR), which has become the most prominent methodology for generating TEL insights in general, and design principles and patterns in particular. According to the authors of the third selected publication in this chapter (Barab & Squire, 2004, p. 2), design-based research, “is not so much an approach as it is a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings.” Among other sources (e.g. learning theories), principles and patterns often serve as key inputs for designing solutions to educational problems in design-based research; and through the design research process, principles and patterns are validated, refuted and refined (cf. McKenney & Reeves, 2012).

Learning Design

The field of learning design is another area in which attention is given to both the processes and the products of (TEL) design and evaluation. The fourth selected publication for this chapter illustrates these perspectives clearly, by presenting a framework for creating and evaluating learning designs that attend to the needs of teachers and learners simultaneously (Laurillard, 2009). In recent years, this framework of learning design has been particularly attuned to CSCL and to distance learning. From the design process perspective, it highlights four main traditions of learning theory (instructionism, constructionism, socio-cultural learning, and collaborative learning (see Chaps. 2 and 5) that should be taken into account in the design process. From the designed product perspective, attention is given to the kinds of factors to which TEL designs must attend (e.g. teacher perceptions, learner perceptions, teacher actions, learner actions) and particularly the relationships between them. Another example of how attention to both process and product combine to inform learning design is evident in the work of Prieto, Dlab, Gutiérrez, Abdulwahed, and Balid (2011), who examine the orchestrated efforts teachers must coordinate to render TEL in their classrooms.

Future Directions

In addition to the fields already discussed (ISD, LS, PPD, DBR and LD), developments elsewhere also stand to inform the processes and products of TEL design and evaluation in the coming years. In particular, we note three that are extremely promising and relevant to TEL, yet remain under-represented in TEL research literature to date: participatory design, design thinking and agile processes.

First, the field of Human-Computer Interaction (HCI) brought important attention to human-centered and performance-centered design, which gave rise to the increasingly popular participatory design movement that continues to gain momentum today. While participatory approaches are increasingly seen in TEL, most research literature portrays a limited view: namely, user involvement tends to be more reactive (e.g. formative evaluation) than generative (e.g. co-design). A notable exception to this can be found work characterized as Design-Based

Implementation Research (DBIR). In DBIR, researchers and practitioners form teams around a persistent problems of practice and commit to iterative, collaborative design (Penuel, Fishman, Haugan Cheng, & Sabelli, 2011), sometimes involving students as designers as well (Fishman, 2014). DBIR in the field of TEL is gradually growing (e.g. Roschelle, Knudsen, & Hegedus, 2010; Tatar et al., 2008).

Second, classic design literature, such as Cross's (1982) *Designerly Ways of Knowing* (also the title of his 2006 book that brings together much of his work in the past 25 years) or Nelson and Stolterman's (2012) book, *The Design Way*, have increased awareness for design thinking in many fields. Though gradually, design thinking is being popularized in education, by large consultancy firms, such as Ideo[1] and by scholars, such as those at Stanford's Research in Education and Design Lab.[2] While invigorating, there appears to be limited evidence of connections, let alone interactions, between these exciting initiatives and existing research programmes related to (technology enhanced) educational design.

Finally, reacting against heavily regimented, planned, linear process models, software developers in the last decade have (re-)turned to lighter, more flexible methods, referred to as "Agile" software development (Beck et al., 2001). Though exceptions exist (e.g. the Seeds of Science/Roots of Reading curriculum which was developed through a partnership between the Lawrence Hall of Science at Berkeley and Wireless Generation used several agile techniques, including scrums), very little TEL development and research literature even mentions, let alone uses or critiques Agile development processes for educational design. We are especially excited about these trends because they stand to increase attention for empathy in design, a trait which the track record of TEL research demonstrates is often lacking.

Finally, teachers are taking an increasingly important role designing TEL. The teachers as designers line of research is recently gaining increased interest as free online tools that enable simple authoring are becoming widespread, and new authoring environments and pedagogical design guidelines for TEL are provided by the LD community. In fact, Laurillard (2012), views teaching as a design science and claims that "Like other design professionals – architects, engineers, programmers – teachers have to work out creative and evidence-based ways of improving what they do" (abstract). We view this line of research as a prominent trajectory that will expand current collaborations between researchers and practitioners and enhance our understanding and exploiting of TEL design and evaluation methods.

[1] http://www.designthinkingforeducators.com/.

[2] http://web.stanford.edu/group/redlab/cgi-bin/index.php.

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Chapter 5
Computer-Supported Collaborative Learning

Sten Ludvigsen and Hans Christian Arnseth

Digitization of Society

In the knowledge society, the development of new infrastructures for information and communication is intertwined with people's everyday, professional and public lives as our societies gradually become more digitized. These developments also change the conditions for human learning and communication. How this plays out is the topic of this chapter. These developments create questions that are important and urgent: How and what do people learn when using new technologies? How and what can be learned in collaborative efforts? The collaborative dimension is important since many societal and institutional problems require collaborative and interdisciplinary problem solving. Collaboration also involves social, emotional, and cognitive mechanisms on which learning is dependent. Collaborative learning is both a means to an end and a process that is important for learning and development in and of itself. Social interaction and collaboration create resources for which people gain the capacities to explore and solve problems together. In human development it is individual, joint and collective intentionality that creates the conditions for cumulative human learning (e.g., Tomasello, 2014).

The computer-supported collaborative learning (CSCL) field is part of the overall development of technology, culture, and society. More specifically, CSCL provides new learning designs that support collaboration and learning in multiple domains and rigorous analyses of emerging social practices supported by digital technology. How knowledge is inscribed and represented in tools changes with new developments in computer science. In this sense, researchers working within the CSCL field merge social, cultural, psychological, and technological developments into a phenomenon we need to investigate to understand how individuals, groups,

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institutions, and society are transformed. The designs and practices used in CSCL contribute to change primarily at the interactional and individual layers of human development. Since the early 1990s, CSCL has been established as an interdisciplinary field for scholars around the globe (Stahl, 2015). For different overviews, see Stahl, Koschman, and Suthers (2014) (the first of our selected papers) and Ludvigsen and Mørch (2010) (the second selected paper). For other overviews of CSCL, see Jeong, Hmelo-Silver, and Yu (2014) and Tang, Tsai, and Lin (2014).

Computer-supported collaborative learning builds on different scientific disciplines and fields, such as the learning sciences, communication studies, computer science (e.g., human computer interaction, computational linguistics) and some branches of the social sciences. Methodologies from a number of fields are part of the repertoire of CSCL researchers. More concretely, methods from experimental psychology, analysis of social interaction, design studies, and field studies are used in the CL part of the CSCL field, while in the CS part, methods are connected to the development of hardware, software and interfaces, and the use of formalism (e.g., Tchounikine, Mørch, & Bannon, 2009). We emphasize that the defining features of CSCL are the interdisciplinary interdependencies between theories of learning, collaboration and computer science.

CSCL Research: The Phenomenon

Since the 1990s, CSCL research has developed together and in parallel with design-based research in the educational and learning sciences. The conceptual frameworks and practices of designing learning environments constitute one important building block of CSCL. The design of a learning environment can have different origins. Generally, careful analysis of learning activities combined with detailed descriptions of technological affordances constitute the starting point. Furthermore, computer support implies that computational tools are involved. Tools, such as scripts (which provide students with predefined roles and sequences of actions they should follow) or prompts as well as content-based scaffolds can offer support that enhances collaborative processes (de Jong et al., 2012; Fischer, Kollar, Stegmann, & Wecker, 2013). In many studies in the domain of science education, simulations and visualizations have been used to enhance students' conceptual understanding (e.g., Donnelly, Linn, & Ludvigsen, 2014).

Several empirical CSCL studies build on learning research that has identified students' learning challenges within a specific domain, such as mathematics or science (Arnseth & Säljö, 2007; Stahl, 2009). Advanced technologies, such as simulations or dynamic visualizations, make conceptual features and relations in a domain visible and others invisible. For instance, in a curriculum unit in the Web-based Inquiry Science Environment (WISE), exothermic reactions are presented and the students can start, stop, reset, and replay a simulation in order to increase their understanding of the reactions. As part of the WISE design of this simulation, a number of questions related to molecules are posed; this implies that students need to engage with the content (Linn & Eylon, 2011).

The meanings of representations always need to be inferred, and research demonstrates that making sense of these tools can be challenging for students. In the same vein, several studies show that it can be fruitful for students to make meaning of these tools in dyads or small groups supported by a teacher. The implication is that students and teachers together must unpack knowledge inscribed into these tools in order to learn the content and be able to use it for inquiry and problem solving. Complex representations constitute meaning potentials that students must work with to develop a deeper understanding.

Learning challenges can, for example, be related to conceptual issues in specific domains, such as learning about protein synthesis in biology, or learning specific procedures, such as performing an experiment in chemistry using virtual labs. Collaborative learning, small group interaction, and the characteristics and functions of social interaction have been important and classical themes in educational psychology, educational research, and the social sciences for many years. What is unique to CSCL concerns how collaborative learning becomes intertwined with computer support; this uniqueness, however, also creates conceptual challenges for the field. Questions related to what constitutes the appropriate unit of analysis and level of description lead to other questions about how to analyze, describe, and measure the learning that takes place in CSCL environments.

The following are key questions in CSCL: (1) How is collaboration and computer support conceptualized? (2) How and what do people learn in collaboration, and how and what do people learn as individuals participating in collaborative encounters? As pointed out in the introduction, joint intentionality cannot be understood only from an individual perspective. As a field, CSCL also needs studies that emphasize how different layers in socio-technical settings influence how collaborative learning is played out.

Conceptualization of CSCL Research

In CSCL research, we find important contributions from three main theoretical perspectives on learning and cognition: cognitive, socio-cognitive, and socio-cultural. These three perspectives are foundational within the learning sciences (Greeno, 2006). Collaborative knowledge building (Scardamalia & Bereiter, 1994, 2014; Stahl, 2009) is a design-based approach that builds on both socio-cognitive and socio-cultural perspectives. In the original work by Scardamalia and Bereiter (1994), knowledge building was based on studies of how experts develop their competences and how scientific communities make progress. However, the social mechanisms that support individual development or scientific progress was not explicitly addressed. In more recent studies by authors who apply knowledge building as their framework, the individual student's progress is still used as the unit of analysis, while others, such as Stahl, use the group as the unit of analysis and the interactional and social dimensions of knowledge building are explicitly addressed (e.g., Stahl, 2009).

A question we might ask ourselves is whether the fact that CSCL is based on different perspectives should be seen as a weakness of the field. We would argue that the opposite is the case. Within the broad area of learning sciences, interdisciplinarity could also be seen as a strength since complex problems can benefit from being framed by different assumptions. Collaboration as a concept is connected to psychology and social sciences, while the modelling of human actions is connected to computer science. This means that the two main building blocks of CSCL research are interdependent. Over time, the accumulation of knowledge from both areas can become more robust, particularly when different research designs lead to the same, or similar, conclusions. In the CSCL field, we see this very clearly in the design of environments such as knowledge building systems, inquiry in science (e.g., Web-based Inquiry Science Environment (WISE) (Linn & Eylon, 2011) and Science Created by YOU (de Jong et al., 2012)) virtual labs, and simulations, where knowledge from different perspectives become translated into the design of new computational tools, including scaffolds that support both social and individual meaning making (de Jong et al., 2012).

In Arnseth and Ludvigsen (2006), we proposed that CSCL research comprises two different orientations and practices: systemic and dialogical. This categorization cuts across the perspectives we have described and gives a nuanced analytic account of the kinds of results produced in different studies. The systemic orientation is grounded in the idea of testing hypotheses based on variables, while the dialogical orientation analyses collaboration and learning as it emerges in situ across different time scales.[1] The systemic orientation can be connected to the factoring assumption (Greeno & Engeström, 2014), which implies that different variables are tested to measure which of the designed features seem to enhance the student's conceptual understanding most efficiently. In studies based on this assumption, the individual's learning outcomes is often the most important measure of success. This orientation provides an explicit model of how one can design features in CSCL environments that improve individual learning outcomes.

In a dialogic approach, one conducts studies that consider how interaction emerges over specific stretches of time, analyzing in detail samples of specific interaction sequences. Here the learning outcome is often endogenous to the activity itself. These studies are inspired by dialogic and cultural approaches in Russian psychology (e.g., Arnseth & Säljö, 2007; Bahktin, 1986; Furberg, Kluge, & Ludvigsen, 2013; Vygotsky, 1978, 1986) and approaches emerging from American pragmatism, such as ethnomethodology (Medina & Suthers, 2013; Stahl, 2009). In addition, the dialogic approach makes use of concepts like argumentation and

[1]In their chapter in the second edition of the *Cambridge Handbook of the Learning Sciences*, Nathan and Sawyer (2014) chose to use the term *elemental* when we use *systemic*, and when they use *systemic* we use *dialogic*. In this chapter, we use the concepts that we introduced in 2006.

communication. Here, psycholinguistics is often used as an analytic resource (for a recent excellent overview, see Baker, Andriessen, & Jävelä, 2013). When collaboration with tools is analyzed as an emerging phenomenon, analysis often demonstrates how students' learning and conceptual development are situationally contingent on cultural tools, joint meaning making, and settings of activity. In such studies, the level of description can vary. The level of description refers to aspects that are included in the work, such as gestures, linguistic details, content, interactional moves, episodic events, and types of sequences (Linell, 1998).

CSCL Research: Orientations and Multiple Layers

As mentioned previously, in CSCL research one can identify influential studies based on the cognitive, socio-cognitive or the socio-cultural perspective. From the cognitive perspective, Roschelle's (1992) article (the third of our selected papers) discusses how students work together to solve problems in physics; the article analyzes how two students interact. It is based on the idea of the students' gradual development of a shared problem space, which in this study means a conceptual convergence between the students. A high number of contributions from socio-cognitive studies focus on motivation, metacognition, and self- and co-regulation (e.g., Hadwin, Järvelä, & Miller, 2011). Studies from the socio-cognitive perspective mostly contribute to the systemic orientation (but one can also find important studies based on a dialogic orientation) that investigates social regulation and perspective taking. In contrast, almost all studies based on the socio-cultural stance are dialogical in their orientations. These studies focus on emerging interactions in domains such as mathematics, science, social science, and art (e.g., Arnseth & Säljö, 2007; Stahl, 2009). These different orientations in CSCL imply that their analytic attentions are directed toward different aspects of learning and human cognition. The most important difference is how collaboration is accounted for. Within the cognitive and socio-cognitive perspective, individual contributions in collaboration and outcome measures are normally assessed. The socio-cultural studies have mostly been concerned with the investigation of emerging interactions and social practices. The studies are conducted in CSCL environments (Stahl, 2009) or in school environments where CSCL tools are used to scaffold specific forms of collaboration and activate resources within a knowledge domain (e.g., Furberg et al., 2013).

While the cognitive and socio-cognitive approaches use a unit of analysis that mainly focus on the individual within settings and environments, the socio-cultural perspective provides us with an analytic stance that encompasses three interdependent layers (social interaction, the individual, and social practices), all of which are needed in order to understand and explain learning, human cognition, and development (Ludvigsen, 2012; Valsiner & Van der Veer, 2000).

The socio-cultural perspectives on learning start with an analysis of micro-interaction. Learning outcomes can be assessed by examining specific forms of arguing or knowledge construction that occur during learner interactions or by measuring the relative contribution of different collaborative features to students' thinking and problem solving (Enyedy & Stevens, 2014). The study of micro-interaction implies a detailed analysis (or measurement) of how students engage in reasoning, arguing, and problem solving in specific knowledge domains or in themes that cross areas of disciplinary knowledge. Collaboration as a specific form of social interaction is crucial because it is here that history, tools, and human action come together and mutually shape one another (Valsiner & Van der Veer, 2000; Vygotsky, 1978). Collaboration with a specific tool, such as a simulation about climate change, creates emerging conditions for learning (Donnelly et al., 2014). This is the first layer in the analysis. The second layer focuses explicitly on how individuals participate in tasks, situations, and activities. Students make their cognitive, social, and emotional competences relevant through a series of actions in collaboration with others. This layer gives insight into how students manage collaboration and their assignments and their mastery of specific forms of knowledge (e.g., knowledge about climate change).

The third layer focuses on the institutional and historical dimensions that create affordances and constraints for students' actions—the social practices. One way to explain what this third layer implies is that institutions, such as schools, come with specific histories and a domain, such as mathematics, that emphasize certain historical norms, values, and ways of organizing knowledge. This could be the use of definitions or ways of arguing about mathematical ideas. Institutions like schools create conditions for ways of participating, and students bring with them different norms for the participation and different experiences of how their contributions are recognized. This orientation emphasizes that we need to account for how institutional settings influence collaborative learning through their histories, their domains, and how their students see themselves in the future. The influence is bidirectional, which means that institutions are produced and reproduced through participants' efforts. The three layers are nested within each other, meaning that all three layers are in principle visible and analyzable in micro-interactions. However, an understanding of micro-interaction often requires a broader historical and institutional analysis using a variety of methods, both quantitative and qualitative.

The processes and outcomes of collaboration can be analyzed based on different methods, such as interaction analysis, observations, log analysis, institutional analysis, and task and artefact analysis and pre- and post-tests. By using different analytic techniques, we understand how the three layers interact to create emerging opportunities for students' learning in collaboration with other actors and the tools involved. The students' learning processes can be conceptualized as intersecting trajectories of participation that include both the temporal and spatial dimensions of learning (Ludvigsen, Rasmussen, Krange, Moen, & Middleton, 2011).

We need more studies that can differentiate analytically between the layers and explain how they can be connected. Some such studies do exist. In Dolonen and Ludvigsen (2012), we investigated how students worked to learn concepts in the domain of geometry. They were exposed to 2D and 3D models and worked in teams of two in a specific environment and with the support of a teacher that engaged with them as he moved through the classroom. Here we combine the individual and interactional layers, while less emphasis is placed on the social practices. In a study of how students use categories in the domain of science, we combined the analyses of the interactional and socio-practices layers (Ludvigsen, 2012). The socio-cultural stance makes it possible to work with different types of analysis rather than with only one analytic layer. Based on the socio-cultural stance, one can use research designs that aim to understand each student's individual progress and to analyze how students collaborate with computer support in an institutional and historical setting. Here the concern is how one conceptualizes the phenomena and that learning and collaboration cannot be reduced to one of the described layers. We argue that the CSCL field needs to recognize that multiple layers influence collaborative learning and perform studies that can contribute to new understandings and explanations about how humans learn together with new computational tools.

CSCL and Scaffolds

Scaffolding is perhaps the most important mechanism in technology-enhanced learning and in CSCL (for a recent overview, see Reiser & Tabak, 2014). In a seminal work by Wood, Bruner, and Ross (1978), the authors describe how scaffolds can function to promote the students' capacity to perform more complex tasks than they could have done otherwise. Another concept that often is associated with scaffolding is the "zone of proximal development" (ZPD) (Vygotsky, 1978, 1986). The ZPD represents a unit of socially mediated interactions and provides a unit for describing the character and direction of conceptual change. It refers to an interactive cognitive system (one or more minds together) working successfully on problems that at least one participant could not solve alone (Newman, Griffin, & Cole, 1989).

In the learning process, scaffolding implies a cognitive division of labor between the students and the tool(s). The overall idea is that the scaffolding should help the students bridge their prior knowledge to tasks and to a future practice. Students can get support to collaborate in more productive ways, and the knowledge represented can be displayed in different ways that can facilitate cognitive development. The knowledge is displayed dependent on what the students choose to do and is adapted to their needs and level of expertise. In some cases, the students can learn so that the scaffolding can be reduced or taken away, while under other conditions, the tools and artefacts become part of the distribution of the cognitive processes involved (Hutchins, 2005). This means that to take away the tool would make the sequence of actions impossible. In CSCL environments, both ideas of scaffolding are used.

In the learning sciences and CSCL, scaffolding is part of designs that aim to cultivate students' advanced skills and participation in different social practices. The idea is not to decompose the scaffolding to a minimal component but to utilize it to support the work with complex problems. The design of CSCL environments and, more broadly, inquiry-learning environments provide us with many of the same features. Here we emphasize four features that are based on a recent review (Donnelly et al., 2014).

The first feature is the exploration of a specific context. We know that tasks and the task structure are important for students to develop the capacities to engage in complex problem solving. To enhance such knowledge, it is important for the tasks to be meaningful. Meaningful tasks for students are often based on a specific part of a practice from science, industry, or an everyday problem. The task and the problem in which the task is embedded create a relevance structure for the students. The context for the tasks can be related to a problem, such as climate change or gene technology, or to engage in mathematical problem solving.

The second feature is the use of simulations and dynamic visualizations. Simulations create affordances in which students can test hypotheses and manipulate parameters. Visualization is often used to model complex phenomena in chemistry, physics, or biology and complex datasets. Visualization can also involve creating models of phenomena that we cannot observe directly with the human eye. In mathematics, visualization can involve features in which students can observe how their actions create differences in a representation (e.g., 2D or 3D environments in geometry).

The third feature is to encourage students to collaborate in their work. To ask students to work together can be done in a number of different ways in dyads or groups or by software that structures student's work together based on a set of criteria. Based on findings from a high number of empirical CSCL studies, one can conclude that students' collaborations do not automatically activate advanced cognitive activities (Fischer et al., 2013; see also Littleton & Mercer, 2013). One of the most influential design approaches is the idea of scripting collaboration, which means that students work based on their internal scripts as well as on the designed external scripts. This approach is described in the fourth of our selected papers (Fischer et al., 2013). These external scripts could consist of components like plays, scenes, and roles. Such components could give students who lack internal scripts for regulation external support so that they can perform epistemic actions. The internal scripts can be seen as closely related to prior knowledge that needs to be activated and made relevant in a CSCL practice.

The fourth feature involves developing students' own goals, distinguishing between ideas and concepts, and linking their ways of reasoning into more complex arguments. The use of metacognitive strategies and students' capacity to self- and co-regulate themselves in socio-cultural environments and to contribute with epistemic actions cannot be taken for granted. Such a repertoire of actions must be cultivated over time. In addition, we emphasize that recent CSCL environments include design of technological features, such as learning analytics. Based on the learning analytics, we can trace what students do (Baker & Siemens, 2014). This information can be used for redesign to improve students' learning processes and outcomes.

CSCL: Impact and Future Challenges

In fields that address questions related to learning and collaboration, the issue of impact on social practice is important. The development of the CSCL field takes advantage of the cumulative growth of knowledge in its own context as well as in the contexts of learning science and computer science. The question becomes whether advanced CSCL environments and tools can be used in all types of educational institutions and in more informal settings (see the work of Math Forum [Stahl, 2009] as one example). CSCL is also used in higher education (Strijbos, Kirschner, & Martens, 2004), and new studies in the mentioned areas continue to be performed (Lindwall, Häkkinen, Koschman, Tchounikine, & Ludvigsen, 2015). We also find new types of CSCL studies in the mobile learning community (see Chap. 8).

We can find success stories, such as the WISE project (Linn & Eylon, 2011), which is used in many U.S. schools and in some European countries, the collaborative knowledge-building approach used in Hong Kong (Chan, 2011), and the work based on knowledge building and knowledge creation (Knowledge Forum) that is used in selected schools and classrooms in many countries (Scardamalia & Bereiter, 2014). We can model practice that represents new ways of designing environments for teaching and learning, and we can demonstrate how CSCL tools can be used. The CSCL field can create impact on social practices through modelling how in-depth learning can take place. To create change on a large scale involves much more than scientific studies and developmental work; local and national politics are often part of large-scale changes as the research on reforms of school systems has shown. However, in Hong Kong and Singapore, research teams have influenced educational policy and make and use CSCL as part of the overall framework for improving the educational system and the performance of teachers and students (Chan, 2011; Law, 2010; Looi, So, Toh, & Chen, 2011).

We think that CSCL design-based research tested in naturalistic environments has provided the research community and practitioners with very important knowledge about how to make use of new technologies in schools. Such studies make the cultures of schooling visible. While the CSCL design often emphasizes that students' work should be modelled based on (parts of) scientific practices, many schools and classrooms are based on other social and cultural conventions. This means that CSCL designs can create tensions and discontinuities in the practices in which students and teachers are involved. Such tensions and discontinuities can be important for creating "seeds for change" for new practices that are based on state-of-the-art learning principles. A strong sign of policy impact is the new study performed by the Organisation for Economic Co-operation and Development (OECD), which includes peer collaboration with tools in their new assessment of 21st-century skills (OECD, 2015).

Most CSCL studies are conducted with relatively low numbers of participants (although see Chap. 6 for a new account of mass collaboration). This means that CSCL studies are often based on either small-scale experiments, quasi-experimental designs, or design-based studies in natural contexts. In experimental studies, specific hypotheses are tested, while in design-based and explorative studies, one investigates what and how students can learn under specific conditions. All these types of studies should be seen as part of the research designs that can bring novel contributions to CSCL. When we ask questions that cut across the different studies, specific patterns emerge that show how we can design for in-depth learning. Different research designs, assumptions, and perspectives then do not need to be fused but rather can be seen as incremental steps toward a more advanced understanding of how and what students learn in collaboration with new technological tools in designed environments that are built on the generalized knowledge from the CSCL field. It is through variation in research design that we see how the different perspectives contribute to CSCL.

We, as a community, must recognize that students need to learn in many different ways. We also need to consider impacts other than those on the systemic, national, or regional levels. We need to see the impact as part of inspiring teachers to make use of the micro-analyses of collaboration with tools, which the CSCL field has contributed. Teachers can then advance their designs for learning and create better tasks for their students.

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Chapter 6
Mass Collaboration with Social Software in TEL

Ulrike Cress and Gerhard Fischer

The Social Web as Cultural Revolution

The Internet has undergone numerous transformations in its less than 20 years of existence. As discussed in the first of our selected papers, a fundamental transformation was its migration from *Web 1.0* (with a broadcast-oriented architecture enforcing a strict separation between consumers and producers) to the social *Web 2.0* (supporting broad-based participation allowing users to create and share collaboratively constructed artifacts) (O'Reilly, 2005).

Web 1.0 environments were focused on a platform where authors could publish information and make it accessible for large audiences enabling flexible opportunities for one-to-many communication. The majority of users were recipients of the content provided by a minority of publishers.

Web 2.0 environments supported the continual evolution and improvement of tools, services, and information repositories by allowing active participation. Users in Web 2.0 can migrate (if they desire to do so) from passive consumers to "prosumers" (Tapscott & Williams, 2006): persons who simultaneously consume and produce information. The produced content can range from small pieces of information (e.g., tags, tweets, ratings, or traces of the navigation behavior) to substantial contributions (an entry in Wikipedia, a movie in YouTube, or a 3D model in Google's 3D Warehouse). Based on a large number of prosumers, these

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small contributions can be aggregated and represent the "collective intelligence of the masses" (Surowiecki, 2005). Web services can harness this collective intelligence and make it accessible for individual users, for example by providing recommendations, tag clouds, or collaboratively written texts.

This technical revolution of the social Web 2.0 was seen initially to have an impact on many aspects of our culture by enabling new business models that are defined by openness, interaction with peers, sharing, and acting globally (Tapscott & Williams, 2006). Tapscott and Williams observe that "millions of people already join forces in self-organized collaboration that produce dynamic new goods and services that rival those of the world's largest and best-financed enterprises" (p. 11). This new mode of innovation and value creation called "peer production" describes what happens when masses of people and firms collaborate openly to drive innovation and growth in their industries (von Hippel, 2005). Jenkins suggests that peer production is not an isolated event by citing empirical data that in the USA "more than one-half of all teens have created media content, and roughly one-third of teens who use the Internet have shared content they produced" (Jenkins, 2009, p. xi). Benkler goes one step further by arguing that the social Web will provide enhanced autonomy of people and will impact democracy, justice and human development (Benkler, 2006). Cress, Jeong, and Moskaliuk (2016) describe how these emerging forms of mass collaboration can have an impact on education.

Learning as Participation

Besides these expectations that the Web 2.0 could have a positive influence on economics and democracy, it has the potential to provide new opportunities for learning. More than 35 years before the concept of Web 2.0 was created, Illich stated that "a good educational system should have three purposes: It should provide all who want to learn with access to available resources at any time in their lives; empower all who want to share what they know to find those who want to learn it from them; and, finally, furnish all who want to present an issue to the public with the opportunity to make their challenge known" (Illich, 1971, p. 75). He dreamed of an "educational opportunity web" where learners can engage in collaborative activities serving as foundations for new learning opportunities. By giving not only access to existing information (e.g., curriculum-based learning materials taught in courses), socio-technical environments based on Web 2.0 architectures also provide opportunities for collaboration in small and large groups (further enriching the learning ecologies provided by more traditional research in Computer-Supported Collaborative Learning CSCL). With social software such as wikis, blogs, Facebook, and Twitter, thousands of people can exchange knowledge and co-construct new knowledge.

These are developments towards what has been described as a second metaphor of learning (Sfard, 1998). Whereas in cognitive psychology "learning" mostly was considered as *knowledge acquisition*, where individuals developed an abstract internal representation of the world around them, more situated approaches describe learning as *participating*. Knowledge, described in this metaphor, is not something that people *have*, but something people *do*. In this perspective, learning happens by participating in sociocultural activities described as legitimate peripheral participation (Lave & Wenger, 1991). This complementary view explores a much broader perspective on learning (Engeström & Sannino, 2010) that is not restricted to formal settings in schools or universities, but happening in real life by observing others and interacting with them (National Research Council, 2009). Paavola, Lipponen, and Hakkarainen added to Sfard's two metaphors of learning a third one: the *knowledge creation metaphor* (Paavola et al., 2004). This metaphor understands learning as a collaborative effort directed toward developing some mediated artifacts including knowledge, ideas, practices, and material or conceptual artifacts.

Brown & Adler (2008), in the second selected paper, describe the new possibilities that the social web has with regard to this understanding of learning. With social software people can directly interact in large-scale virtual worlds and participate in projects where they interact and collaboratively create knowledge. One unique opportunity of Web 2.0 is support for *long-tail learning* (Collins, Fischer, Barron, Liu, & Spada, 2009) by providing opportunities for interactions of passionate learners sharing an interest in idiosyncratic niche topics. Whereas traditional formal education provides learning environments in support of a selected curriculum, the web offers content and social ties to an almost unlimited number of people. Long-tail learning occurs in socio-technical environments that provide information and support special interests of individuals.

One of the hottest topics these days is creating Higher-Education Courses with massive enrolments (also referred to as a "massive open online course" (MOOC)) having the objective to support education for everyone and for all interests. There is currently a substantial interest based on developments such as:

– MIT's and Harvard's *edX project* offering online learning to millions of people around the world[1];
– *Coursera,* offering free courses for everyone by an alliance between Stanford, Princeton, Michigan, and Penn[2];
– *Udacity*, a private company with the goal of creating and offering classes to hundred thousands of students.[3]

Interesting questions to ask based on these developments are:

– *What is covered* by these educational experiences (by being free, open, and large-scale; by containing rigorous content; and by offering learning analytics opportunities (Duval, 2011) based on very large numbers of participants); and

[1]https://www.edx.org/.
[2]https://www.coursera.org/.
[3]https://www.udacity.com/.

– *What is not covered?* (If MOOCs base on the traditional model of an instructionist classroom, there is little support for self-directed learning, debate and discussions, and reflective conversations. However platforms where developed hat take into account an explicit pedagogy of collaborative and social learning, e.g. the platforms FutureLearn or OpenClassrooms?)

Interesting complementary developments (covering a very large number of idiosyncratic topics and thereby being supportive of the Long-Tail framework for learning) are:

– the *Khan Academy* that advertises its role as "Watch. Practice. Learn almost anything for free with over 3,100 videos"[4]
– *iTunes U* (organized by Apple) supporting the design and distribution of courses to allow students to "learn anything, anywhere, any time"[5]; and
– the *One Laptop per Child (OLPC)* initiative focused on the $100 computer, which so far has been delivered to over 2.4 million children and teachers primarily in developing countries[6]

Theoretical Frameworks for Learning with Social Software

As the world is becoming more complex and interconnected and the changes within human life times are further accelerated (Drucker, 1994) new learning ecologies are needed. The knowledge needed to cope with systemic problems transcends the individual, unaided human mind. Social software focused on connecting humans and artifacts provides new opportunities, and theoretical frameworks are needed to create a fundamental understanding of the strengths and weaknesses of mass collaboration.

Whereas in former times collaboration was mostly bound to smaller groups, social software now provides the possibility for collaboration of masses of users. Because this is a new phenomenon, only some initial theoretical frameworks exist so far (Benkler, 2006). Following the initial vision of Illich's learning webs, Scardamalia's and Bereiter's knowledge-building model (Scardamalia & Bereiter, 1994) represented an early important forerunner for the social Web. They used a platform where students can generate their own theories about a given topic, describe it and share it with others by writing contributions into a shared artifact where the articulated ideas could be discussed with others for further elaboration and/or criticism. Through such a logic of "abduction" (Glassman & Kang, 2011) the group as a whole reaches deeper insights into the domain of interests and allows the group members to develop a shared understanding.

[4]https://www.khanacademy.org/.
[5]http://www.apple.com/education/itunes-u/.
[6]http://one.laptop.org/.

The third selected paper describes the "Co-Evolution Model of Individual Learning and Collective Knowledge Building" (Cress & Kimmerle, 2008; Kimmerle, Moskaliuk, Oeberst, & Cress, 2015) that explicitly deals with mass collaboration. It takes into account that in mass collaboration users need not necessarily form a group with common interests or common goals. Instead, users can just work in parallel and each can make use of the shared artifact. Nevertheless, as users refer to each other and interact with them, the group represents a self-organizational system. Users, considered by the model as cognitive systems, interact with the artifact by internalization and externalization. As a result of this interaction, learning occurs in four ways: as internal accommodation or assimilation (the individual learns) or as external accommodation or assimilation (the social system learns) (Cress, 2013).

The research of the Center for LifeLong Learning & Design (L3D) at the University of Colorado, Boulder, has been grounded in the basic objective that a science of learning for the 21st century needs to explore richer learning ecologies than traditional curriculum-based classroom learning by conceptualizing learning as an inclusive, social, informal, participatory, and creative lifelong activity (Collins, & Halverson, 2009). The learning goals and the content of the learning activity should not only be determined by curricula but by interest-based, self-directed learning objectives. Many problems (specifically design problems) are unique and ill-defined and the knowledge to address them is not "out there", requiring contributions and ideas from all involved stakeholders (Fischer, 2007, 2016). Learners in such settings must be active contributors rather than passive consumers and the learning environments and learning organizations must foster and support mindsets, tools, and skills that help learners become empowered and willing to actively contribute.

L3D's concept of "cultures of participation" (Fischer, 2011) (the fourth selected paper) articulates a framework and describes socio-technical environments that provide learners of all ages with the means to become co-creators of new ideas, knowledge, and products in personally meaningful activities. The research on cultures of participation has focused on three specific aspects: (1) *meta-design* that defines and creates social and technological infrastructures in which cultures of participation can come alive and new forms of collaborative design can take place; (2) *social creativity* that creates environments in which participants collectively can transcend the individual human mind by supporting interactions between people and shared artifacts; and (3) *richer ecologies* that create different levels of participation by differentiating, analyzing and supporting distinct roles with regard to people's variations in expertise, interests, and motivations.

Examples for Empirical Analyses of Mass Collaboration

An increasing number of studies analyze learning and mass collaboration with social software. Some prototypical examples are:

– Bryant, Forte and Bruckman investigated *how people become Wikipedians*. Based on the concept of legitimate peripheral participation they show that users, as their participation becomes more central and frequent, adopt new goals, new roles and use different tools. Their perceptions of Wikipedia change, they start to identify with the site and the community (Bryant, Forte, & Bruckman, 2005).

- Kittur and Kraut examined the *quality of the mass collaboration* with regard to explicit and implicit forms of coordination of mass settings. They investigated how the number of editors in Wikipedia and their coordination methods affect the quality of an article. They came to the conclusion that adding more editors to an article improved article quality only when the authors used appropriate coordination techniques and it was harmful when they did not (Kittur & Kraut, 2008).
- Another social software tool, which stimulated empirical research about its potential for learning is *social tagging*. Fu, Kannampallil, Kang, and He provided a cognitive model of semantic imitation showing that users over time adapt to the conceptual structure of the collective. Their data show evidence that by using a social tagging system users internalize the conceptual structure of the community, and thus learn incidentally (Fu, Kannampallil, Kang, & He, 2010).
- *Citizen science* facilitated by the web and conducted by pro-amateurs (Leadbeater & Miller, 2008) in areas such as protein folding (e.g., Fold It[7]), astronomy (Galaxy Zoo[8]), and life on earth (animals and plants in the Encyclopedia of Life (EOL)[9]) have created synergistic interactions between professional and pro-amateurs creating new learning cultures that benefit all participating stakeholders.

Drawbacks of Mass Collaboration

Mass collaboration with social software opens up new opportunities for TEL, but the approach is not without drawbacks (Keen, 2012; Carr, 2010). One such drawback is that in many situations humans are reluctant to participate actively. Even if they wish to have access to other people's information and knowledge, they are not willing to contribute their own knowledge and information, especially if this needs effort (Kimmerle & Cress, 2008). Furthermore, humans may be forced to cope with the burden of being active contributors in *personally irrelevant activities* that can be illustrated by "do-it-yourself" societies (Fischer, 2011). Through modern tools, humans are empowered to perform many tasks themselves that were done previously by skilled domain workers serving as agents and intermediaries. Although this shift provides power, freedom, and control to customers, it also has forced people to act as contributors in contexts for which they lack the experience that professionals

[7]http://fold.it/.

[8]http://www.galaxyzoo.org/.

[9]http://eol.org/.

have acquired and maintained through the daily use of systems, as well as the broad background knowledge to do these tasks efficiently and effectively (e.g., companies offloading work to customers).

More experience and assessment is required to determine the design trade-offs for specific contexts and application domains in which the *advantages* of cultures of participation (such as extensive coverage of information, creation of large numbers of artifacts, creative chaos by making all voices heard, reduced authority of expert opinions, and shared experience of social creativity) will outweigh the *disadvantages* (accumulation of irrelevant information, wasting human resources in large information spaces, and lack of coherent voices). The following research questions need to be explored:

– Under which conditions is a fragmented culture (with numerous idiosyncratic voices representing what some might characterize as a modern version of the "Tower of Babel" and others as refreshingly diverse insights) better or worse than a uniform culture (which is restricted in its coverage of the uniqueness of local identities and experience)?
– If all people can contribute, how do we assess the *quality and reliability* of the resulting artifacts? How can curator networks effectively increase the quality and reliability?
– What are the roles of *trust, empathy, altruism, and reciprocity* in such an environment and how will these factors affect cultures of participation?

Challenges and Opportunities for Future Research

Mass collaboration with social software in TEL is a new phenomenon providing many interesting challenges and opportunities for future research. Some of those are the need to: (Fischer, 2011):

– identify the *social abilities, technical skills, and cultural competencies* people need for active participation;
– extend the *theoretical framework* to support the design of socio-technical environments in which users can act as co-designers in personally meaningful problems;
– analyze different *design objectives and requirements* (e.g., creating seeds for open, living artifacts) and consumers cultures (e.g., create complete systems);
– broaden the scope of human-centered design from the usability of systems to providing resources, incentives, information to encourage participation and sustain it and allow users to reflect upon *changing their behavior*;
– create a deeper understanding how TEL approaches harness important social benefits related to *national priorities such as* energy sustainability, lifelong learning, education, and healthcare; and

– differentiate domains in which TEL approaches will flourish and be successful from the ones which are not suited by exploring the *drawbacks* associated with these new approaches.

With consideration of these topics mass collaboration has the potential to change our view on learning by pointing to the strong interrelation about individual processes of knowledge acquisition and collaborative and social processes.

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Chapter 7
Learning Spaces

Brett Bligh and Charles Crook

Abstract Sociocultural accounts of education emphasise that learning occurs in and through mediated interactions with the world; technology in education mediates those interactions, and commonly strives to create distinctive experiences centred upon particular spaces. Yet, until relatively recently, most analyses have typically underemphasised those spatial aspects of how technology in education functions—how tools come to be used in particular spaces, to intersect and challenge spatially embedded practices, and might thereby be designed "with space in mind". In this chapter, we set out some bases for a "spatial turn" in Technology Enhanced Learning (TEL) research. We argue that those of us working in the field need to better understand both technology and learning as spatial phenomena; that we must better conceptualise the design of technology and the spatial contexts of use; and that we should become more directly involved in designing and evaluating Learning Spaces themselves—thereby coming to view space as an integral part of the "technology" that might mediate learning. We emphasise the difficulties in conceiving how space and learning are related, and sketch six different models that view the development of spaces and learners as intertwined in increasingly complex ways. We conclude by considering some particular types of Learning Spaces and related issues such as apparent informality and flexibility; by considering pertinent directions in research on the design and evaluation of educational spaces; and by celebrating some of those strands of work within the TEL research field that do already strive to account for the spatial implications of technology.

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Introduction

Let us consider some particular educational settings. A primary school classroom has brightly-coloured furniture; it has been arranged so as to focus attention on an interactive whiteboard. A new secondary school building is organised around “learning corridors”; these are punctuated by display technologies that can be connected to learners’ mobile devices. A university library—an “Information Commons”—provides food, drink, comfortable seating and computer terminals; it is a meeting place for students, where learning occurs within a bustling café atmosphere. A museum exhibition incorporates both projectors and interactive consoles; the ecology of information surfaces strives to create a reflective ambience, to encourage exploration while providing a coherent experience for visitors.

Those examples serve to illustrate how one important way that technology interacts with and re-shapes learning is by creating distinctive experiences that are centred upon particular spaces. Learning is neither immaterial nor non-corporeal. That is an apparently obvious point, but one that nonetheless eludes many analyses of sociality within TEL. In this chapter we argue that TEL researchers need to take something of a “spatial turn”—to better understand spatiality, to acknowledge spatial context when designing technology, and to increase our involvement with the design and evaluation of learning spaces themselves. Therefore, we suggest that ‘Learning Spaces’ can be seen both as an important, specific area of inquiry within TEL and as an underpinning way of enriching our accounts of *how learning happens*, so as to provide useful insight into how we might more sensitively design and evaluate technology. Let us begin by elaborating each of those priorities in turn.

Understanding Technology and Learning as Spatial

Those of us working in the TEL field would benefit from a better understanding of spatial concerns and practices and of how to evaluate educational uses of technology in material terms. We need to focus, for example, on how learners experience examples of TEL innovation as flesh and blood human beings. Some prominent points of focus for the TEL community—cloud-based services, learning analytics, particular applications for mobile devices, and so on—evoke visions of learning that may seem rather removed from those material concerns more readily associated with studying or designing co-present classroom interactions. Yet nearly all TEL tools will be experienced, via some interface, by particular learners within particular material settings. Better appreciating this fact is an important step towards gaining insight into why the experiences created by TEL projects may sometimes fall short of our aspirations.

Designing and Developing Technology for Use Within Space

TEL design projects would benefit greatly from better awareness of relevant spatial relationships. That means, for example, that designers should take into account how existing settings present design opportunities or constrain how a tool will be used; how technology might re-shape existing spatial practice; and how a tool itself might support users to change or adapt their own practices—even to go "against the grain" of dominant spatial norms. At present, TEL design processes most commonly attempt to engage with spatial issues where the model of learning renders the role of space obvious. For example, some mobile learning applications are designed to select the information that they provide to users based on what is known about the current task context and physical location—where information about the latter is derived from GPS or tagging data. Other TEL technologies are designed to be used in particular locations, such as within museum exhibitions. Accepting that *all* learning is spatial would impact how design processes are conceived more generally within the field.

Engaging with Learning Space Design

In our view there is a great need for researchers in the TEL field to engage directly in designing, implementing, evaluating and theorising Learning Spaces themselves. Technology-enabled learning spaces are a crucial resource for the re-shaping of learning. Those who identify with the TEL field should intervene directly within this area, while being aware of the interdisciplinary and institutional challenges that will arise when doing so. The remainder of the chapter will elaborate on that argument, and revisit those points more fully.

What follows is arranged into three sections. First, we examine a range of different models that suggest increasingly interdependent relationships between learning and space within the context of TEL. Second, we emphasise some key issues that are currently posed in the area of Learning Spaces. Third, we introduce four papers recommended as an introduction to the topic.

How Are Space and Learning Related?

Discussing the relationships between space and learning is important, though far from straightforward. Given widespread scepticism, it is perhaps important to establish first of all that empirical evidence does support increasingly confident claims in the literature that space has an 'impact' on learning, however that impact might be conceived. At the granular room level, for example, quasi-experimental research by Brooks (2011) finds a positive, and statistically significant, impact on learners' grade outcomes for a learning activity undertaken in a technology-rich

"Active Learning" space, when that context is compared with a more traditional classroom within the same university. The result of Brooks' research is particularly interesting because his quasi-experiential design controls for many of the differences in space *usage* that might otherwise be considered a likely explanation. At a less granular, campus level, Hajrasouliha and Ewing (2016) are similarly confident about the impact on student retention and attainment of what they call the "morphological measures" of campus design. In the compulsory education sector we can find similar claims. The approach of Barrett, Zhang, Moffat, and Kobbacy (2013), for example, distinguishes between different features related to design and usage within a multi-level model of classroom data from ten UK schools. Barrett et al. suggest that particular factors of space design and usage are particularly important for improving student learning outcomes: important design-related factors include natural lighting and carpet colour, while salient usage-related features include multiple 'zoning' within a room and ease of classroom re-configuration for teachers (p. 688).

Yet the more substantial issue of *how* and *why* the relationships between learning and space are manifest remains unclear; Learning Spaces, as a theoretical concept, remains underdeveloped and fragmented. In this section we sketch our own typology of theorised relations between educational spaces and educational activities. We illustrate each theory-type within the typology (hereafter, "view") by indicating links to prominent, particular theoretical perspectives and by providing pertinent examples of actual technological developments and TEL research projects. Furthermore, we show that each view links space with how students learn by emphasising a different object of investigative activity. As we proceed, the views that we consider increasingly serve to position the relationship between educational activities and space as more explicitly *dialectical*, by which we mean increasingly interpenetrated and dependent, as well as constantly developing (see Ollman, 2003). In each case, we also identify systemic points of focus that appear to be in contradiction, driving practitioners to make progress in order to overcome the contradictions they encounter. For brevity, we largely confine our scope to perspectives that can be identified within TEL and related work in Education and Human Computer Interaction (HCI) and do not dwell on the competing conceptual languages within fields such as Architecture and Philosophy.

(0) Space as "insignificant". Much work within TEL takes no systematic view of space. Viewing space as *insignificant* means ignoring spatial concerns entirely or engaging in opportunistic discussion only where spatial issues directly intrude into data—for example, where learners focus on some aspect of space during a focus group discussion. It has been suggested that researchers are not *prompted* to engage systematically with space because established theories of learning fail to engage satisfactorily with the issue. Neary et al. (2010) review four theories of learning and conclude in each case that spatial issues have been under-problematised. That is despite the fact that in many instances the vocabulary used within each particular theory is steeped in spatial metaphor, such as when discussing "surface learning", "threshold concepts" or "liminal spaces" (p. 11). Similarly, Boys (2011, pp. 37–39) provides a list of 28 learning theories and suggests that many fail to highlight spatial context. Yet there are signs that spatial issues are slowly being taken more

seriously within the TEL community. For example, Thomas (2010) discusses how our “inability to articulate where learning takes place” (p. 502), when analysing innovation in TEL, is to a great extent a problem of better understanding spatial and material concerns. The present chapter also contributes to that emerging discussion.

(1) Space as “impeding”. Viewing space as *impeding* means understanding space as some set of *generalised* obstacles to desired actions or educational needs that must be overcome. Temple (2008), in the first of our selected papers, notes that students themselves rarely highlight the role of space within their learning experiences unless they have been irritated by some aspect of those spaces they have used. The *impeding* view suggests that “adequate” space meets a variety of basic needs and thus recedes to the periphery of users’ attention. Correspondingly, if certain spatial criteria are met then learning can be provisioned with the opportunity to occur satisfactorily, though that opportunity may or may not be realised in practice (since that realisation is not seen as primarily spatial).

Within the literature, *impeding* views have been expressed in the form of *hierarchies* of needs that must be met. For example, Watson, Anderson, and Strachan-Davis (2007, p. 14) conceptualise users’ needs within learning spaces as a Maslow Triangle diagram. Maslow (1943) posited a theory of human motivation based on a hierarchy of needs—in turn related to physiology, safety, love, esteem, and self-actualisation—where “higher” needs only come to dominate particular organisms once those lower in the hierarchy are satisfied. By analogy, Watson et al. suggest that learners’ most basic need is for sufficient space, followed by an equitable internal environment, a suitable data communications infrastructure, flexible configuration, and a positive ambience.

We should say that the *impeding* view of space has considerable traction within educational policy. For example, the view that *inadequate* spaces impede learning was prominent in the large scale UK Government programme *Building Schools for the Future*, which ran from 2005–2010 (Woolner, 2010). The impeding view positions *standards* as the central object of investigation—standards that must take into account a range of constantly developing estates benchmarks and other legislative prerequisites while also seeking to support changing institutional aspirations. That relationship between pre-requisites and aspirations is usually conceived of in relatively blunt terms; in describing their hierarchy of needs, for example, Watson et al. suggest that the aspirations of learning are built “on top of” the pre-requisites they have identified (p. 15). We suggest that the bluntness of the impeding view does, if accepted uncritically, limit the potential for innovation by TEL practitioners. It has TEL researchers plausibly designing and evaluating technologies that meet particular needs, such as classroom control systems that place room configuration in the hands of learners, or digital displays used to create a particular “ambience”. Yet, overall, the *impeding* view is imbued with a sense of space as relatively homogenous that can serve to restrict our ability to see the potential to shape learning positively through design.

(2) Space as “containing”. The *containing* view suggests that spaces have particular properties and contents that support or restrict the practices of the people within them. Consequently, this view emphasises that spaces must be materially

configured so as to support those *scenarios* that are envisaged to occur within them. Consistent with this view, Jamieson, Fisher, Gilding, Taylor, and Trevitt (2000) discuss how seating arrangements in classrooms with computers may restrict learners' movement and constrain opportunities for group work. The implication is that spaces can be designed so as to support desired practice and, furthermore, that flexibility in design might allow a space to successfully support more varied practices. The physical relationship to learning that is described by the *containing* view echoes work on the ergonomics of learning environments, where "the design of educational technologies is best informed by an understanding of the actuality of learners' work" (Goodyear, 2008, p. 254). Yet, importantly, this *containing* view focusses on supporting *existing* practice, rather than inviting novel interactions or learners' exploration.

One important way in which the *containing* view differs from the *impeding* can be found in its increased particularity, a relatively closer focus on the actual properties of particular spaces rather than standards to be attained for spaces in general (or types of spaces). Yet, in common with the impeding view, the overriding concern of work of this type is that learners should be constrained in their (pre-)desired activity to the minimum extent possible. The notion that physical space might positively change learners' actions is not emphasised by this view; while the *containing* view does invoke some vision of affordances, it does so in a way that foregrounds the *closing down of possibilities for action,* rather than the perceptual models of affordance more prevalent in TEL. Much work on computer-mediated communication (CMC) implicitly adopts a *containing* view, particularly when the affordances for collaboration of video conferencing systems are recognised as different from those available in the physical world. A section of the paper by Jamieson et al. (2000), the second selected paper, rehearses these arguments in ways that recall HCI work on CMC that stretches back for several decades.

(3) Space as "stimulating". Physical space plays a role in *stimulating* our thinking in a number of ways. Spaces can be designed to invite reflection and exploration, particularly in situations where space itself is the object of our activity. Space is also a vehicle to externalise our thoughts. The *stimulating* view of space corresponds well with the perceptual, invitational nature of how educational affordances are understood within TEL. The object of investigation is *provision*, primarily because particular spatial elements are seen as *providing for* certain kinds of thinking and action, but also with reference to the intentions of designers to provide those underpinning elements. A range of other theoretical perspectives also inform work on how space stimulates learners. Models of spatial cognition are widely used in mobile HCI, to assist people to experience space vicariously or to support their exploration of space *in situ* (Mark & Freundschuh, 1995). The *exploration* of space is discussed within Architecture as invigorating, or even healing, due to the way our senses are stimulated (Pallasmaa, 2005, p. 41). At a micro scale, within the context of work on tangible technologies, it has been heavily emphasised that learners may undertake exploratory physical manipulation in ways that *precede* their development of verbalised understanding (e.g., O'Malley & Stanton Fraser, 2004). Technology and space may also combine to invite such exploratory action at larger scales, such as in technology-augmented museum exhibits (Wishart & Triggs, 2010).

Space can also make us aware of the presence of our own bodies, inviting us to engage in personal, exploratory narratives. The technology-focussed *Speckled Computing* project (Leach & Benyon, 2009) explicitly sets out to investigate how people might act to *forage* for information within augmented reality spaces; their project uses miniaturised, embedded devices to form wireless sensor networks that people *physically* navigate using their bodies, supported by a range of personal devices. The learning-focussed work of Ruchter, Klar, and Geiger (2010) shows how technology (a mobile guide) can encourage learners to explore an outdoor area with the aim of increasing their awareness of environmental issues. We are invited to reflect on our relationships to our environment, as human beings, and to explore the potential for new relationships.

(4) Space as "associative". The *associative* view of space analytically separates what is conceived of as objective, material space away from more subjective space (often referred to as "place"). It then theorises how those two constructs are interrelated, and suggests that the object of inquiry should be how learners might feel a particular "sense of place". The *associative* view of space suggests that *place* is constructed by learners in ways that are dependent on historical, cultural and social factors. Objective space remains understood as a "container" for things and people (echoing the *containing* view of space above), yet the precise nature of that container is suggested to be less important than how it is 'read' by learners. The canonical distinction used to illustrate the space-place dichotomy is that between *house* (a material space) and *home* (a place construct), a separation of meaning directly supported within the English language.

A range of *associative* formulations for place construction have been proposed but, for reasons of brevity, we will restrict ourselves to a particular example. Harrison and Tatar (2008) suggest that our experience of place depends on two phenomena. First, our experience depends on a complex "semantic tangle" of: *people*, (human beings in all their complexity, as opposed to the abstract profiling of "users"); *events*, or temporal phenomena and the constructed meaning of temporal experience; and *loci*, as used in lieu of the contested word "space" to mean that which exists to be recruited into meaning-making when humans do engage in place-construction. Second, our experience of place depends on the embodied physical experiences that underpin the development of our analogies, metaphors and abstractions. Harrison and Tatar argue that the *abstract* conceptions of place that technology designers utilise when undertaking development projects contrast unfavourably with the *embodied*, human conceptions of place held by the eventual users of the tools they are designing. Consequently, the outcomes achieved when using abstract, spatial design metaphors may be disappointing.

Designers of new Learning Spaces within the Higher Education sector frequently invoke a desire to create particular "places". For example, recognising learning as inherently social and frequently informal has stimulated interest in the creation of *third places*—places of conviviality that are neither workplace nor home (Oldenburg, 1999). That identification of third places underpins the interest within the Higher Education community in re-shaping University libraries into more social, Information Commons spaces.

Clearly, taking advantage of place metaphor when designing intertwined technologies and spaces can be a powerful way of leveraging the prior experiences and expertise of learners. Some learning space designers have suggested that place metaphors can be used directly as triggers for ideas within design processes. An example is the work of Watson (2007), who describes how particular spaces were designed using metaphors such as "the busy city", "the airport departure lounge" and "the domestic living room" (p. 261). Yet, equally clearly, relying on the invocation of senses of place is hardly a precise endeavour. Senses of place are influenced societally and historically, potentially carrying unanticipated or undesirable baggage; while the reading of place is also to a great extent individual, meaning that place cannot just be designed but only designed *for* (Ciolfi & Bannon, 2005). Furthermore, the very idea of space as defined by subjective, representational metaphor has attracted some controversy, since it takes for granted many of those productive and reproductive processes that act to control how space is understood and used (see Boys, 2011).

(5) Space as "constitutive". Human beings are materially a part of their surroundings, and the *constitutive* view of space problematises the boundaries separating "inner" from "outer". According to this view we ourselves constitute, and are constituted by, space. The object of investigation is the mutual *permeation* of the mind, the body, and the surrounding environment, with each of those terms requiring considerable clarification of their generally ascribed meanings.

Different theories of embodiment and distributed cognition provide mechanisms for conceiving how our mental processes are part of our immediate material surroundings. Distributed cognition, for example, proceeds from observations that human beings routinely *offload* their cognition onto accessible tools and onto other human beings (cognizers) (Dror & Harnad, 2008). The way that humans think – using both spatial metaphor and through the internalisation of initially external tools such as language – is a product of that offloading.

Importantly, distributed cognition suggests that our cognition is really *so* offloaded that defining boundaries between what is internal or external is challenging. We might say that we think *using* space, and operationalise those physical and mental actions so as to produce a psyche that is thoroughly and profoundly spatial. Dror and Harnad (2008) discuss the concepts of the "extended mind" and the "wide body", metaphors that attempt to capture some of the attendant implications. In a variety of ways, emerging technologies are playing a significant role in that extension of "cognition". Dror & Harnad suggest that the increasing information processing power and the "disappearing" nature of those technologies that surround us is affecting our brain development, organisation and capacity (p. 21). In doing so, they invoke the vocabulary of *ubiquitous computing*, whereby computing devices blend into the physical world, disappear into the periphery of our attention through familiarity, and move seamlessly back into the centre of our attention as we engage with the content they offer (e.g., O'Malley & Stanton Fraser, 2004. See also Chap. 8).

The TEL community has been active in taking advantage of developments in ubiquitous computing (UbiComp) to influence processes of learning. An example is the work on "scriptable classrooms" by Kaplan and Dillenbourg (2010), the third selected paper. UbiComp is just one of a group of inter-related areas of work that focus on how computing devices are embedded in the fabric of the built environment, with others including the topics of tangible technology, augmented reality and ambient media (O'Malley & Stanton Fraser, 2004). The TEL community has also been involved in attempting to leverage those other possibilities—for example, by investigating how the ambient display of information in classrooms might extend cognition and interaction (e.g., Bligh & Sharples, 2010; Börner, Kalz, & Specht, 2011). The distinctive feature of the constitutive view is to emphasise how efforts of that kind should be viewed not as merely influential *on* cognition but as quite literally building aspects *of* cognition itself.

(6) Space as "socially constitutive". The *socially constitutive* view of space departs from a focus on individual learners and instead suggests that *community* should be the focus of our attention. The view privileges relations between the spatial and the social (including the interpersonal, but with heavy emphasis on the communal and the societal), rather than the individual, and proceeds from the notion that social space is a social *product*. Communities, institutions and societies act in ways that serve to reproduce themselves and in doing so, according to this view, they produce spatial forms, or repertoires, that act on our consciousness.

Within the Learning Spaces community the work of Jos Boys (2011) illustrates one prominent example of a *socially constitutive* view: one that is directed towards examining Higher Education spaces. Boys draws on the work of the Marxist philosopher Henri Lefebvre and on the Communities of Practice literature to argue for the importance of understanding, for specific contexts and locations, three intersecting aspects of Learning Spaces. Those may be summarised as: (i) *individual engagement and adaptation*, or how people understand, are affected by, and use their environment, thereby transforming it through their use; (ii) *community spatial routines*, or everyday social and spatial practices that affect and are understood by others within the community; and (iii) *design provision*, or how repertoires of design ideas have come to be established and how processes of innovation occur. Importantly, spatial design theories are seen as influencing the relationships between learning and space, by virtue of the power they exert over space production and because of how the theories themselves reciprocally develop as new kinds of space are produced. Thus spatial theories, such as the different "views" discussed in this chapter as well as the vocabulary of architects, themselves form part of the dialectical relationship between space and learning activities within particular communities.

Boys' work explicitly downplays views of space that she considers "metaphorical", which would seem to include those concepts such as "place" that are prominent within *associative* views of space. Instead, Boys focusses on the relationships between the activities of educationalists, architects and estates planners, and studies how learners use ecologies of spaces to traverse communities of practice within Higher Education settings. Boys' book provides a number of examples of technology-enhanced spaces, but usually with a focus on appropriate provision of tools rather than on the design of novel technologies.

Reflecting on the Typology

The different "views" of space we highlight here should not be understood as arising in isolation. Yet neither are the boundaries between them sharply defined. For example, the *associative* view of space seems to both react against and build upon the *containing* view; the loci that contribute the construction of place, according to that view, bear some similarity to *containing* space. In other cases, the views' discourses attempt to occupy the same territory and seem starkly opposed. Harrison and Tatar (2008), for example, suggest that "production models" of space (e.g., our *socially constitutive* view) are obstacles for design processes, because they chiefly draw attention to societal structures that sit outside designers' sphere of influence. Boys (2011), on the other hand, suggests that place metaphors (our *associative* view) can serve to restrict critical thinking about Learning Spaces. In our account, we ordered those views such that the relationship between space and learning was recognised as increasingly dialectical. This ordering is represented visually in Fig. 7.1, whichalso summarises the object of inquiry and systemic contradictions

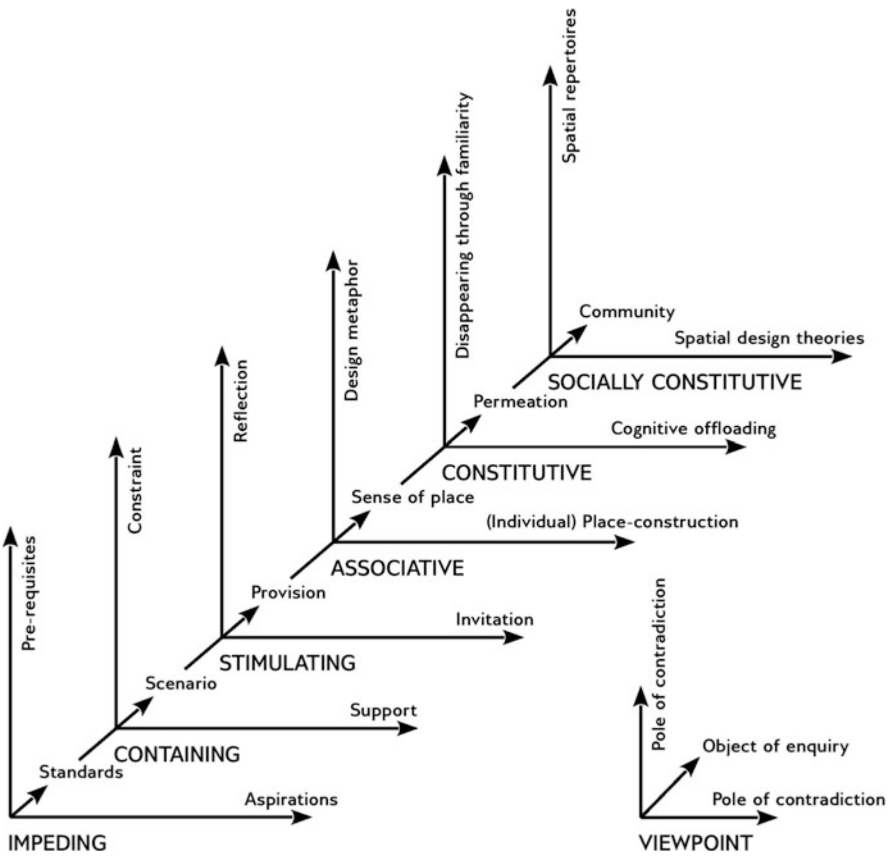

Fig. 7.1 An increasingly dialectical view of relationships between educational activities and space

described by each view. Our intention in doing so is *not* to produce another hierarchy wherein the issues posed at higher levels are only seen as relevant once accounts have been settled at lower ones. Instead, we wish to suggest that viewing space and learners as increasingly dialectically related means both accounting for increasingly complex mechanisms of mutual influence *and* re-problematising those that we might earlier have taken for granted. For example, the *containing* view is already imbued with a sense of particularity that requires a more situated vantage point than the *impeding* view, while also challenging the universal appropriateness of standards. The *socially constitutive* view, on the other hand, not only emphasises community and the use of theory—but also asks us to understand and challenge those productive processes that give control of standards and ownership of spaces to particular stakeholders, that act to define our place metaphors, and so on.

Nonetheless, the conceptual and disciplinary fragmentation of the Learning Spaces concept remains very real, and timely resolution of attendant debates is unlikely (and perhaps even undesirable). Thus, we hope that this relational mapping of different of views will prove useful to the TEL community, in lieu of providing a single, definitive model that cannot yet exist. We should emphasise, however, that those engaging in Learning Spaces work will not only need to contend with that dense tapestry of related yet competing theories; but also with a range of identifiable, more practical issues. We discuss some of those in the next section.

Significant Issues in Learning Spaces

Having mapped the different theoretical underpinnings used to connect space, learning and technology, in this section we briefly consider some significant, and interconnected, issues with which TEL researchers ought to engage.

"Types" of Learning Spaces

Whereas our typology, above, was theory-driven, here we wish to draw attention to how the literature categorises educational spaces themselves.

Learning Spaces research in compulsory education frequently engages with familiar school spaces. School classrooms provoke significant debate within the literature around issues such as colour, student ownership and relationships between seating areas and open "carpet space". There is a decades-long history of advocating *open plan* spaces, where several classes of learners are taught simultaneously (Woolner, 2010), though this concept has struggled to gain traction. At larger scales, the building and refurbishing of whole schools invites a focus on the potential of circulation routes and atria as spaces for informal learning.

Within Higher Education, the different architectural environments for learning have been categorised as group teaching/learning spaces, simulated environments, immersive environments, peer-to-peer and social learning spaces, and learning clusters (AMA Alexi Marmot Associates & haa design, 2006). Locational *integration* of different services (including formal teaching areas, social environments, library and technical support services) in "learning clusters" is seen as particularly important within HE.

Outdoor spaces are an issue for researchers in both sectors, who argue that their potential is under-realised. Institutional space "types" will continue to raise issues for Learning Spaces researchers for the foreseeable future; yet, as we have already argued above, the challenge for TEL researchers is to perceive the opportunities within those spaces rather than perceiving only fixed configurations that restrict innovation.

Formality, Informality and Flexibility

Often discussed within the literature, the meaning of these concepts requires further careful examination. Informal learning is increasingly recognised as a very valuable practice, and one common response in the Learning Spaces community is to create specifically "informal" environments—perhaps based on *associative* assumptions that learners, prompted by particular furnishings such as café furniture or beanbags, will construct their own informal sense of place. Yet others (e.g., Boys, 2011) call for critical examination of how such spaces actually work. Sutherland and Sutherland (2010), for example, suggest that spaces can be formal, semi-formal, semi-informal, and informal, drawing those more precise distinctions based on how the learning purpose and the centrality of teacher orchestration within the space are rendered explicit.

Jamieson et al. (2000) also emphasises the distinction between the degree of formality of space and that of learners' practices when he suggests that spaces should *flexibly* support different activities—either concurrently within the same session, or across different sessions where, for example, rooms might be used informally by students when not booked for formal teaching. More broadly, Goodyear (2008) suggests that providing flexibility for learners at macro, meso or micro-*time*scales can take quite different forms. We would extend that point to space as well as time. Potentially, micro-spatial flexibility might refer to easily moved furniture or configurable lighting; meso-spatial flexibility to how clusters of co-located spaces support activity transitions where students move between differently configured areas; and macro-spatial flexibility to how institutions provide a range of appropriate spaces to support different forms of learning, making those available to learners and teachers through appropriate booking and drop-in systems.

Institutionality, Interdisciplinarity and Participative Design

Research work on Learning Spaces will often need to become involved more closely with institutional procedures, visions and politics than is the case for much TEL research. Support from institutional leaders will often be important if space designs are to be realised, ongoing support provided, and cost potentially shared between research teams and institutional budgets. Furthermore, it is likely that spatial designs will need to be developed in highly interdisciplinary ways that involve, as a minimum, TEL researchers collaborating with those from backgrounds in educational research, disciplinary teaching practice, architecture, estates management, IT support, and senior management, as well as students themselves.

A range of methods have been suggested in the literature to support such collaboration through participatory design. For example, Woolner (2010) considers participative design processes that include learners, teachers, parents and others. She advocates activities such as the "diamond-ranking" of photographs and the creation of paper maps representing "school days" as mechanisms to allow different stakeholders to articulate their experiences. The diamond ranking activity, for example, involves people collaboratively placing photographs of school spaces on a whiteboard to indicate preferences in relation to emerging criteria, prior to labelling the diagram so as to highlight more particular experiences (p. 61). The aim is to enable different participants—including young children—to come to a comparative understanding of various physical environments without recourse to professionalised terminology. Analogous approaches to participative design have also been documented in the literature on post-compulsory education; for an overview see Bligh (2014).

Evaluation

Processes that evaluate space are also subject to institutional pressures that may be unfamiliar to those within the TEL community. That may explain the "paucity of clear, replicable empirical studies" of school-sector Learning Spaces (Woolner, 2010, p. 17). Based on work in the University sector, Bligh and Pearshouse (2011) discuss how space evaluation is an essentially political act: one subject to tensions between the empirical possibilities for investigating space and institutional and cultural constraints. Spaces might be assessed on whether they (a) are in demand, (b) change learning outcomes, (c) satisfy their occupants, (d) enable specific learning scenarios to be enacted, (e) support desirable spatial activities, (f) fit into a wider ecology of provision, or (g) enhance an institution's brand. Bligh & Pearshouse suggest, however, that too few examples of learning space evaluation observe actual activity occurring in space.

One example of relevant work that does do so, combining structured observation with on-the-spot interviews and focus groups to examine space use, is that of Crook and Mitchell (2012). Crook & Mitchell investigated students' activities within a University Library refurbished, along the lines of the Information Commons model, to include social spaces, a variety of collaborative technologies and a café. The ostensible aim of the refurbished space was to support intensive forms of collaboration, yet Crook and Mitchell observed students working productively in a variety of ways—including intensely collaborative problem solving, more intermittent exchanges, serendipitous encounters, and apparently solitary study. Importantly, students had specifically chosen to undertake their solitary work in the new space due to its "ambient sociality", notwithstanding that such activity was not congruent with the intentions of those who had commissioned the space. In general, learning space evaluations must avoid restricting their conclusions to fit institutional visions, yet they must not simply disregard the institutional context in an attempt to make their results appear more generalisable.

Accounting for Space in TEL

In our introduction, we suggested that studying Learning Spaces has an *underpinning* potential for the TEL field. Yet to realise such potential requires that theories and frameworks in other areas of TEL acknowledge spatial issues. Despite the fact that some theories in Education view space as *insignificant*, some work within TEL does acknowledge spatiality in ways that need to be celebrated and built upon. We focus here on four such examples.

In the arena of mobile learning, Vavoula and Sharples (2009) discuss how learners create *micro-sites for learning* out of the physical and social resources that have been made available around them. Physical settings for learning are suggested to vary in terms of their "vagueness", where classrooms are relatively conventional and static while the settings of personal mobile learning are less predictable.

Cook's (2010) concept of *Augmented Contexts for Development* also draws attention to the role of available physical resources for mobile learners. Cook focusses on design aspirations, suggesting that "designed contexts" can partly supplant the role of more knowledgeable people in a model that draws inspiration from Vygotsky's *Zone of Proximal Development* (ZPD).

Luckin (2010) also considers the role of the physical environment in a ZPD-inspired model. Luckin suggests that material space constitutes a *resource* within a learner's *Zone of Available Assistance*, from which their *Zone of Proximal Adjustment* is constructed in collaboration with more able partners.

Bielaczyc's (2006) *Social Infrastructure Framework*, on the other hand, adopts a collective, environmental vantage point rather than one focussing on a particular learner. One of Bielaczyc's four "dimensions" for successful social infrastructure is the *socio-techno-spatial relations dimension*, "the organization of physical space and cyberspace as they relate to the teacher and student interactions with technology-based tools" (p. 304). That difference of vantage point is important. Where focussing on mobile learning lends itself naturally to a focus on the personal narratives of individual learners, engaging with Learning Spaces requires a focus on supporting different learners with different needs, concurrently and over time, or learners who are at different stages within their processes of learning.

In our view, work within TEL also needs to focus on how technology might undermine spatial conventions to benefit learning. For example, Bligh and Sharples (2010) document the design of Multi-Display Learning Spaces, where innovative display technologies challenge established, front-facing classroom design repertoires. The display space is used to create enabling juxtapositions of visual materials that support students' verbal contributions to small group teaching scenarios. Furthermore, work in TEL needs to better account for space when scripting learning, or creating repositories of re-useable learning scenarios. For example, Pérez-Sanagustín, Hernández-Leo, Nieves, and Blat (2010) suggest a space model for representing Learning Spaces within the scripting language IMS-LD, based on top-level constructs such as space types, dimensional areas, and electronic and non-electronic components. We must take care, however, to ensure that how we account for space retains a focus on the profound contingency of what is important in-the-moment. In other words, we should avoid the temptation to become wedded to particular representational models of space in ways that disregard the context of activity.

Four Papers

The four papers highlighted in this section were chosen because they offer different contributions that build further on those discussions that we have introduced here.

Learning spaces in higher education: an under-researched topic by Temple (2008) is a discussion of how space affects learning based on a funded literature review project. Several themes emerge from that work. Temple underlines how *space management* privileges particular forms of learning and argues that place construction has institutional underpinnings—where spaces are a microcosm of how an institution sees its own mission and identity. The paper also highlights how spaces enable the formation of communities, and critiques common assumptions about relationships between form and function. Next, Temple problematises relevant design approaches and the role of technology. An attendant note of caution permeates the paper. While that perhaps originates from the disciplinary reach and review-based nature of the work, the lack of methodologically sound work that Temple highlights, together with the rarity of rigorous institutional evaluation (Bligh & Pearshouse, 2011), is a real obstacle to progress and an area where TEL researchers can usefully contribute.

Place and Space in the Design of New Learning Environments by Jamieson et al. (2000) is a general introduction to Learning Spaces for an audience of Higher Education researchers. The paper provides guiding principles for Learning Spaces development and concrete examples of projects that complement our own, more theoretically targeted introductory comments. Jamieson et al. adopt what we would term a broadly *associative* view of space, focussing on learners' sense of place and how designers might access those ideas. The paper successfully links the re-design of University campuses to emergent practices, including those of distance education. The authors court controversy by positioning teachers and academic researchers as forces of conservatism, while their occasional distinction of place as *electronic* space is now uncommon. The paper certainly poses more questions than answers—rather usefully for readers of the present book. One particularly timely question, at a time of rapid expansion in distance education, concerns those aspects of face-to-face interaction that are both essential and that cannot be rendered obsolete by distance education approaches.

Scriptable Classrooms by Kaplan and Dillenbourg (2010) explores how a range of UbiComp technologies can be used to support co-present learning activity. Desks with embedded LED displays, miniature projectors, embedded cameras, and distance and RFID sensors are used to support the scripted collaboration of learners. The aim is to support dynamic group formation, learners switching roles within groups, transitions between different activities (of individual, group or whole-class composition) and an aspiration of *bidirectionality*, in which information is both presented to and gathered from learners by the classroom systems. The paper foregrounds how roomware technologies can be used to support two prominent concerns within the TEL field: scripted collaboration, where learners' interactions are pedagogically guided by a set of instructions, and classroom orchestration, in which teachers' roles in managing and supporting activities happening around the space are recognised as crucial. The authors usefully draw together how such a varied set of technologies can form part of a classroom ecology. One unanswered question, particularly from what we have called the *socially constitutive* vantage point, concerns how such a complex synthesis of technology can become better embedded within practice—widely and longitudinally, culturally and institutionally—so that it can be appropriately supported and reproduced beyond its original research setting.

The NiCE Discussion Room by Haller et al. (2010) documents a design-based project with a twin-track focus on creating a collaborative space and designing particular technologies in a spatially-aware way. The NiCE Discussion Room contains attractive furniture along with tools designed to support large-scale digital sketching, the incorporation of paper, the streaming of content from laptops, environmental control through tangible devices, and communication and orchestration facilities. Haller et al. raise many important issues regarding the design of "roomware" to support co-located collaboration. Those include how people occupy and move through space when using a range of technologies, supporting concurrent task diversity, creating and sharing different forms of content, and connecting activities happening within the space to the outside world via users' own devices. Haller et al. document how their own design responds to those issues. From the perspective of studying learning, rather than HCI, we would have preferred to see an evaluation involving authentic users undertaking culturally embedded tasks rather than groups undertaking closely-bounded design problems. Nonetheless, Haller et al. usefully document how their users struggled to integrate their work after finishing breakout sessions, indicating that further design work (and accounting for the conventions of practice) is still required. Other work presenting novel designs for technology or space exists in the literature (e.g., Bligh & Sharples, 2010; Kaplan & Dillenbourg, 2010; Wilson & Randall, 2012). Despite the fact that Haller et al.'s paper focusses more explicitly upon collaboration than learning, this paper is noteworthy because it involves designing a novel Learning Space and novel technology together.

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Chapter 8
Mobile Learning

Mike Sharples and Daniel Spikol

The Evolution of Research in Mobile Learning

Mobile learning has emerged as a field of research and development over the past decade. What differentiates it from other forms of technology-enhanced learning is a focus on mobility of the learner supported by a variety of personal and handheld technologies. By putting mobility as an object of analysis we may come to understand how interactions between people equipped with personal handheld devices such as smartphones and tablets can support flexible learning.

People move among locations, times, objects and social interactions. Even within a fixed setting such as a school, children move between classrooms, teachers, equipment, topics, and from individual to group working. Research into mobile learning can inform the design of software for smartphones and tablets, to help learners connect knowledge across settings such as school and home, and support a lifetime of learning in an increasingly mobile world.

The four selected papers illustrate the diversity and evolution of the field, from a focus on software for mobile devices, to embedding learning into everyday locations and the continuity of learning across locations. Early research into *wirelessly connected classrooms* with one device per child (Roschelle & Pea, 2002) led to exploration of new forms of classroom learning, with mobility between individual, group and whole class activity, supported by a combination of teacher and personal devices such as netbooks and tablet computers. A separate strand of research on

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mobile learning outside the classroom—in museums, galleries, workplaces and campuses—has examined how learning can be maintained across settings, such as between workplace and home, and how contexts for learning are continually created through interactions between learners, technologies, locations and social environments (Sharples, Taylor, & Vavoula, 2007). The technical challenges of providing 'anytime anywhere' access to learning materials have evolved into a consideration of *ubiquitous learning*, where learning comes from engagement with interactive and information-giving objects embedded in the environment (Ogata & Yano, 2004). These perspectives of mobility of activity in the classroom, mobility across locations, and ubiquitous learning, can be compatible. Recent work has explored how the notions of the mobility and ubiquity can be combined through the concept of *seamless learning*, where portable technologies support a continuity of learning across formal and informal settings including classrooms, non-formal learning environments such as museums, homes, and outdoors (Wong & Looi, 2011).

Handheld Devices in Classrooms

The first selected paper by Roschelle and Pea (2002) identifies an opportunity for wirelessly connected handheld computers (which they describe as Wireless Internet Learning Devices, or WILD) to enable new forms of learning through collaboration in the classroom. In their vision of the future classroom, students work towards shared understanding in groups, building joint representations of their knowledge through interacting with computer simulations, manipulable models of mathematics and science, and interactive diagrams. By connecting their devices to form a shared learning space, students can move easily from working individually on a problem to contributing towards a group solution, or they can explore their understanding by running a group simulation or collaborative learning game.

An example of this collaborative classroom in action is the Virus simulation game by Colella and colleagues at MIT Media Laboratory (Colella, 2000). They developed "participatory simulations" in classrooms using small custom wearable computers called "Thinking Tags". The aim was to give each child a personal experience of being a participant in a simulation of a dynamic system. Their best-known example was the Virus Game, where each child wore an electronic tag that that engaged them in the simulation of an epidemic. Though every tag appears the same, one of them starts the spread of a disease by simulating a virus. This spreads electronically from person to person as the children move closer to each other within the class. The tags then start to indicate symptoms, until over time the tags show that all the children are infected. The initiation, rate of spread and time till the symptoms appear can all be controlled so that the game can be repeated to explore aspects of viral behaviour. According to Colella (2000), the combination of people and tags form a digital ecology, where the devices run the simulation and the children can move around, interacting freely with each other, sending automatic messages between tags, exploring the consequences as the system unfolds.

This notion of a classroom ecology of learners and handheld technologies has been investigated by Nussbaum and colleagues in a series of studies of Mobile Computer Supported Collaborative Learning (Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010; Zurita & Nussbaum, 2004). The approach is to explore how two networks can be combined to enable productive learning: the social network of children working together around a classroom table, and the technological network of their interconnected handheld computers which coordinates and supports the collaborative learning activity. Their studies have shown that students equipped with communicating handheld devices, running software to coordinate their learning activities, can learn effectively by solving a problem individually, then coming to agreement in a group, and then presenting their result to the teacher or class. The teacher also has software running on a handheld device that shows a "dashboard" of how each child and group is performing.

Learning Within and Across Contexts

A broad contribution of mobile learning research has been to probe some tacit assumptions of traditional education. One of these assumptions is that the physical context of learning is fixed and unproblematic, i.e. that children learn at desks in school classrooms or labs, supported by a teacher. We have come to understand that learning could occur anywhere, with or without the assistance of a teacher. Much of this everyday learning is not new: a discussion in the corridor, a chat at a party, a chance meeting in the street. But increasingly, these informal encounters are mediated by technology that offers both a source of information and an extension of the physical discussions into virtual spaces through social media and remote conferencing. For these to support learning, the opportunity of the moment needs to be captured, related to previous knowledge, and made available for recall at a later time and place. Mobile devices can assist by recording these encounters through sound and image, and also by preserving the context of learning, for example using the sensors on mobile phones to capture the time, location and possibly other data such as weather or movement.

Central to this theory of informal mobile learning is an examination of the continuity of learning within and across contexts. Within a classroom, the context is familiar and largely under the control of the school and teacher, providing standardized resources and facilities. Beyond the classroom the familiar context is removed, so learners (and where appropriate a teacher or mentor) may have to establish "micro sites" for learning (Vavoula & Sharples, 2009) in the form of ad hoc learning spaces, such as a patch of grass on a field trip, instrumented with appropriate technologies and resources. Learning not only occurs in a context, it also creates context through the continual interaction between learners, their technologies, resources (e.g. teachers, learning materials, experts), and locations, to achieve mutual understanding and shared goals (Boyle & Ravenscroft, 2012). For example, a group of people are standing in front of a painting in a gallery, discussing the artwork. They are creating a micro-site for learning through their situated discussion, bringing to the conversation their differing knowledge of art and their journeys to reach the painting. Thus, the common ground of learning is continually shifting as we move from one location to another, gain new resources, or enter new conversations. A challenge for mobile learning is to design mobile assistants that will enhance these context-dependent encounters without dominating or replacing the conversation as happens with the current generation of museum audio guides.

Architectures for Mobile Learning

From 2002, the European Commission funded a series of major research projects to explore mobile learning beyond the classroom. These projects, that included MOBIlearn[1] and M-Learning,[2] developed and evaluated technologies for learning in settings that included museums, university campuses, workplaces and the home. MOBIlearn was an ambitious project, involving 24 partners from academia and industry, to develop, implement, and evaluate a computer systems architecture for mobile learning, based on theories of informal and context-dependent learning (Da Bormida, Bo, Lefrere, & Taylor, 2003). The Open Mobile Access Abstract Framework (OMAF) was a general architecture for mobile learning services such as user registration and messaging, management of content, and specific tools for mobile interaction and context awareness. The services could be distributed across the web and were accessed through a portal that adapted to mobile devices including mobile phones, PDAs and tablet computers. The MOBIlearn system was implemented and tested with three scenarios in a museum, workplace and campus setting.

For the museum setting, the MOBIlearn project developed a context-based museum and gallery guide (Lonsdale, Baber & Sharples, 2004), using ultrasonic location sensing accurate to within 10 cm indoors. The information it offered depended on the user's location, path, interests and time at the location. As the visitor walked past a painting, the guide mentioned its title and artist. If the user stopped for a few seconds at a painting, the guide offered a short description. After a longer wait, the guide indicated interesting features of the painting—a feature intended to prompt discussion among groups of visitors.

Other European projects developed support for vocational education and training using mobile phones to deliver learning content. From all these projects came an extended conception of mobile learning as "Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies" (O'Malley et al., 2003).

[1] http://cordis.europa.eu/pub/ist/docs/ka3/mobilearn.pdf.

[2] http://cordis.europa.eu/project/rcn/58411_en.html.

Learning in a Mobile World

The second selected paper, by Sharples et al. (2007), is the culmination of a study within the MOBIlearn project to understand learning in a world of technology-enhanced mobility. It draws on theories of learning as conversation (Pask, 1976), learning through context (Westera, 2011), and learning as a cultural historical practice (Engeström, 1996), to propose a framework for understanding mobile learning as a tool-mediated process of coming to know across continually changing contexts.

The paper distinguishes what is special about mobile learning compared to other types of learning activity, suggesting that a theory of mobile learning must be tested against the following criteria:

– Is it significantly different from current theories of classroom, workplace or lifelong learning?
– Does it account for the mobility of learners?
– Does it cover both formal and informal learning?
– Does it theorise learning as a constructive and social process?
– Does it analyse learning as a personal and situated activity mediated by technology?

From these general criteria, the paper proposes a definition of mobile learning as: “the processes of coming to know through conversations across multiple contexts amongst people and personal interactive technologies”. This emphasised the processes of learning in a mobile world, as opposed to gaining knowledge from handheld devices. As the paper indicated: “The focus of our investigation is not the learner, nor their technology, but the communicative interaction between these to advance knowing” (Sharples et al., 2007, p. 225). The paper describes a dynamic process of learning through conversation that overlays the technological mediation of communication channels, devices and human-computer interactions, with the semiotic mediation of social rules, communities and conversations. This conception of mobile learning as conversations across contexts undermines the solid ground of education as the transmission of a fixed curriculum within known constraints. Learning in a mobile world involves continual communication with and through technologies, merging real and virtual spaces, extending education outside classrooms to the conversations and interactions of everyday life.

Ubiquitous Learning

Ogata and Yano (2004) further developed the concept of context-based learning to propose a ubiquitous technology-enabled environment where support for learning is embedded into sensor-augmented “smart objects” such as furniture and utensils. The new technology extends traditional location-based learning, for example on field trips or in museums, by enabling personalised interaction with “semantic objects” such as household items that describe themselves in a foreign language, or buildings that can explain their energy usage. The third selected paper, by Ogata and Yano (2004) describes a context-aware language-learning support system called JAPELAS (Japanese Polite Expressions Learning Assisting System) which enables students of Japanese to understand appropriate polite expressions in context, based on the context of the word and the level of formality of the setting. Another prototype system, named TANGO, uses RFID tags attached to objects in a room to enable the learning of vocabulary in context.

Seamless Learning

Building on previous research into classroom, contextual and ubiquitous mobile learning, a global research collaboration produced a jointly-authored paper (Chan et al., 2006) that sets out a manifesto for research into learning for a world where every person has a networked personal computing device. Predicting that over the next 10 years personal, portable, wirelessly-networked technologies would become ubiquitous and pervasive in the lives of learners, the paper asks "how will classroom life and everyday life be connected?". It proposes a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different environments which it terms "seamless learning." Seamless learning implies that students can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly, using personal devices and embedded learning technology to store, share and recall contextualised knowledge. The research aims to lessen limitations of human learning, such as the difficulties of transferring learned knowledge from one setting to another and recalling a previous learning episode at a different time and place. A personal seamless learning device can provide knowledge augmentation, for example by capturing direct information and peripheral context on a field trip or visit then allowing the learner to re-visit that learning context at a later time, to reflect on the experience, extract new understanding, compare knowledge with other visitors, and abstract shared memories. Or it can support inquiry learning where the student develops an inquiry science question in class, supported by a teacher, then continues the inquiry at home or outdoors with the personal computer acting as a scientific toolkit and guide, then concludes back in the classroom by sharing and presenting findings (Anastopoulou et al., 2012).

Wong and Looi (2011), in the fourth selected paper, offer a survey of research into Mobile Seamless Learning (MSL), identifying ten salient features that emphasise technology (access and multiple device types), pedagogy (multiple learning tasks and models) and the learner (spanning formal/informal, personalised/social, physical/digital learning across time and space):

(MSL 1): Encompassing formal and informal learning.
(MSL 2): Encompassing personalized and social learning.
(MSL 3): Across time.
(MSL 4): Across locations.

(MSL 5): Ubiquitous access to learning resources.
(MSL 6): Encompassing physical and digital worlds.
(MSL 7): Combined use of multiple technology device types.
(MSL 8): Seamless switching between multiple learning tasks.
(MSL 9): Knowledge synthesis (prior knowledge, new knowledge, multidisciplinary learning).
(MSL 10): Encompassing multiple pedagogical or learning activity models (facilitated by teachers).

From an analysis of 54 relevant research papers they conclude that investigations into the continuity of learning across time, location, and setting have been well-addressed, as have ubiquitous access to knowledge, bridging formal and informal learning, and connecting physical and digital worlds. Studies of short-term learning on field trips emphasise continuity of learning across locations and the seamless switching between learning tasks, whereas research into longer-term learning emphasises ubiquitous access to knowledge and synthesis of prior and new knowledge, and support for multiple levels of thinking skills.

A consequence of seamless learning is that people can be empowered and supported to learn wherever and whenever the need arises, not just by delivering content on demand, but by equipping a learner to make sense of context and learn according to need. This raises deep ethical issues such as the limits of schools, universities and employers to intrude into everyday life by providing continuous teaching and training on personal mobile devices, or to monitor students' everyday activities such as web browsing and social networking for evidence of informal learning (Traxler & Bridges, 2004). Therefore, areas for future research include understanding how learning can be appropriately supported outside the classroom, maintained across major life transitions (such as the transition from school to college, or college to workplace) and continued over long periods of time. A vision for the future is to support people in a lifetime of learning: to capture and recall personally meaningful events, explore the natural world, engage with others in inquiry-led projects, and learn by creating and sharing works of art, literature and science. Some of these activities will be part of formal education, in which case they may need to be supported with curriculum materials and presented for assessment. Others will belong to personal learning projects or be a part of everyday informal learning, so they may need to be organised and blended into family and social life. The challenge for research is to bring our understandings of experiential and lifelong learning, human memory and recall, learning through inquiry and conversation, and physical and social contexts, to the design of a new generation of technologies that promote long-term seamless learning.

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Chapter 9
Virtual Worlds for Learning

Maggi Savin-Baden, Liz Falconer, Katherine Wimpenny, and Michael Callaghan

Introduction

This chapter reviews some of the most compelling evidence regarding learning and teaching in virtual worlds. For the purposes of this review, virtual worlds are considered to be online, multi-user, immersive 3D environments in which users can interact with their surroundings and other users. Interaction with other users is normally through text and/or voice communication channels, and the new generation of virtual worlds is beginning to develop methods of shared physical interaction. Typical examples of the first iterations of virtual worlds include Second Life, Active Worlds and Kaneva, which have been available for up to 20 years. The second generation is currently being developed, examples being High Fidelity and Project Sansar. This chapter examines four papers that we deemedto have been

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influential in the use of virtual worlds for learning, however, we also draw on a range of other research and literature in order to locate virtual world learning in the broader landscape of higher education.

Understanding Virtual Worlds and the State of the Art

There is wide variation in the terminology used to describe virtual worlds and terms are invariably used interchangeably The rationale for using learning in virtual worlds to enhance teaching and learning in higher education suggested here, is because practicing skills within a virtual environment offers advantages that complement learning through real-life practice: in particular the exposure of learners to a wide range of scenarios (more than they are likely to meet in a standard face-to-face programme) at a time and pace convenient to the learner. It has been widely acknowledged that virtual worlds do present educational potential in terms of role-playing, building and scripting items and fostering dialogic learning and social interaction (Savin-Baden, 2008, 2010). Virtual worlds can offer learners the opportunity to make mistakes without real-world repercussions, and to experience situations that may be ethically or practically difficult, or indeed dangerous, to experience before they qualify; for example, carrying out a realistic accident investigation that includes interviewing real-time witnesses (Falconer, 2013). Students can also experience immediate feedback that results from their actions, both from the reactions of other users and changes to the virtual environment; for example, a group task for paramedics attending the scene of an explosion could require the group to change their activities during the exercise, depending on feedback from the casualties and the increasing risk of a secondary explosion. In the past, techniques of adaptation and personalization have been considered in the context of virtual reality in general. The earlier techniques mainly focussed on adaptive navigation support and adaptive presentation. For instance, Brusilovsky (2001) has integrated some classical adaptive hypermedia methods into 3D virtual worlds to support different navigations for different users.

More recently there have been examples of virtual world simulations of real-world activities being incorporated into vocational education programmes at undergraduate and postgraduate level (see, for example, Duncan, Miller, & Shangyi, 2012; Gil Ortega & Falconer, 2015). Further, recent research on virtual reality and simulations would seem to suggest that transfer is more likely from virtual situations to real life situations, than early work on transfer across different real world settings had previously implied. For example, the level of motivation to learning that immersion provides is also important. Dede (1995) argues that the capacity to shape and interact with the environment is highly motivating and sharply focuses attention, and Warburton (2009) has suggested that the immersive nature of the virtual world can provide a compelling educational experience, particularly in relation to simulation and role-playing activities. Herrington, Oliver, and Reeves (2003) refer to the authenticity of the virtual settings and argue they have the capability to motivate and encourage learner participation by facilitating learners' willing suspension of disbelief. Further, recent studies into virtual world learning suggest that sound pedagogical decisions and careful consideration about the reasons for using virtual worlds are needed, to ensure that the technology can be transformative in its application rather than merely being used as a replacement way of doing something tutors typically do (Wimpenny, Savin-Baden, Mawer, Steils, and Tombs (2012); Hughes, 2005; Mount, Chambers, Weaver, & Priestnall, 2009). Indeed, as Dalgarno and Lee (2010) contend, ongoing development of, and investment in, 3D virtual worlds for learning should be contingent on understanding how such environments provide advantages over other pedagogical techniques, including those offered by their non-3D counterparts.

Central Themes in Virtual Worlds Literature

Despite many cogent arguments and the varied possibilities for their use, there has been relatively little situated pedagogical rationale for the use of virtual worlds in higher education. Mayes and de Freitas have argued that "for good pedagogical design, there is simply no escaping the need to adopt a learning theory" (2004, p. 6), and this is particularly so in virtual worlds. Duncan et al. (2012) observe that there are "... rich veins of current research and practice in associated educational theory and in simulated worlds or environments, ... (but a)... paucity of work in important areas such as evaluation, grading and accessibility." Others suggest the need for strong pedagogical scaffolding in order to support effective learning (Salmon, 2009), although it is not entirely clear why this is more the case in virtual worlds than other environments. Furthermore, there has been a notable reluctance either to situate or theorise learning in virtual worlds when turning to learning theories, such as supercomplexity (Barnett, 2000), threshold concepts (Meyer & Land, 2006) or the conversational framework (Laurillard, 2002), although the latter is seen as largely too structured for use in virtual worlds. Additional themes in the literature include the integration of VWs with other learning technologies such as virtual learning environments (Livingstone, Kemp, Edgar, Surridge, & Bloomfield, 2009). There are also an increasing number of virtual-world-specific software developments such Trainingscapes™ and Datascapes™ (Daden, 2016). These are web-delivered, immersive learning and data visualisation applications that enable a significant degree of customisation for specific learning needs. From a review of literature examining the educational uses of virtual worlds in higher education we suggest central themes that emerge are located around:

- Socialisation
- Presence and immersion in virtual world learning
- Learning collaboratively
- Trajectories of participation

In the following section, examples from four papers are used to explore each theme and consider pedagogical issues about the use of virtual worlds for teaching and learning.

Socialisation

The social aspects of virtual worlds have been the subject of considerable research over the past 10–15 years. Researchers have become increasingly interested in the similarities and differences between socializing in the real world and in virtual worlds. For example, a frequently cited paper by Yee, Bailenson, Urabnek, Chang, and Merget (2007), the first of our selected papers, discusses the findings of a case study that explored whether the norms of social gender, interpersonal distance and eye contact transferred into virtual world environments. They found significant similarities, such as the interpersonal distance of male–male avatars was greater than that for male–female avatars and that male–male avatars maintained less eye contact than female–female avatars. In a more recent paper, Mennecke, Triplett, Hassall, Conde, and Heer (2011) undertook a study to examine three issues that relate to collaborative interaction and task completion in virtual worlds, viz. embodiment, context and spatial proximity. They synthesised these issues with notions of presence and co-presence and continued to develop the theory of Embodied Social Presence (ESP), first proposed in an earlier paper (Mennecke, Triplett, Hassall, & Jordan-Conde, 2010). The 2011 paper discusses the findings of a case study with students on a postgraduate e-commerce course. The researchers found that 68% of the students achieved ESP at some point during the exercise, expressing this through visual, emotional and non-verbal behaviours when engaging in a shared activity. They found that when ESP is achieved, collaborators are more engaged in the conversation and the team's shared activities. They, therefore, argue that ESP theory can inform the design of learning experiences in virtual worlds.

Jarmon, Traphagan, and Mayrath (2009) undertook a single case study and suggested that the highly interactive nature of virtual worlds, with particular reference to Second Life, provides rich opportunities to accommodate project-based experiential learning. The study by Jarmon and colleagues focused on students' skill-levels in communicating and interacting effectively with diverse audiences of differing worldviews across different disciplines. A semester-long team project was used to develop students' abilities to engage in cross disciplinary team working practices, for example through practising greater flexibility of outlook, and using communication strategies to enhance their ability to work and learn across disciplines more effectively. Second Life was viewed as providing an opportunity to apply and test communication strategies beyond the scope of the physical classroom. Students were required to take field trips in Second Life, interact extensively with other educational communities (for example over 200 universities and colleges as well as libraries and museums) and engage with other non-academic communities in Second Life (2009, p. 171).

The key themes emerging from the study, albeit from data from one graduate course and five graduate students, revealed the local and global learning opportunities offered by the programme, with students describing Second Life as providing an important space and context-rich setting within which to practice communication skills. Far from being limited to classroom discussion, the students were able to work with a context that provided an opportunity to be actively inventive and imaginative, pushing learning boundaries, including what it meant to learn. Students described learning in Second Life as: "safe, playful … increasing one's own creativity" (2009, p. 174). The playfulness and dynamic nature of learning offered through using the virtual world were highlighted in enabling real life application of the theories and strategies used within the course. Despite frequent technological difficulties and students' initial apprehension of using Second Life for collaborative learning, it was apparent that learning in the virtual world enabled students to apply, question and revise their understanding of learned theories of communication through active experimentation. In addition, the rich 3-D environment was seen to create an enhanced sense of embodiment and social presence supporting the experiential learning cycle. What was viewed as being of value was a project which enabled students to apply their learning from a project-based graduate course on interdisciplinary communication into real life practices, through work which offered tangible outcomes resulting in students creating a real life product through collaboration in a virtual world. Two virtual model homes were created in Second Life, one of which was actually reported as being built in a low-income neighbourhood. Model homes had a persistent presence in Second Life which enabled people from around the world opportunity to walk (or fly) through the "Alley Flats", Jarmon et al. (2009, p. 173). The interdisciplinary learning opportunity was also deemed by students to be highly valued, resulting in enhanced understanding and skill development when working with others from a range of disciplines.

Presence and Immersion in Virtual World Learning

Themes relating to presence and immersion in virtual world learning are similarly captured in Bayne's (2008) study, the second selected paper. Drawing on Barnett's (2007) "pedagogy of uncertainty", Bayne examines the theory of "the uncanny" in relation to the uncertainty students experience when learning in virtual worlds. Adopting a virtual ethnography (a research methodology developed by Hine, 2000 to examine the ethnography *of, in* and *through* the virtual), Bayne uses data gathered from mature postgraduates, considered as relative newcomers to virtual worlds. Drawing on both Royle's (2003) account of the uncanny and Freud's (1919) essay on the theme, Bayne suggests that there are connections between the uncanny and intellectual uncertainty, through students' depictions of their learner experiences, suggesting that learning in virtual worlds can prompt ontological shifts about the self and world view and what it means to learn through engagement with troublesomeness (Perkins, 2006; Meyer & Land, 2005a, 2005b). What she seems to mean here is that Second Life prompts the blurring of boundaries between what is real and what is fantasy, and can be compared to students coming to terms with how intellectual uncertainty is integral to being a student in higher education. Indeed, Bayne suggests that Second Life and other virtual worlds may provide a space where a positive "pedagogy of uncertainty" (Barnett, 2007, p. 137) may be explored. The role of an avatar and its interaction with the "real person" is also discussed. Students can experience varying levels of immersion through their avatar and the impact that language, silence and space can have on users interacting in virtual spaces. Bayne goes on to suggest that the uncertainty of interacting with others in virtual worlds creates opportunities to explore identity, including its disorientating effects. However, whilst some students may find the experience exhilarating, for others it can be "deeply disturbing". Bayne goes on to acknowledge the intellectual uncertainty "in which reality and imagination become inseparable" (2008, p. 202). She suggests:

> The ontological uncertainty foregrounded in the student accounts given here perhaps simply indicates that Second Life and other virtual worlds materialise this uncertainty in new ways—they defamiliarise our sense of selfhood and our mode of being together within the pedagogical context, and in doing so ask us to reflect on it afresh as teachers and learners. (Bayne, 2008, p. 203)

Bayne concludes by suggesting that for certain students, in certain contexts, (she does not state who or where) learning in virtual worlds can provide rich understandings of being in a digital age, with all the openness, unpredictability and daring that digital ways of being can invite.

Learning Collaboratively

Active Worlds, a visually rich, user-extensible 3-D virtual environment, is the focus of Dickey's (2005) study, our third selected paper. Two case studies are presented which use Active Worlds to foster collaborative learning amongst spatially distant learners. Themes drawn from this study focus on the resources for distance learners, which were designed through the use of an intuitive user interface, with roads and paths providing navigational routes through course content. Although student narratives are not presented, nor was it possible to track individuals' specific actions, due to the anonymity offered as students tried out the various Active World tools, what Dickey reports is that *most* students were seemingly impressed by the environment and the sense of learner embodiment experienced. Furthermore, attrition rates on the course dropped significantly. It would appear this was partly due to the real-time communication and visual environment offered. Active Worlds enabled a group of distant learners to try out new roles, share multiple perspectives and engage in activities which would not otherwise be possible. Student anonymity necessitated trust and accountability for and with one another. In addition, the virtual world provided both the academics and students the availability to construct their learning environment, using materials, models and tools in creative ways, providing "multiple means of representation and interaction" (Dickey, 2005, p. 449).

In the second case study, Active Worlds provides a synchronous in-world learning environment for a 3D object modelling course. Using text chat, the tutor was able to present concepts illustrated by sharing sample 3D objects of her own creation. Through their avatars, the students were able to locate themselves in specific positions to appreciate the design objects. Drawing on the use of authentic contexts and situated learning (Brown, Collins, & Duguid, 1996), access to expert modelling (Brown et al., 1996), the benefits of mentoring (McLellan, 1996), and the sharing of perspectives (Brown et al., 1996), Dickey highlights how the students were offered a rich learning environment in order to problem-solve and develop skills for their discipline from a first person perspective. Similar to the study by Jarmon et al. (2009), the virtual environment provided an opportunity for collaborative and cooperative learning and was seen to be valued by the way in which students engaged with the course. Such findings have implications for the design and increasing use of approaches such as problem-based learning in virtual worlds, which are used in a range of disciplines such as palliative care nursing and engineering (Miles, Savin-Baden, Tombs, & Milecka, 2012; Savin-Baden, Tombs, & Tombs, 2011).

Trajectories of Participation

Themes relating to virtual world learning in the final selected paper explore how people learn from play (Oliver & Carr, 2009). Whilst the paper from Jarmon et al. (2009) considered earlier extols the benefits of play in terms of enlivening learning contexts, Oliver and Carr question the notion of play through exploring the use of games and learning, especially with regard to how trajectories of participation can be used to inform pedagogy. This study explores the experiences of couples that play World of Warcraft (WoW) together. The findings reveal the potential problems students may face which need to be considered when designing ways to use virtual worlds for formal education, especially when related to how people learn through play and the use of games specifically designed as curriculum resources. The key themes of participation and trajectories of participation emerged from the data. These were analysed in light of Wenger's (1998) communities of practice and include a focus on participation and trajectories of participation. In examining such trajectories, Oliver and Carr developed analogies relating to the varying degrees of participation the couples demonstrated which led to them withdrawing or remaining committed to the WoW game. In particular, overcoming material and social tensions were significant: for example, negotiating out-of-game as well as in-game social patterns, managing other routine daily commitments, making and maintaining friendships with other players, turn taking between partners or the tension created in increasingly challenging and risky role playing aspects of the game or when one partner stopped playing while the other continued. Those couples who persisted were able to negotiate and overcome material and social tensions, whereas those who struggled with work, family and study commitments did not. When considered in relation to students in formal education, the use of games in education was deemed problematic if students are not supported to reflect on their relevance. More recently, as highlighted by Olasina (Olasina, 2014, 2016), learner experiences may be enhanced when examination of cultures and intercultural relations in the contexts of gaming are recognized, enabling the potential for diverse cultural backgrounds and means of expression. In addition, students' sense of identity along with that of their peers and tutors, is also of note when considering the social commitments demanded of certain games. Further, the social and material tensions related to learning reveal the challenge of managing competing demands, which has been seen in the research into learning games such as the Quest Atlantis Project (Barab et al., 2007) and the River City MUVE (Galas & Ketelhut, 2006).

Discussion

There is sometimes a misconception that research into situated and experiential learning in virtual worlds is very new. The field actually began to develop in the late 1990s (see, for example, Bares, Zettlemoyer, and Lester (1998) and has continued since then. However, in addition to a lack of clear educational policy, there remains a wide range of issues surrounding the use of virtual worlds for education. It is also important to put learning in virtual worlds in the context of their developing use generally. Statistics on VW usage worldwide suggest that there are now more than 2.6 billion VW user accounts, with the majority of those accounts being held by children between the ages of 10–15. The number of registered accounts in VWs used by adults, such as Second Life, doubled between 2011 and 2015, and (KZero, 2016) whilst it is true that the majority of users are not experiencing VWs for the purposes of education, but rather for social and entertainment purposes, it is also true that, as a form of communication and interaction, they are proving increasingly popular and are being widely used. This does not mean that they can or should be automatically adopted for educational purposes, but it does mean that future students will be increasingly familiar with this form of technology. Virtual world learning seems to offer opportunities to move away from scaffolding learning in higher education, since immersive learning spaces such as Second Life (SL) are universal, not bounded by time or geography, and in particular adopt different learning values from other learning spaces. In terms of future directions, one of the main changes in technology has been the ability to integrate virtual worlds and virtual learning environments. The ability to access full 3D environments through a standard web browser has become a reality. The emergence of HTML5/WebGL[1]

[1] https://www.khronos.org/webgl/.

allows highly functional, full 3D worlds to be created in games engines (e.g. Unity[2] and the Unreal engine[3]) and displayed in a browser. These developments will have a major impact on eLearning by facilitating frictionless access to 3D environments. The virtual world can be rendered inside the browser/virtual learning environment without any additional configuration or setup overhead and this eliminates issues related to firewalls, client installation, plug-ins and updates and the need for two clients, namely virtual world client and web browser access.

Conclusion

Computers change not only what we do, but how we think about ourselves and the world. Such suggestions would seem to be exemplified in perspectives on and studies into virtual reality and immersion, and certainly Žižek (1999), in his deconstruction of the film *The Matrix*, suggests the possibility that the deletion of our digital identities could turn us into "non-persons"—but perhaps a more accurate idea would be one of becoming changelings, rather than deletions. However, what strikes us most of all is that whatever we have use of that can be adapted or adopted for higher education should be harnessed to improve student learning. For some, possibly many, virtual learning is now a norm, for others, it is something to ignore or abandon at all costs. Yet higher education is on the move, and virtual learning is something we need to take with us into this unknown future, whilst recognising that living at the interstices of learning and technology are important places to stand.

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[2] http://unity3d.com.

[3] https://www.unrealengine.com/what-is-unreal-engine-4.

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Chapter 10
Adaptive Intelligent Learning Environments

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Introduction

Adaptive Intelligent Learning Environments (AILE) are computer systems that help people to learn in a personalized manner. They build a model of the learner and use this model for selecting, scheduling or recommending relevant learning material, and for keeping the learner motivated and engaged. AILE has been an active research area since the 1970s, and is considered a major enabling technology for self-directed, collaborative and informal learning.

SCHOLAR (Carbonell, 1970) was one of the first intelligent teaching programs, which taught South American geography by engaging in a dialogue with the learner. The system remembered the concepts that had already been covered and tried to progress adaptively and gradually through the curriculum. SCHOLAR is considered the first ITS. Since then, the field has progressed significantly, embracing a range of intelligent techniques and covering a huge variety of domains and learning contexts.

Intelligent Tutoring Systems (ITS) and Adaptive Educational Hypermedia (AEH) are the two most significant types of learning systems that have evolved into the broader class of AILE. The ITS community focuses on the use of artificial intelligent techniques in tutoring applications. Initially, these applications were

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stand-alone, desktop applications, but nowadays most ITS systems are web-based. The AEH community emerged as a sub-area of the adaptive hypermedia community, which focuses on user modelling and personalization of web-based systems. Nowadays, both research streams have a significant overlap in the platforms, learning contexts and adaptation mechanisms that they develop.

This chapter will briefly outline ITSs and AEH systems, followed by a short description of the main concepts and technologies that they share. Further, we provide an overview of past and current trends and topics in the field, as identified in recent review articles.

ITS: Intelligent Tutoring Systems

ITSs are computer applications that support highly interactive, personalized, tutor-like instruction. The goal of an ITS is to simulate an individual tutor who closely follows students' progress, understands their current strengths and difficulties, and provides timely feedback in the form of hints and explanations.

In order to do so, ITSs rely on a range of technologies from the fields of Artificial Intelligence and Cognitive Psychology. ITSs maintain several rigorous models that represent the knowledge (or expertise) necessary for performing meaningful tutoring:

- a *domain model* defines a set of elementary knowledge components (e.g. concepts) that a student needs to master;
- a *learner model* (usually a subset—or an overlay—of the domain model) helps an ITS to keep track of what the learner knows;
- a *tutoring model* formalizes the necessary pedagogical principles and strategies to make intelligent decisions on how to best maintain the tutoring process.
- an *interface model* controls the interaction of a learner with an ITS.

Over the 40 years of ITS history, numerous systems implementing a multitude of techniques and approaches have been developed; notable examples include SHERLOCK (Lajoie & Lesgold, 1989), SQL-Tutor (Mitrovic & Ohlsson, 1999) and ActiveMath (Melis, Goguadze, Homik, Ullrich, & Winterstein, 2006).

As a representative example, the Andes system (Schulze, Shelby, Treacy, Wintersgill, Vanlehn, & Gertner, 2000) *(our first selected paper)* was designed to help students solve learning problems in the domain of classical physics. Every problem was represented as a Bayesian Network of rules that students had to master in order to solve it. As the students progressed through the problem, Andes traced their actions and updated the mastery probabilities of the corresponding rules. Andes provided students with instructional feedback and on-demand help, and selected the next problem based on the state of the learner model.

AEH: Adaptive Educational Hypermedia Systems

AILEs have been a major focus in the adaptive hypermedia community (Brusilovsky, 2001), which aims to provide alternatives for the 'one-size-fits-all' approach of traditional web-based systems. Early AEH systems mainly used hand-written rules and models for adaptive behaviour, but soon artificial intelligence techniques from the intelligent tutoring community and the user modelling community were adopted.

Traditional AEH personalization techniques are adaptive presentation and adaptive navigation (Brusilovsky, 2001). Adaptive presentation aims to provide relevant content by hiding, adding, annotating or modifying text fragments or by customizing multimedia material. Adaptive navigation aims to provide personalized guidance through learning material by suggesting next steps, offering personalized overviews and menus, or by hiding, adding, annotating or modifying links between the pages of an AEH system.

One of the earliest AEH systems is ELM-ART (Weber & Brusilovsky, 2001). Originally an interactive textbook, ELM-ART featured adaptive curriculum sequencing, tests and exercises. The 'traffic light' metaphor of ELM-ART—the color of a link indicates whether the learner is advised to follow it or not—has been adopted by many other systems. Another well-known AEH system is AHA! (De Bra, Aerts, Smits, & Stash, 2002) *(our second selected paper)*, which uses a dynamic overlay model where actions (e.g., reading about a concept) are propagated to related concepts: for example, reading about a particular Belgian beer also increases knowledge on Belgian beers in general.

Learner Modeling

A particular characteristic of any AILE is the techniques that it uses for eliciting, maintaining and using models of the learners and/or their contexts. In this section, we discuss various approaches towards learner and context modelling.

Modeling Knowledge, Cognition and Metacognition

Parameters defining the learner's cognitive state have always been the main factors influencing the adaptation of the learning process. Since the very beginning of AILEs, learner models included characteristics such as knowledge, background, goals and tasks. Early AEH systems like ELM-ART inferred learner knowledge by observing which pages learners have read and which exercises they have (or have not) solved. The ITS community used more theory-based approaches, such as the ACT-R cognitive architecture (Corbett & Anderson, 1995), which provides a computational framework for simulating how humans acquire, process and apply knowledge.

Besides domain knowledge and abilities, there exists another set of general and strategic skills that help us to regulate how we learn, process information and perform instructional tasks. This dimension of our cognitive apparatus is called *metacognition* (cognition about cognition). It includes components such as self-assessment and reflection, planning and monitoring, general problem-solving and help-seeking strategies, and the ability to self-explain your solution and self-regulate your learning. Several AILEs addressing the metacognitive traits of their users were designed. For example, Roll, Aleven, McLaren, and Koedinger (2007) presented an ITS that modelled students' help seeking behaviour and tried to teach them better strategies for soliciting instructional feedback from the system.

Beyond Cognition: Emotion, Affect and Context

Good human tutors adapt their teaching strategies not only to the learners' knowledge, but also to their emotional states and the context in which the learning takes place.

Most affective models are based on established theories from the field of psychology. But how does one measure emotion? Conati and Maclaren (2009) *(our third selected paper)* investigated two approaches. First, they created a probabilistic model that derives the learner's emotional state from the interaction with the system: does the learner 'have fun' or does the learner 'avoid failing'? Second, they used physiological sensors (heart rate, skin conductance, electromyogram) as a source for affective evidence. The approaches have been evaluated extensively, with both direct and indirect observational methods.

Emotion and affect are not (yet) part of a typical AILE's learner model. Measuring and modelling learner's emotional states is inherently difficult, and it is yet not clear how studies as described above can be generalized to other contexts.

Apart from the learner, the learner *context* is increasingly used as a basis for personalization. Adaptation to the learner's environment (such as time, location, velocity, noise level) and the device characteristics (like input devices, screen resolution, bandwidth) has been subject of various research projects.

Open Learner Modeling

Self (1988) suggested to 'make the contents of the student model open to the student, in order to provoke the student to reflect upon its contents and to remove all pretence that the ITS has a perfect understanding of the student.' An early, simple implementation of this idea was the 'skillometer' (Corbett, Anderson, Carver, & Brancolini, 1994), which showed a set of progress bars to inform the learners about the current learning state.

Since then, researchers identified several benefits of allowing learners to see their learner models, including raising awareness, promoting reflection, helping learners to plan and monitor their learning, facilitating collaboration and competition among the learners, aiding navigation through learning material, fostering independent learning, and—in some cases—improving the accuracy of leaner modelling. *Scrutable* learner models (Kay, 2006) form a specific category of open learner models that allow learners to inspect and edit the observations, inferences and assumptions that a system holds about them.

Emerging Trends in AILE

Currently, instead of hand-written rules and formal strategies, many systems use statistical models that rely on machine learning and data mining techniques for discovering learner knowledge and interests. This change started in the early 2000s (Brusilovsky, 2001), and later research on Recommender Systems and Web Usage Mining has strengthened the trend. Bayesian networks were one of the first machine learning techniques that were adopted (e.g. Conati & Maclaren 2009). Currently, many other techniques are used as well, including clustering, classification, collaborative filtering and association rule mining (Romero, Ventura, & Garca, 2008) *(our fourth selected paper)*.

Recommendation—the most popular commercial personalization technology—has found a rather limited use in e-learning thus far; in contrast to products in online stores, it is not sufficient to recommend material 'that other learners like'. As argued by Drachsler, Hummel, and Koper (2008), they should also take into account the current learning goal, prior knowledge and other learner characteristics. Therefore, it remains a challenge to design algorithms and interfaces that take these aspects into account.

The increasing importance of collaborative, self-directed and lifelong learning has led to a new type of adaptive systems: Personal Learning Environments (PLEs) (Gillet, Law, & Chatterjee, 2010). PLEs are aggregations (or mash-ups) of standard or dedicated (Web 2.0) tools for learning, collaboration and productivity. An important difference with traditional adaptive systems is the focus on personalized *functionality* rather than personalized content. Current research topics include the nature of self-regulated and community based learning, suitable recommendation techniques, inter-operability standards and in particular the usability of PLEs.

Concluding Remarks and Future Perspectives

The techniques and approaches for Adaptive Intelligent Learning Environments have changed considerably in the past few decades. Traditional ITSs provided adaptive sequencing of curricula and problem solving support through adaptive feedback and scaffolding. With the advent of the web, adaptive hypermedia techniques became increasingly popular as well.

The models and components constituting the ‘intelligence’ of AILEs used to be primarily based on formal rules and theories. Recently, adopting data-driven, empirical, and collaborative techniques has become a popular trend in AILE design. In addition, techniques for addressing the learners’ metacognitive skills and affective states gain a lot of attention. Finally, the focus of AILEs shifts more and more from formal education contexts towards supporting self-regulated and informal learning.

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Chapter 11
Self-Regulated Learning in Technology Enhanced Learning Environments

Donatella Persico and Karl Steffens

Introduction

Self-regulated learning (SRL) has become an important topic in the last two decades, because it is seen as an essential process allowing people to cope and operate effectively within our technology rich and fast developing society. In fact, SRL has been listed as one of the key competencies for lifelong learning by the European Council (2006). SRL is of paramount importance to adapt to new environments, solve unfamiliar problems and interact effectively with other people, both face to face and in virtual contexts. Although the literature about SRL does not refer to a specific theory of learning, much of it takes a cognitive approach (see Chap. 2). The idea of learners' self-regulation is in line with a constructivist vision of learning which assumes learners are active and even pro-active in building upon their existing knowledge to develop new knowledge, resorting to social, critical and evaluative abilities. In addition to this, self-regulated learners consciously monitor the process of knowledge construction and metacognition plays an essential role in this. The concepts of situated cognition and cognitive apprenticeship have had a strong influence on this field of research, and many authors maintain that the development of SRL skills needs scaffolded practice and subsequent fading of the guidance (Beishuizen & Steffens, 2011; Azevedo & Hadwin, 2005). More recently, the culture of openness in education and the ideas of connectivism (Siemens, 2004) have increased awareness of the importance of SRL when it comes to informal learning

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contexts (Dabbagh & Kitsantas, 2012), professional learning at work (Littlejohn, Milligan, & Margaryan, 2012) and learning in Massive Open Online Courses (MOOCs) (Bartolomé & Steffens, 2015; Milligan, Littlejohn, & Margaryan, 2013; Steffens, 2015).

In the last decades, developments in technology have made it possible to create complex Technology Enhanced Learning Environments (TELEs). We are using this term in a very broad sense here applying it to any real, virtual or hybrid environment where technology plays a role in making learning possible. TELEs may provide learners with rich opportunities to use digital technologies to interact with, to configure and to control their learning environments, to communicate with other learners, and to receive quick feedback from all the actors involved. The relationship between TELEs and SRL is somewhat paradoxical. Some TELEs offer learners freedom and choice thus providing them with the opportunity to make strategic decisions about their own learning (Harrison, Crook, & Thomas, 2011). As a consequence, these TELEs allow students to practice SRL, which is considered the main strategy to foster it. However, since learners are not always prepared for full autonomy, these TELEs often pose some important challenges to their users in term of self-regulation because they require a high degree of autonomy, well-developed critical thinking skills and, when online collaboration is involved, social skills that are peculiar to online communication. The latter are described in the literature about computer-mediated communication by referring to the concept of "social presence" (Rourke, Anderson, Garrison, & Archer, 1999; Stacey, 2002), that is "the ability of learners to project themselves socially and affectively into a community of inquiry" (Rourke et al., 1999, p. 1). So the potential freedom and learner-centeredness provided by many TELEs has to be balanced by a higher degree of self-regulation of the learner. The paradox can, however, be faced by exploiting the affordances of TELEs to put learners in charge of their learning in a progressive way, scaffolding them as far as they need and fading when they show the ability to self-regulate.

Very broadly, within the literature about SRL, we can distinguish between theoretical studies about the nature of SRL and those concerning the relationship between SRL and some kind of TELEs. The former mostly include educational or developmental psychology studies proposing models and theories concerning the way human beings develop SRL skills, the way individuals self-regulate their own learning, and other fundamental aspects that have to do with this complex concept and cannot be ignored when attempting to study how the development of SRL skills can be fostered in TELEs. The latter category includes a wealth of studies aimed at better understanding the relation of SRL and TELEs, addressing questions such as whether and how a given type of TELE supports the practice or the development of SRL and what design principles should guide the development of TELEs that facilitate SRL (Bartolomé, Bergamin, Persico, Steffens, & Underwood, 2011; Beishuizen, Carneiro, & Steffens, 2007; Winters, Greene, & Costich, 2008). Empirical research on SRL in TELEs tends to analyse individual learning environments or typologies thereof, but a few researchers have addressed more general questions such as what kind of TELE affordances have potential for SRL development. Out of the large number of publications on SRL and on SRL in TELEs, we have selected two articles that fall in the first category and two belonging to second, which we suggest for reading.

The first is Zimmerman (2000), which contends that self-regulation of learning is achieved in cycles of (1) forethought, (2) performance or volitional control, and (3) self-reflection. There are a number of different models of SRL (Zimmerman, 1998), but the Zimmerman model is probably the best known one and it has been used by many authors as a basis for their studies in the field of SRL in TELEs (Carneiro, Lefrere, Steffens, & Underwood, 2011).

The second selected paper (Steffens, 2006) provides a survey of the most important theoretical models of self-regulation for academic learning and is an ideal starting point for understanding the general picture of SRL theory. It thus focuses on studies aiming to favour the development of SRL abilities, some of which are based on the idea that the teacher should model SRL, while others encourage the application of SRL principles and tactics, and yet others are based on scaffolding and fading support for SRL. Particular emphasis is also given to the European dimension of research on SRL, with special attention to the results of the EU-funded TELEPEERS project, aimed at identifying the features of TELEs that favour the use and development of SRL.

The third selected article is Dabbagh & Kitsantas (2004), which analyses different categories of TELEs and investigates their effectiveness in supporting various aspects of SRL. This study uses a mixed-approach (qualitative and quantitative) to map tools to the aspects of SRL they best support. For example, content creation and delivery tools support goal setting, help seeking, self-assessment, and task-related strategies. Collaborative tools support goal setting, time planning and management, and help seeking. Administrative tools mostly support self-monitoring, self-evaluation, time planning and management, and help seeking. Assessment tools support task strategies, self-monitoring, and self-assessment. This paper is particularly relevant to teachers and learning designers because its findings provide guidance about how to design TELEs that support SRL practice and development.

In the fourth selected article, Underwood and Banyard (2011) discuss facilitators and barriers to future developments of TELEs and their affordances for SRL. They argue that the concept of SRL is still not very well understood in (and adapted to) our educational systems and that there seems to be little evidence that TELEs development takes into consideration the need to foster SRL. They provide arguments to support the idea that TELEs have a great potential for SRL development, and that the key principle to take advantage of this potential is to endow learners with more freedom to organise their own learning environments and control their learning.

Self-Regulated Learning: An Overview of Theoretical Studies

"Students can be described as self-regulated to the degree that they are metacognitively, motivationally, and behaviourally active participants in their own learning process" (Zimmerman, 1989, p. 329). As mentioned above, according to Zimmerman, Self-regulated learning (SRL) involves cycles of (1) forethought, (2) performance or volitional control, and (3) self-reflection (Zimmerman, 2000). At the same time, there seems to be agreement that self-regulation involves "*cognitive*, *affective*, *motivational* and *behavioural* components that provide the individual with the capacity to adjust his or her actions and goals to achieve the desired results in light of changing environmental conditions" (Zeidner, Boekaerts, & Pintrich, 2000, p. 751).

It needs to be mentioned here that the concept of SRL is very close to that of Self-Directed Learning (SDL). SDL refers to learning for which the individual takes the initiative and full responsibility. In SDL the learners, generally adults, set the goals, find the resources, choose the strategies and evaluate the outcomes of their learning (Knowles, 1975; Gibbons, 2002). Research on SDL originated in the 1960s and thus preceded that on SRL which developed mostly in the last 30 years. While SDL focused on sociological and pedagogical aspects, emphasizing external management of learning activities, SRL was mostly investigated by psychologists who focused on concepts such as motivation, self-efficacy and metacognition (Pilling-Cormick & Garrison, 2007).

SRL is central to current efforts to prepare learners for a society in which knowledge is dynamic, distributed and complex, in other words, a society which increasingly relies on higher order thinking skills, problem solving in interdisciplinary fields, and the ability to communicate, negotiate and collaborate effectively with others. This type of knowledge cannot be developed once and for all. Learning seen in this way becomes a continuous process across the life-span and increasingly occurs in non-academic environments. Such environments are likely to be less tutor-oriented and more learner-oriented, which means they will require self-regulatory skills to a greater extent.

However, in formal educational settings, there arises a problem. If students are given the opportunity to fully self-regulate their learning, they should have the freedom not only to decide when, where and how to learn, but also—to some extent—what to learn. An adequate model of SRL would also have to consider not only how the achievement of goals set by the learning environment (the teacher, the institution or any other organization the learner belongs to) is regulated by individuals but also how they handle personal goals. In her model of adaptable learning, Boekarts distinguishes in a somewhat similar vein between learning goals and ego-protective goals (Boekaerts & Niemivirta, 2000; Boekarts, 2002), i.e. aims individuals pursue to protect the ego and restore well-being. This may happen, for example, when appraisal of a learning situation induces fear of failure and thus activates goals such as ability display rather than ability development. Ego-protective goals might therefore impede learning, because they make it difficult for young inexperienced learners to set their own goals for learning, especially in fields they do not know at all. It is perhaps for this reason that much of the literature on SRL concerns higher education and adult education. However, it has been acknowledged that SRL must be nurtured starting at a very early age (Paris & Paris, 2001).

Empirical research into SRL also needs to tackle the problem of measuring self-regulated learning (Winne & Perry, 2000). This is traditionally done by using questionnaires or self-reporting interviews aiming to investigate the extent to which learners use SRL strategies. Thinking aloud (Veenman & Beishuizen, 2004) is one of the possible measurement techniques. The use of SRL strategies within TELEs can also be studied by taking advantage of the tracking capabilities offered by most TELEs (Dettori and Persico, 2008).

Given the desirability of SRL competence, several authors (Delfino, Dettori & Persico, 2011; Zimmerman, Bonner, & Kovach, 2003) have investigated ways of developing self-regulation in learners. In particular, SRL development seems to be effectively supported through a scaffolding and fading approach, where support to the various phases of the SRL cycle is initially provided and gradually decreased while the learners' autonomy increases (Azevedo & Hadwin, 2005; Van de Pol, Volman & Beishuizen, 2010).

Studies Concerning Self-Regulated Learning in TELEs

In the following, we discuss a few important areas where TELEs have shown significant potential to scaffold self-regulation: metacognition, assessment, and personalisation.

Metacognition

The term metacognition was coined by Flavell (1971) and can be defined as "cognition about cognition", that is the knowledge concerning one's own cognitive processes. For example, the ability to choose suitable strategies for learning and the ability to assess one's own learning are considered important meta-cognitive abilities. It has become common to distinguish between (1) knowledge about one's cognitive processes and (2) monitoring and regulating these processes (Hacker, Dunlosky, & Graesser, 1998). In TELEs, metacognition, and particularly self-monitoring, is facilitated by the fact that online learning systems can keep track of the learning dynamics and therefore allow learners to go back to their previous actions and reflect on their learning processes, strategies and progress. For example, when computer-supported exchanges between learners and tutors take place, the persistency of the messages exchanged allows learners to re-read and reflect on the contributions of all parties, especially when the data can be captured, re-presented and accessed in ways that facilitate such reflections. Similarly, many digital learning environments allow their users to compare their achievements with their previous performances, with those of their peers or with the desired objectives, thus engaging in self-evaluation activities. Learners do so most effectively when they are explicitly encouraged and scaffolded to carry out this task (Azevedo & Hadwin, 2005). For this reason, research in SRL and TELEs has investigated ways to promote meta-cognition, bringing about techniques and good design practices such as that of devoting a forum to meta-reflection in online courses (Delfino, Dettori & Persico, 2010) or providing tools (e.g. agendas and planners) to implement organisational strategies and to plan learning activities (Dabbagh & Kitsantas, 2004). Recent research trends in learning analytics, addressing the problem of how to analyse big data concerning interactions in TELEs and present them to users to facilitate understanding of the learning dynamics, can contribute to this line of work (Ferguson, 2012; Persico & Pozzi, 2015). While it is true that the availability of these tools does not guarantee use, the role of scaffolds is indeed that of establishing the habit of using them.

Assessment

Assessment is one of the most important factors influencing student behaviour in formal learning, so it is essential that it is aligned with the planned learning outcomes and does not act counterproductively (see Chap. 12). To foster and take advantage of SRL, the intended learning outcomes should in turn be aligned with the learning outcomes desired by the learners. According to Ellis and Folley (2011), this can be achieved with TELEs thanks to their affordances for students' choice concerning at least five aspects of assessment: (1) *format*, that is the way they present their learning achievements; (2) *subject*, that is the topics and/or problems students engage with; (3) *criteria*, that are the way their achievements will be measured; (4) *timing,* that are the deadlines for different phases of work and, finally, even the (5) *result*, that is the grade or summative assessment they receive. Having students involved with choices on some of these aspects may generate anxiety in students and perceived risk on the side of teachers and institutions. For example, while negotiation on subject between students and teachers is sometimes practiced in several contexts (for example, in formal education, when students choose the topic of their essays for final assessment), learners have hardly a say concerning result because many teachers and institutions see it as a potentially "subversive" practice.

Using technology can help a lot to manage the practical possibility of increasing students' choice about assessment. For example, the accessibility and affordability of multi-media production tools allow the learners to choose the media that best accommodates their content and best suit their presentation preferences to produce their artefacts. These tools, combined with the use of web 2.0 resources, allow a type of assessment where the results of the students' work can be published, shared, and discussed together with the criteria and the result of the assessment. Students will thus be compelled to evaluate their skills and decide which skills they need to improve. A good example is the use of eRubrics for self-evaluation (Serrano Angulo

& Cebrián de la Serna, 2011). The sharable nature of web 2.0 objects also breaks the traditional view of assessment as a private affair between teachers and learner, which leads to the healthy habit of encouraging students to compare their work with that of others, which is regarded as an important factor favouring self-regulation.

An example of tools that seems to have a particular potential to support self-assessment and—more generally—SRL, are Digital Portfolios. This potential is examined in contributions by Abrami et al. (2008), Alexiou and Paraskeva (2011) and Beishuizen et al. (2006). A portfolio is a collection of artefacts in any format (documents, audio, video, images) organized and connected with appropriate personal development objectives, plans, and outcomes. The advantages of e-portfolios include easy access, portability, visibility, flexibility, personalisation opportunities and the ease of sharing with others. Depending on how e-portfolios are used, they may foster processes like planning, documenting one's activities, reflection, sharing of results and feedback. As a consequence, these tools can support all phases of SRL, that is, planning, monitoring and evaluation of the learning process.

Personalisation

As mentioned above, learners are self-regulated when they manage to control their own learning process, including, to some extent, the learning environment. This entails, according to Underwood et al. (2008), that TELEs which can be customised and personalised by learners create a favourable condition for self-regulated learning. The concept of personalisation thus focuses on the learning environment and on the possibility for learners to control and configure their own environment in such a way that their control over the learning process is optimal. For example, a TELE that includes the possibility to bookmark, to highlight portions of content, to choose between different representations of content or different media, to select between degrees of difficulty, to filter information according to given criteria and to monitor progress favours practice and thus development of self-regulation better than one that does not offer these options (for a discussion of the concept of Personalised Learning Environment (PLEs) see Fiedler & Väljataga, 2013). As in the case of tools supporting metacognition, the availability of these functions does not guarantee their use but allows scaffolding actions aimed at encouraging use.

In their discussion of the relationship between SRL, PLEs and Social Media (SM), Dabbagh and Kitsantas (2012) contend that the already large use of SM by university students could become a springboard for integrating formal and informal learning, thus supporting student self-regulated learning in higher education contexts. To this end, they provide a three-level pedagogical framework for encouraging students to use SM to create PLEs that support their self-regulated learning. In this view, SRL and PLEs are two sides of the same coin. In a similar vein, Milligan, Littlejohn and Margaryan (2014) outline a range of behaviours and related tools that are essential for knowledge workers to effectively self-regulate in the workplace. These behaviours leverage on informal networks and PLEs. These claims are applied by Persico, Milligan and Littlejohn (2015) to the context of teacher professional development.

SRL and Inquiry Learning

According to a definition by Linn, Davis and Bell (2004), "inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments". As a consequence, inquiry learning involves exploring the natural or material world, and is based on asking questions, formulating hypotheses and systematically testing those hypotheses to reach a deep understanding and make new (personal) discoveries (NSF, 2000). Self-regulation, in this process, plays a role of paramount importance. Although inquiry learning is rather difficult to implement and time-consuming for teachers, it is a powerful learning approach (Hmelo-Silver, Duncan, & Chinn, 2007), especially in scientific fields, in that it allows to achieve deep understanding of complex phenomena. The use of this learning/teaching approach is intertwined with actions devoted to SRL development, in that the process of making hypothesis, planning experiments, monitoring and evaluating their outcomes to make sense of the results, is by definition a self-regulated process (van Joolingen, de Jong & Dimitrakopoulou, 2007). Systems that provide guidance by prompting students during the different phases of inquiry would thus help acquire and improve SRL competences and inquiry learning at the same time.

In particular, the skills that are practiced in inquiry learning include the above mentioned approach to scientific reasoning, but also transversal and metacognitive abilities such as planning, critical thinking, problem solving through inductive and/or deductive reasoning, self-monitoring, and last but not least, teamwork and interpersonal communication. All of these skills are strictly intertwined with self-regulatory ones, and are needed to become effective life-long learners and "science active" citizens.

Outlook

Much of the literature concerning SRL supports the idea that the ability to control one's own learning is highly desirable in general, and even more so in technology rich personalizable environments where students have ready access to a variety of sources of information and tools for learning. These affordances, in fact, may turn out to be useless or even counterproductive if learners are not able to take advantage of them. Self-regulated learners can make use of them to pursue their learning objectives by interacting with peers and experts, choosing the digital resources that suit them best and constantly monitoring their achievements. Research on

SRL and TELEs has yielded interesting results as to how teachers, tutors and learning designers can sustain the development of SRL skills in TELEs (Delfino & Persico, 2009), what features of a TELE best scaffold SRL (Dabbagh & Kitsantas, 2004; Dettori & Persico, 2009), and how technology can support the practice of metacognitive skills and self-evaluation (Azevedo, 2005; Azevedo & Hadwin, 2005). Significant results have also been obtained in terms of the methods that can be used to investigate and keep track of SRL behaviour in some kinds of TELEs, such as, for example, those based on online collaboration (Tsai, Shen & Fan, 2013; Dettori & Persico, 2008).

However, there still are some relatively unexplored areas of investigation. For example, since much research has focussed on the cognitive aspects of SRL, it would be interesting to see more investigations focussing on the emotional and motivational aspects of SRL (Wolters, 2003). How are emotional aspects of SRL being dealt with in TELEs? How can technology support and sustain motivation, for example by taking advantage of the affordances of social learning tools or those of serious games? Pioneering studies in this direction could employ Artificial Intelligence techniques to identify emotions and even predict them (Arroyo et al., 2009). From a more theoretical perspective, an interesting model of self-regulation online that takes into consideration emotional and motivational factors is proposed by Artino (2008).

Another area deserving more investigation is SRL development in children. Although SRL is more easily found and studied in adults, scientific literature in this area exists (Perry, 1998) and is complemented by more pragmatic works dealing with individual aspects of SRL such as learning to learn strategies, creative thinking, problem solving or metacognition (Fisher, 2005). In addition, some studies suggest that SRL development can and should start as early as possible (Perry, Phillips & Hutchinson, 2006). How can this be achieved? It is not unlikely, for example, that self-regulation strategies applied in games can be transferred to the advantage of self-regulation in learning.

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Chapter 12
Assessment for Learning

Carlo Perrotta and Denise Whitelock

Introduction

The aim of this chapter is to discuss four influential papers that exemplify the level of theoretical and empirical development in e-assessment.[1] Within the field of Technology Enhanced Learning (TEL), e-assessment could be said to have something of a distinctive status. TEL research has been mostly concerned with the ways in which technology can transform or "disrupt" traditional instruction. Popular research topics include ICT for knowledge building and sharing, communication and collaboration; learning outside of formal educational institutions and practices; and the ways in which educational technologies are mediated by the cultural context (Laurillard, Alexopoulou, James, Bottino, & Bouhineau, 2007; Sutherland, Eagle, & Joubert, 2012). E-assessment tells a slightly different story, in which the development of approaches and tools in both schools and HE has been driven by the need to increase efficiency and manageability of "traditional" assessment practices, rather than to explore innovations that could help bring assessment in line with notions of learning and education in the twenty-first century (Nicol & Macfarlane-Dick, 2006). This criticism notwithstanding, it is important to resist

[1]Throughout the chapter, the definitions "e-assessment" and "technology-enhanced assessment" will be used interchangeably.

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the temptation to launch easy attacks. Assessment has an important and difficult role in education, and calls for innovation must account for a range of complex issues and constraints—not least the need to sustain a system capable of ensuring reliable, valid and manageable evaluations of very large student populations. It is also important to keep always in mind the distinction between summative and formative forms of assessment. The most popular example of summative assessment is the high-stakes exam, used to inform key decisions and choices relating to students' futures. On the other hand, formative assessment has a developmental function and its main objective is to provide students with constructive feedback to improve performance (Black, Harrison, Hodgen, Marshall, & Serret, 2010). Given this distinction, perhaps it is unsurprising that innovation is more common in formative than in summative assessment. The reasons for this are to be sought in the nature of the regulatory environments in most education systems around the world. These environments favour experimentation in the area of low-stakes, developmental assessment, but tend to constrain the adoption of more innovative approaches in high-stakes, summative assessment.

There are however notable attempts that have helped move assessment as a whole towards more innovative and progressive territory. These attempts are aptly illustrated by the work carried out by the CAA (Computer Assisted Assessment) community, which over the last 13 years has made strides towards providing automatically generated feedback that can assist learning as well as paying attention to the real drivers of the practice and scholarship of assessment: validity and reliability. In the same spirit, this chapter aims to provide an introduction to some influential and seminal contributions in technology-enhanced assessment. Some important distinctions and definitions, underpinned by a moderate amount of theory, will be introduced in section "Introduction". This theoretical discussion will pave the way for section "The Theory of Feedback at the Heart of e-Assessment", which will deal specifically with the technology-related implications. The final section of the chapter will be instead a more critical analysis of why and how assessment should innovate.

The Theory of Feedback at the Heart of e-Assessment

As a point of departure for this brief account of relevant scholarship in technology-enhanced assessment we would like to turn to the first of our selected papers and to the work of Royce Sadler (1989), who provided some of the key definitions and identified challenges that have shaped the field of technology-enhanced assessment as we know it. Sadler's most enduring contribution is concerned with the relationship between formative and summative forms of assessment. In this respect, the key distinction lies in the notion of feedback. Sadler described this concept as "information about how successfully something has been done or is being done" (1989, p. 120). While a summative assessment provides feedback in the form of evaluation based on the "correct" information, a formative assessment ensures that such feedback also points to one or more paths to progression and improvement, thus creating a more supportive environment through which physical, intellectual and social skills are not only evaluated but can also be further developed. Sadler's work and subsequent contributions could be said to have shaped the theoretical background of technology-enhanced assessment. This background is broadly aligned with a number of perspectives: socio-cultural theory, metacognition and learner-centred approaches.

The main tenet of socio-cultural theory is that the person and the social environment constantly influence and shape each other (Wertsch, Del Río, & Alvarez, 1995). Metacognition assumes, in a nutshell, that awareness of the processes that underpin learning (e.g. motivation, attention focusing strategies, and so on) is crucial to enable autonomous, self-reliant learning. Similarly, a learner-centred approach assumes that students must be placed at the heart of the educational process, and given the resources to monitor the quality of their own work. This requires that they appreciate what high quality work is, and that they have the skills necessary to modify their approach to learning accordingly.

These ideas can be traced in Sadler's thought, and they undoubtedly have far-reaching implications for the development of technological systems that aim to support and "enhance" assessment. The main points in this respect are:

- The need to move away from an idea of learning as transmission of knowledge and towards more learner-centred education that emphasises, above all, self-regulation. (Black & Wiliam, 2009; Boekaerts & Corno, 2005; Pintrich & Zusho, 2002).
- The need to move away from a developmental model that sees individual ability as fixed, given and unchanging (Levy & Dweck, 2003; Whitelock & Watt, 2008).
- The need to appreciate the importance of socio-cultural and dialogic factors that regulate interactions, communication and collaboration in an effective feedback process (Chaiklin, 2003; Laurillard, 2002; Vygotsky, 1978).

We will see in the next section how these theoretical assumptions have informed the investigation of technologies meant to support teachers in the demanding task of integrating formative and summative functions of assessment.

Putting the "E" into Assessment

This section will mainly focus on two papers: the second of our selected papers provides seven principles of good assessment practice (Nicol & Macfarlane-Dick, 2006), and something of a "companion paper" (the third of our selected papers) that applies those principles to e-assessment (Nicol & Milligan, 2006). In this respect, the work of Nicol and colleagues represents a timely attempt to bridge scholarship that provided key conceptualisations and definitions in assessment, and emerging research and practice in e-assessment. Nicol and Macfarlane-Dick (2006) are very clear in grounding their contribution within a model of self-regulated learning. They draw on Sadler's work, as described in the previous section, but also acknowledge their debt to subsequent developments which helped reposition assessment and feedback within a wider framework that includes self-regulation and motivation (e.g. Butler & Winne, 1995; Schunk & Zimmerman, 1994; Pintrich & Zusho, 2002). Moreover, although their focus is on higher education, they make important observations that could also apply to secondary and possibly even primary education.

Nicol and Macfarlane-Dick (2006) introduce a conceptual model of self-regulation which takes into account the relationship between cognitive skills and motivation, that is, between ability and "drive". This model rests on seven principles of feedback practice, backed by a large body of literature and defined as "anything that strengthens the students' ability to self-regulate their own performance" (2006, p. 205). Following on from the introduction of the seven broad principles of good feedback practice, Nicol and Milligan (2006) explored how the seven principles could inform practice in contexts which support and enhance face-to-face interactions using digital technology. In the interest of synthesis, we will provide a unified account of these two distinct, yet closely related papers; for more detailed descriptions and references readers are encouraged to consult the original publications. The seven principles and the technology—related implications and suggestions are summarised below.

Good feedback practice . . .

(1) *Clarifies good performance*
Feedback is effective when it clarifies in unambiguous terms the goals, criteria, and expected standards in a learning context. This is essential in order to narrow the gap in understanding that often exists between teachers and students about what constitutes an effective performance.

Online discussion spaces can help students feel free to ask questions about assessment tasks and their underlying criteria; students may be even prompted to do so. Exemplars could be provided within a virtual learning environment (VLE), and might be supported by additional activities that encourage students to interact with, and externalize, criteria and standards.

(2) *Enables self-assessment*
Feedback is effective when it helps the development of self-assessment and reflection in learning, by helping students identify standards or criteria that will apply to their work, as well as make judgements about how their work relates to these standards.

Online tests and quizzes can be used by students to assess their understanding of a topic or area of study. Limitations of this approach need to be considered, such as the fact that students usually have no role in setting goals or standards for online tests and may not be able to clarify the test question or its purpose. Online or Virtual Reality simulations (e.g. in engineering or science) can be effective in providing students with direct, immediate and dynamic feedback about the effects of their actions. This feedback is also likely to be more conducive to self-regulation as it clarifies further the link between performance and specific targets and standards. The development of e-portfolios also requires that students reflect on their achievements and select work that meets defined standards.

(3) *Delivers high quality and timely information*
High quality and timely information helps students troubleshoot their own performance and self-correct, thus helping them take action to reduce the discrepancy between their intentions and the resulting effects, before it is too late to change their work (i.e. before submission).

Online contexts can assist teachers in giving feedback on written work to large groups of students, for example through streamlined feedback reports. However, Nicol and Milligan note that such approaches are in need of more robust evidence that could help identify what types of feedback comments are most effective. Recent developments in Learning Analytics, based on the application of computational methods to large amounts of learner data, hold great promise in this regard (Arnold & Pistilli, 2012; Clow, 2012).

(4) *Encourages peer dialogue*
Teacher and peer dialogue around learning increased the likelihood that students and teachers will share the same understanding about the meaning of the information being discussed.

There are classroom technologies that can help orchestrate feedback dialogue. Nicol and Milligan describe a system in which handsets send signals to wall-mounted sensors. Students' responses are collated in real time and then displayed on a digital projection as a bar chart. This simple mechanism proved to be an effective way to support peer interaction.

(5) *Encourages positive motivation and self-esteem*
By encouraging positive motivational beliefs and self-esteem, good assessment practice helps students move away from an "entity view" of their ability (Dweck, Mangels, & Good, 2004)—the view that their ability is fixed and that there is a limit to what they can achieve—and towards the belief that ability is malleable and depends on effort and dedication (the "incremental view").

Assuming they can access it from a variety of contexts and from their own homes, technology can help students by enabling them to assess their understanding in private and make comparisons with their own learning goals rather than with the performance of others, which has positive effects on self-worth. Technology also allows to re-take tests many times in order to improve performance, which can be highly motivational.

(6) *Helps close the gap between current and desired performance*
One of the key principles of formative assessment is that feedback should be used by learners to produce improved work, which might involve redoing the same assignment or providing opportunities for resubmission at specific moments of the feedback cycle.

Although Nicol and Milligan acknowledge that not all student work can, or should, be resubmitted, they emphasise that resubmission should play a more prominent role to support formative assessment. When appropriate, technology provides the means to enable resubmission in effective and manageable ways. It also enables feedback on work in progress and allows students to engage in the planning of remedial actions The main pedagogical challenge with technology and formative feedback is with the e-assessment of free text and with the provision of meaningful 'advice for action', as suggested by Whitelock (2010), in order to support students in writing essays for summative assessment. In OpenEssayist, Whitelock, Twiner, Richardson, Field, & Pulman (2015) have built a system that uses unsupervised graph-based ranking algorithms to extract key words, phrases and sentences from student essays. OpenEssayist is a system that offers opportunities for students to engage with and reflect on their work, in any subject domain, and to improve their work through understanding of the requirements of academic essay writing.

(7) *Shapes teaching*
Good assessment practice provides information that can be used to shape teaching or, more specifically, provides teachers with material that reflects progression along a continuum or trajectory, so that once it is known where a student is positioned, the very nature of the continuum helps determine what kinds of instructional experiences should follow.

Technology can help perform diagnostic tests more easily and effectively, thus helping teachers generate information about students' current levels of understanding and adapt teaching accordingly. Nicol and Milligan describe how "classroom communication systems" (i.e. classroom response systems: handheld devices used for real-time interaction, also known as "clickers") allow teachers to gain regular feedback information about student learning within large classes by using short test-feedback cycles. The inbuilt reporting functionality of several online assessment tools can also provide teachers with quantitative and qualitative information about learning, at the classroom level as well as the individual level, which can be used to inform teaching.

The Futures of e-Assessment

So far, we have described three papers that illustrate, according to us, seminal contributions and current developments in e-assessment. In this concluding section, we would like to talk about the future of e-assessment. We believe that this conclusive discussion will provide the reader with some "food for thought" that will assist a more informed and critical understanding of why and how assessment should innovate. For this purpose, we will discuss the fourth of our selected papers, Randy Elliot Bennett's oft-cited paper about the "inexorable" advance of technology and the "inevitability" of change in educational assessment (Bennett, 2002). Bennett's paper is seminal in that it aptly infuses the e-assessment field with a sense of urgency and necessity: qualities often invoked in all technology-based endeavours to justify the need to embrace innovation. Bennett's argument rests on the assumption that the advancement of technology is inexorable inat least two ways: the exponential increase in capability and the pervasiveness of technology in the area of office-based work which, he argued (in 2002), was beginning to influence learning as well.

Bennett's warning is formulated in a familiar way, drawing on a discourse of inevitability underpinned by a "faith" in the power of technology to offer a transformative and undeniably "better" way of doing things. Such themes are not new in educational technology and in fact they tend to remain constant, whilst at the same time adapting to new developments and trends. In this chapter we would like to suggest that important implications for e-assessment can be derived from the analysis of how the "inevitability theme" shifts and evolves in the literature. For example, Bennett's paper, written in 2002, is ostensibly based on a view of technology as productivity-enhancer: a must-have feature in schools, given its pervasive position in the world of work. Hence:

> knowing how to do intellectual work *with* technology – to model a problem using a spreadsheet, create a presentation, use data analysis tools, find information using the internet, or write and revise a paper with a word processor – is becoming a critical academic skill. (Bennett, 2002, p. 7)

Since then, there has been a move away from a view of technology-enhanced learning as "inevitably" shaped by the culture of office productivity and by office-based tools and practices. Nowadays, the emphasis is on other "innovative" aspects: mobility and ubiquity (Sharples, Taylor & Vavoula, 2007), participation in the "web 2.0" practices of media creation (Ito et al., 2008), immersive experiences based on the same mechanics and principles used in video games (Schaffer, 2006). It goes without saying that an approach to e-assessment that emphasises office-based productivity leads to substantially different results than, say, an approach that chooses to focus on informal practices of media creation, or on the immersion in simulated worlds (see Chap. 9). The underlying assumptions would differ greatly: what to assess, how to assess it, how to ensure validity/reliability and so forth. For instance, as noted by Whitelock (2010), Web 2.0 tools facilitate collaboration and offer the potential to move away from the assessment of individual skills to implement a social constructivist view of learning.

In this final section, we wish only to convey a very crucial point: the "socially shaped" (Williams & Edge, 1996) ways in which influential authors talk about technology and learning more broadly have profound implications for e-assessment, and radically different systems, practices and paradigms tend to follow on from different concepts of technology in formal or informal contexts. While it remains true that assessment shapes teaching in the classroom to a more or less large degree, we suggest that different ways of talking about and interpreting technology, in the context of the broader educational discourse, have in turn a profound influence on assessment and e-assessment, by shaping modalities, times, purposes and determining roles and expectations. In this sense, it could be argued that calls for change and the need to embrace technology acquire a whole new meaning and emphasis in assessment: an arena where the many contradictions and tensions that surround education are brought into sharp relief.

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Chapter 13
Learning Objects

Tom Boyle and Erik Duval

Introduction

How can we improve the quality of educational resources on a global scale? This is the challenge that motivates work on learning objects that began in the late 1990s. The key direction of learning objects work was captured in phrases like “share and reuse” (Forte, Wentland-Forte, & Duval, 1997). Sharing the effort of producing and exchanging high quality educational resources, it was argued, should be of enormous benefit for all involved.

In fact, as definitions of what constitute a “learning object” vary wildly (a point we will address below), so do examples of what can be a learning object. One extreme is to consider a single picture as a potential learning object: a photo of, for example, the Eiffel tower can certainly be used in many different learning contexts. The other extreme is to consider a module or a complete course, with an explicit learning goal and a target audience, as a learning object. The main point is that “learning objects” can vary from small pieces of content (a photo, a slide, a text definition, etc.) that can be used for learning, over larger pieces of interactive content, (a mobile app, a quiz, a simulation, etc.) to still larger and more complex learning resources that typically have an explicit learning design (a module, a course, even a curriculum). The early realisation, however, that most learners and teachers want to adapt resources to their own requirements led to a focus on small levels of granularity; one popular analogy at the time was that of “Lego blocks” that could be combined in flexible ways to build a wide variety of larger conglomerates.

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Attention to reusable resources led to a number of concerns. These included the identification of these "learning objects"; their storage and "findability" in large repositories, and their reuse and combination. The theme of "metadata" gained prominence early on. Metadata basically describe learning objects in some detail and make it possible for people and search algorithms to identify objects that satisfy specific criteria. In order for this approach to scale, it is important that the descriptions be clear, reliable and shareable, which led to the IEEE standardization of "learning object metadata" (IEEE, 2002). The work on metadata was paralleled by a continuous debate on the properties that facilitate the reuse, repurposing (reshaping to meet new local demands) and pedagogical impact of these learning objects. The selected papers discussed with this chapter articulate key themes and issues in this debate on the nature, description and combinatorial reuse of learning objects.

Contribution of the Key Papers

The papers we selected have contributed in significant ways to the discourse that shaped research and development into learning objects. A number of key themes are addressed in these articles. The distinctive input of each paper contributes to a more rounded understanding of these themes and related courses of action. The main topics addressed in the papers include:

- What are learning objects and, in particular, how do we go beyond the vagueness of the standard definition of a learning object as "any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning"? (IEEE, 2002)
- How can we model learning objects conceptually, e.g. what are the different types of learning objects, and how are these types related to each other, e.g. in a taxonomy?
- How should we author and develop learning objects?
- What is the relationship between technical standardisation and pedagogy in understanding and utilising learning objects?

An important advantage of reading the four papers together is how they reveal different perspectives on common topics: e.g. just what are learning objects, what is important about them, and where does the value of learning objects derive from? There is a running theme of the productive tension between pedagogical and software engineering perspectives. Sometimes this is manifested within papers, but also in important narrative strands across the papers. Are learning objects predominantly software engineering constructs or pedagogical constructs, or in what sense are they both? The papers are presented in terms of how they contribute to the overall debate.

The first of our selected papers (Duval & Hodgins, 2003) sets out a "LOM Research Agenda". This provides an overview of issues in learning object research and development from a predominantly software engineering perspective. The second selected paper by Wiley on "Connecting learning objects to instructional design theory" explicitly argues for the central importance of pedagogy, expressed here as instructional design (Wiley, 2000). The third selected paper by Boyle on "Design for Authoring Dynamic, Reusable Learning objects" (Boyle, 2003) enunciates principles for the design and development of learning objects based on an explicit synthesis of software engineering and pedagogical principles. The fourth selected paper by Polsani provides a further perspective on key themes that emerge from the first three readings (Polsani, 2003).

The first paper, enunciating a "LOM Research Agenda", is a rich article covering a range of important themes (Duval & Hodgins, 2003). Duval and Hodgins point to the vagueness of the IEEE definition of learning objects (as do nearly all the papers). They respond to this problem by presenting an overall view for structuring the learning object universe. They provide a "lens" that views learning objects as hierarchically structured where

(a) "Assemblies" can be aggregated from
(b) "Single purpose learning objects". These single purpose learning objects are, in turn, composed of
(c) "Information objects", which represent combinations of
(d) "Raw media elements" (e.g. a picture with added text).

This paper also provides a perspective on authoring learning objects—a theme that is tackled in different ways by all the papers. The approach advocated here is authoring by creating an "aggregation" where items are selected from repositories and assembled into learning objects. The vision is one of a hierarchical domain where authors can move up and down across different levels of aggregation. The article also discusses the challenge of interoperability and business models to encourage widespread (re)-use of learning objects.

The second selected paper on "Connecting learning objects to instructional design theory" shares this strategic approach but explicitly argues for an "instructional design" perspective (Wiley, 2000). Wiley offers a working definition of learning objects as: "any digital resource that can be reused to support learning" (p. 7). Technical standards, he argues, are not enough to promote learning. He argues that the combination and sequencing of learning objects should be based on instructional design principles. Decision on granularity or size should also be guided by instructional design principles, though how this should be achieved is not elaborated on in detail.

Wiley offers an alternative metaphor to the traditional "Lego brick" analogy for learning objects. He prefers the metaphor of an atom. A key aspect of this argument is that the internal structure of the "atom" (learning object) will determine which other entities it will link with. Wiley also proposes a taxonomy for learning objects. The purpose of this taxonomy is to "differentiate different types of learning objects *available for use in instructional design (p. 23)*" (their italics). This may be compared with the taxonomy proposed by Duval and Hodgins (2003) which is focused on inclusion of learning objects within other (higher order) learning objects in a hierarchical relationship. There are overlaps between the two taxonomies but also some clear differences in emphasis. In particular, Wiley is interested in structural characteristics that affect their facility for combining with other learning objects from an instructional design perspective.

The third paper on "Design for Authoring Dynamic, Reusable Learning objects" switches the emphasis to principles for authoring learning objects. It enunciates explicit principles for the design and development of learning objects based on a synthesis of ideas from software engineering and pedagogy (Boyle, 2003). The aim of design is to create learning objects that are pedagogically effective, highly re-usable, and open to re-purposing (adaptable to new different contexts of use). Boyle introduces two key principles derived from software engineering: cohesion and de-coupling.

- Cohesion means that each learning object should do one thing and one thing only. Each learning object should thus be based on one clear learning objective or goal.
- Linked to this is the principle of de-coupling (or more accurately minimised coupling): each unit should have minimal bindings to other learning object units. Thus if a learning object has references such as "following from last week's class" then its reuse in a different context may be markedly impaired. The issue of how coherence should be managed is discussed in the paper (Boyle, 2003).

These structural principles are balanced by an emphasis on creating a coherent learning experience that enables students to achieve the target learning goal. The vision then is to create pedagogically rich, cohesive and decoupled learning objects.

As a simple example illustrating several of the issues discussed so far, we may consider a scenario where a tutor wishes to produce a text-based exercise: "Create your own learning object". This presents a strong, clear goal that provides the basis for a cohesive learning object. To make the learning resource widely reusable, however the author needs to think about the links between this resource and the broader course. References to other parts of the course should thus be placed in a course level introduction to the resource, *not with the resource itself* (e.g., "You should re-reread your lecture 7 notes before starting this exercise"). In this way course coherence is maintained but it does not interfere with the reuse of the learning resource in a different context. The author may also wish the students to access external Learning Object Repositories to reuse materials, such as pictures or animations. To avoid coupling to a particular repository the author can provide links to several repositories. Thus, if one repository stops functioning it will not undermine the learning resource.

The resource may be now standalone and highly reusable. But how do users find out about it and download it for their own use? The author can deposit the resource in a Learning Object Repository which provides guidance on how to add metadata (e.g. name, keywords, description and permission to reuse) and package the learning object for deposit in the repository. Any user may then search the repository, locate the desired learning object, and download it for use in a new course.

Boyle's paper delineates how higher order learning experiences can be built, and repurposed, while retaining the reusability of the individual learning objects. It illustrates how "compound learning objects" can provide multiple perspectives on learning topics, while retaining the reusability of individual learning objects. It also elucidates the concept of explicit "layers of organization" that are designed so that higher layers (e.g. particular syllabi) have maximum freedom to reuse the resources from lower levels (e.g. individual learning objects). The principles discussed in the paper are illustrated through the development of a set of learning objects for Introductory programming in Java. The project led to substantial improvements in pass rates in the Java modules.

Polsani's paper provides a further perspective on key themes that emerge from the first three readings (Polsani, 2003). The stated objectives of the paper are "to assess current definitions of the term *Learning Object*, to articulate the foundational principles for developing a concept of LOs, and to provide a methodology and broad set of guidelines for creating LOs. (Para. 1 in online paper)" The paper provides a useful review of a number of definitions of learning objects and then clearly states its own: "A Learning Object is an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts (Section 2.2 in online paper)". It then explores the conceptual structure of learning objects through the two "fundamental predicates" of learning and reusability. Polsani argues that a learning object should be "wrapped in a learning intention". However, unlike (Boyle, 2003) he argues that learning objects "in themselves are insufficient to generate significant instruction". Therefore, several learning objects have to be brought together in order to create an instructional situation". Boyle argues that each learning object should be based on achieving a specific learning goal. Higher order learning sequences can, in turn, be constructed by combining these base learning objects. Polsani provides further perspectives on developing learning objects and standards and specifications before a longer discussion on learning objects and electronic books.

Key Further Developments

Advances have been made in both the formal and pedagogical aspects of learning objects. These developments include a clearer model of layers of learning object aggregation, and empirical work that improves our understanding of how learning objects are used. The issue of the reuse of learning resources, pioneered in the learning objects work, has gained considerable traction. This is reflected in significant links with major related developments in Open Educational Resources (OER) and Learning Designs (LD)—both the subject of separate sections in this Reader.

The overall view of the universe of learning objects has been considerably elaborated by the development a clear hierarchical model of learning object aggregation (Verbert & Duval, 2008). This "ALOCoM" model outlines a hierarchical model where each layer incorporates and organises resources from the layer below Verbert & Duval, 2008). A variety of existing learning object models are mapped to a generic Abstract Learning Object Content Model. Boyle (2010) has used this model to explicitly link learning objects and learning design.

After the original standardization work around learning object metadata, additional technical standardisation work focused on further functionalities of learning objects, including how they can be "packaged" (much like zip files package content files), how they can interact with technical environments like learning management systems or virtual learning environments (by activating standardized so-called Application Programmer's Interfaces that enable learning objects to communicate with external systems). The result of this work is the Sharable Content Object Reference Model (SCORM), a widely deployed content standard services that provide additional interoperability on top of learning object repositories (Dodds, 2001). These include a query language for such repositories (Simple Query Interface or SQI), and a service for pushing learning objects into a repository (Simple Publishing Interface or SPI) (Simon et al., 2005).

Duval and Hodgins (2003) called for more empirical analysis of learning object (metadata) use. This work has led to advanced analysis that provides the foundation for learning object recommendation (as recommendations can, among others, be based on earlier use of learning objects by "similar" users) (Recker & Wiley, 2001). This leads to a more pro-active approach than mere reactive search (Verbert et al., 2012), which can also leverage data gathered in more recent "learning analytics" (Siemens, 2012). Thus Ochoa and Duval (2009) provided detailed quantitative analysis for repositories of learning objects, their size, growth over time, and the distribution of contributions, observing the typical "long tail" distribution that characterizes many Internet phenomena. Cechinel, Sanchez-Alonso, and Garcia-Barriocanal (2011) analyzed highly rated learning objects and point to the development of automated (and thus more scalable) quality assessment of learning objects.

The learning objects movement has had considerable influence on the areas of Open Educational Resources (OER) and Learning Design (LD). The ethos of repositories of reusable educational resources together with (simplified) metadata that describe the resources was adopted by both the OER and the LD movements, where similar repositories were deployed. Just as in the case of learning objects, re-use is a key objective in both OER and LD research.

In order to facilitate the sharing and reuse of learning objects, the legal base for reuse needs to be clear. Quite early on, many educators adopted a Creative Commons licence (Hilton, Wiley, Stein, & Johnson, 2010) which specifies the rights that the creator grants to users for using and adapting the learning resource. This has had a major impact on facilitating the "open education" movement.

Boyle (2010) addresses the crucial theoretical link between learning objects and learning design. The two key dimensions in this model are "layering" and "instantiation". He proposes a layered model of learning design where each layer provides services for the layer above. This model explicitly maps layers of learning design to the ALOCoM model of learning object aggregation. Learning objects then provide instantiation of learning designs (either implicit or explicit) at each layer in the learning design hierarchy.

There are thus crucial links in the learning objects work to OER and LD. Finally, the idea of base learning objects as small self-contained learning resources fits well with the concept of mobile learning (Bradley, Haynes, Cook, Boyle, & Smith, 2009).

All in all, learning objects research provides a productive area for ongoing and future development, either in its more original form, or through some of the concepts that originate back to learning objects, as developed in areas like Open Education Resources, open education, learning design and mobile learning.

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Chapter 14
Technical Learning Infrastructure, Interoperability and Standards

Xavier Ochoa and Stefaan Ternier

Introduction

Over the last 20 years, there has been a strong push in TEL to shift from the development of research prototypes to deploying mature systems. Different TEL application areas now have established tools that have proven their value, for example Moodle[1] for Learning Management Systems, OER Commons[2] and LRE[3] for Learning Content Repositories, and Open edX[4] for Massive Open Online Courses administration. All these system can be effectively used by students, teachers and administrators to facilitate the learning process. This shift from prototypes to mature systems, however, is not trivial and requires a concerted effort among researchers, practitioners and industry. Among the many factors that determine the emergence of these successful systems are their capacity to adapt and scale to different contexts (flexible infrastructure) and their capability to exchange information with other major systems (interoperability). This chapter will provide the reader with a review of the main efforts in the TEL field to enable these two factors through the development of specifications and standards.

[1] Moodle LMS: http://www.moodle.org.

[2] OER Commons: http://www.oercommons.org/.

[3] Learning Resources for Schools (LRE): http://lreforschools.eun.org/.

[4] Open edX: https://open.edx.org/.

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The TEL community has carried out early work in the definition of specification and standards. The first selected paper (Duval, 2004), concisely explains the need for standardization in order to reach interoperability between TEL systems, with the final goal of increasing their usefulness and adoption. In the words of Duval: “The essential feature in this context [Web standards] is interoperability: this means that independently developed software components can exchange information so that they can be used together”. While somewhat outdated, (Duval, 2004) provides insight on how this process could and has taken place for different aspects of new learning technologies. This article exemplifies how three web standards (HTTP, URL and HTML) facilitate interoperability between HTML editors, web browsers and web servers. Duval applies insights from the article to interoperability between Learning Object and Learning Management System Technologies, that were at that time new technologies (see also Chap. 13 on Learning Objects).

This chapter will guide the reader through several papers discussing past and current efforts to improve the maturity of TEL systems. Initially, most of these specifications and standards concentrated on the production and sharing of learning content and activities. Currently, most standards focus on the high-level interoperability between learning tools and the sharing of information about the tracking of learner actions. Respecting this historical development and to clarify the presentation of these papers, they have been grouped around five themes according to the specific tasks they address: (1) management, sharing and reuse of learning content, (2) design and production of learning content and activities, (3) deployment of learning content to the learner, (4) assessment and tracking of learner actions, and (5) high-level interoperability between learning tools. While these five themes could be seen independently, in reality they are interlinked. For example, to achieve high-level interoperability between learning tools (group 5), they should share information about the student actions (group 4) and the resources they worked with (group 1).

Group 1: Management, Share and Reuse of Learning Resources

While apparently simple, the concept of a learning resource has changed through the evolution of learning technologies. Several terms such as “learning object”, “courseware” and currently “open educational resources” have been used to label what is intuitively seen as the materials and content that are used for teaching and learning. However, independently of which label is preferred, many authors agree that the main reason for standardizing the description of learning resources in TEL is to be able to share and reuse them. This share-and-reuse functionality has complex technological requirements: (1) it should be easy for the sharer to publish the resource and easy for the reuser to find it, (2) information about the resource needs to be shared between the parties involved and (3) the sharer could be using a different tool or system to publish the resource than the reuser does to search and retrieve it. To solve these technological problems three solutions have been developed by the TEL community: Standard ways to describe the learning resource through what is known as “metadata standards”, the specification of a common infrastructure element to store and retrieve learning resources, known commonly as Learning Object Repositories, and standards to interchange information between these repositories.

Metadata Standards

To facilitate the sharing of learning resource information, several bodies have prescribed standard ways to represent this information. According to the IEEE Learning Technologies Standard Committee, the purpose of this data about the resource (metadata) is to facilitate the “search, evaluation, acquisition, and use of learning objects” (IEEE, 2002, p. 1). For example, publishing the title of a learning resource would help an interested party to find it. A review or comment created by a user would help to evaluate the relevance of the resource for another user. The link pointing to the actual resource, as well as the information about the copyrights of the resource would help to access and use the object in a legal way. Finally, the technical information about the resource, such as file type or size, would help the user or learning system to select the right tools to access the resource. Given that any information about the resource could be considered metadata, it is important to express this information in a previously agreed format (common schema) with a previously agreed meaning for each piece of information (common semantics).

Between 1995 and 2000, two initiatives appeared for the standardization of the metadata about learning resources: Dublin Core (DC) and Learning Object Metadata (LOM) (Duval, Hodgins, Sutton, & Weibel, 2002). They had their origin in different domains but in essence solve the same issue. Dublin Core stems from the domain of Digital Libraries and defines metadata for the purpose of resource discovery. LOM has been created with the purpose of managing, locating and evaluating learning resources. These two standards describe a schema that defines what information fields are shared and what values these fields can have. Due to the difficulties to agree on a common meaning for those values, both of these initiatives fell short of describing a common semantic (Duval and Hodgins, 2003). To know more about the features and shortcomings of these two standards, the reader is invited to review (Anido et al., 2002).

Learning Object Repositories

Learning resources can be shared in several ways. They can be just published on the web, made available in online forums or passed personally from user to user. These ways, however, have some disadvantages. For example, the web search engines do not provide any feature to differentiate content designed for learning from other type of general content. Online forums, even if focused on learning resources, do not provide any common way to categorize or describe the published material. TEL has devised a better conceptual way to manage the sharing of learning resources: Learning Object Repositories (LOR). In their most common form, LORs usually store the learning object itself and the metadata description associated with it. The LORs provide some sort of indexation facility, where users can add new learning resources together with their metadata. They also provide search or browsing facilities to provide access to the content of the repository. The main research papers about LORs focus on their evolution (Richards, McGreal, Hatala, & Friesen, 2002), their types (McGreal, 2008) and how they grow (Ochoa & Duval, 2009). Although LORs seem to be a good idea, they are not generally perceived as useful by teachers and students. The most common LOR implementations have been plagued by several shortcomings that limit their usefulness: ignoring or misusing the social aspect of sharing, lack of user-friendliness for indexing new content and focus on archival instead of usage, among others. See Ochoa (2005) for a critique on LORs and possible improvements. A new wave of LORs, such as OpenStax[5] (previously Connexions), OER Commons and LRE have proven that these learning infrastructure components, with mature implementation, can be useful and are actually being used in the real world.

Sharing Resources Between Repositories

Consortia managing TEL infrastructures for sharing learning resources realized that the creation of structured metadata by experts is cost-intensive and does not scale (Meire, Ochoa, & Duval, 2007). In addition, publishing learning resources and their metadata in isolated repositories impedes share and reuse. In order to achieve a critical mass of resources, several repositories should be interconnected and their resources pooled. Currently, two independent technical solutions are adopted to connect heterogeneous repositories: Federated Search and Metadata Harvesting (Ternier et al., 2009). In Federated Search, the search requests are distributed in real-time to the various repositories in the network and the user is presented with an aggregate results list that combines the results provided by all the responding individual repositories. Federated search always searches in the current version of the metadata, however, network delays and repository outages, have an impact on the end-user experience. On the other hand, Metadata Harvesting aggregates metadata to single location beforehand to create a metadata cache. The query is executed at one location and because it does not suffer from network delays, the search request is faster and easier to manage, however, the metadata could be out-dated. Research in search protocols like SRU/SRW (Morgan, 2004) and SQI (Simon, Massart, Van Assche, Ternier, & Duval, 2005) originally led to

[5]OpenStax Repository: www.cnx.org.

architectures for federated search. An early example of this approach is Edutella (Nejdl et al., 2002), a peer-to-peer federated search network, that has put strong emphasis on the query capabilities of the network building on a Semantic Web infrastructure. MERLOT (Cafolla, 2006) builds on federated search to dynamically route user queries to the different repositories in a learning object repository network. However, more recent infrastructures in TEL tend to build on more generic Web protocols like OAI-PMH (Lagoze, Van de Sompel, Nelson, & Warner, 2002), RSS (RSS 2.0 Specification, 2009) and Atom (Nottingham & Sayre, 2005) to harvest metadata. The GLOBE alliance,[6] an initiative that connects all major learning object repositories in the world exemplifies this. GLOBE, that originally only supported federated queries, currently provides a search interface that relies on metadata harvesting.

The most representative paper on the experience of sharing resources between repositories is (Hatala, Richards, Eap, & Willms, 2004), our second selected paper. This presents the eduSource Communications Layer (ECL) that implements the IMS Digital Repository Interoperability (2003a, 2003b) specification. This article not only discusses in detail the various initiatives and techniques for digital repository interoperability, but also presents ECL as a framework for interoperability including both federated search and metadata harvesting techniques.

Although connecting learning object repositories helps to reach a critical mass of content, that is, enough materials are findable and accessible from a single query interface to motivate teachers and students to use it, there is also value in making the publication of new objects less cumbersome. Standards like the Simple Publishing Interface (SPI) (Ternier et al., 2009) and SWORD (Allinson, François, & Lewis, 2008) emerged to facilitate this process. They provide interoperability between parties that publish content (e.g. authoring tools, learning management system) and parties that manage content (e.g. repositories).

Group 2: Design and Production of Content and Activities

Defining information about a learning resource and having a way to share it is only the first step to render learning content useful for the learner. These resources are commonly embedded into sequences of learning activities that the student follows. The most common standard to represent, package and sequence the learning resources and activities is SCORM. The Sharable Content Object Reference Model (SCORM, n.d.) is a collection of standards that was developed by the Advanced Distributed Learning (ADL) initiative. SCORM defines a specification for representing the content structure of a course. In addition to representing content, SCORM also defines an Application Programming Interface (API) that details how content objects can communicate with the Learning Management System (LMS).

[6] GLOBE Alliance: http://globe-info.org/.

While SCORM focuses on the structure of content and focuses on sequencing this content, IMS Learning Design (2003a, 2003b) pays attention to the learning process. It specifies how to organize activities rather than content and is concerned with the roles of participants in these activities. While the role of metadata for content description is to communicate information about a single resource, here the role of metadata is to encode how the content or activities are structured. SCORM and IMS LD enable the learning objects such as SCORM resources or IMS Learning Designs to be created in an authoring environment and to be consumed by an LMS, a typical example of interoperability.

In Koper (2001), our third selected paper, the foundations of the educational modeling language EML are presented. Defining semantically the learning from a pedagogical perspective, EML aimed at providing reuse and interoperability. EML later evolved to IMS Learning Design (IMS LD) that is made up of three levels, with each level extending the previous level with more functionality. By enabling instructors to capture their designs, learning designs can be reused, contextualised and replayed. From 2009 onwards, user-friendly tools started to emerge that implement this specification. The ReCourse editor (Griffiths, Beauvoir, Liber, & Barrett-Baxendale, 2009) is such a tool. Unlike modern word processors, this ReCourse does not provide a direct visual interface (What You See Is What You Get—WYSIWYG) interface to user. The learning curve for this tool is rather steep, as the user needs a comprehensive understanding of all levels of the IMS LD. LAMS System (Dalziel, 2003) and Cloudworks (Conole & Culver, 2009) were also inspired by this work and provide usable interfaces to realize the learning designs. Currently, the vanguard in activity design, production and sequencing tools is exemplified by Learning Designer[7] (Laurillard, 2013), an authoring tool and repository for learning design patterns (exemplary sequences of activities that could be populated by different content) and the activity creation tools from MOOC platforms such as edX Studio.[8]

Group 3: Infrastructures to Deploy Learning Content to the Learner

Once learning resources and activities have been sequenced and packaged, they are ready for distribution to the learner. This distribution typically relies on Learning Management Systems (LMS). These systems rely on content standards to import and play content. Most Learning Management Systems support SCORM or IMS Content Package to interchange from individual files to whole courses. This provides a minimum level of interoperability between LMSs. If teachers want to

[7]Learning Designer: http://learningdesigner.org/.

[8]https://studio.edx.org/.

migrate from for instance Blackboard to Moodle, they can use the export function from the first system and the import function of the second.

Currently, the most advanced standard for sharing learning content between large TEL systems is IMS Common Cartridge.[9] This standard is, in reality, a collection of other standards such as LOM and Content Package that facilitate the description and transfer of not only learning content, but learning activities between systems. For a discussion of the advantage of Common Cartridge over the more traditional SCORM, please refer to Gonzalez-Barbone and Anido-Rifon (2010).

Group 4: Assessment and Tracking of Learners

Maybe one of the last aspects of the learning process to receive the attention of standardization bodies has been the tracking and assessment of student learning. This is due to the complex and heterogeneous nature of the task. It is no surprise then that the most mechanical part of assessment and online evaluation has the oldest and stronger standards in this area: the IMS Query and Test Interoperability (QTI) specification. This standard allows systems to interchange test, questions and their results. It is widely supported by most LMSs and learning tools. For a critique of the QTI standard, see the reader could review (Conole & Warburton, 2005).

For more complex assessment information, the focus has been concentrated on the management of student record information, mostly oriented to the administration of the institutions. Examples of this kind of standards are the ones proposed by the Schools Interoperability Framework Association (SIF) and the Postsecondary Electronic Standards Council (PESC).

Recently, due to the ability of most systems to capture, store and process large amounts of data about user actions in diverse tools, a new field called Learning Analytics is revolutionizing the way to conduct assessment of students. This new field, however, still lacks a standard to share the captured information in order to enable the interoperability between these enhanced assessment tools. An early attempt to create such standard is represented by the Contextual Attention Metadata (CAM) initiative (Wolpers, Najjar, Verbert, & Duval, 2007), the fourth of our selected papers. While not a standard, the CAM initiative enables capturing user actions from heterogeneous tools and provides a common repository for this data. More mature and widespread initiatives to share action-based metadata (also known as paradata) are TinCan API (also known as Experience API) (Poltrack, Hruska, Johnson, & Haag, 2012) and the Learning Registry (Bienkowski, Brecht, & Klo, 2012). It is predicted that these type of specifications (standards in the future) can have a strong impact on the evaluation of the effectiveness of the learning that occur in the different TEL systems.

[9] IMS Common Cartridge: http://www.imsglobal.org/commoncartridge.html.

Group 5: High-Level Interoperability Between Learning Tools

Learning activities involve more than just working with sequences of content. Learning activities can rely on different tools such as wikis, shared whiteboards, video-conference applications, online question-answer, video blogging or student e-portfolios, among others to provide learning opportunities to students. It is unrealistic (and maybe undesirable, in an open world) to expect that any TEL system could provide all possible functionality by itself. Even LMSs, the most comprehensive TEL systems to date, only provide a small subset of all the tools or applications that can be used for learning. Due to the difference between the implementation of different learning systems and the lack of a widespread standard for software reuse, it was has been more difficult to share functionality between learning systems than to share packaged content.

Current standardization efforts in the TEL community try to provide seamless ways in which different learning tools can interoperate at a higher-level, sharing not only learning resources, but learning applications. For example, LMSs that do not provide a learning tool natively, can rely on external services in order to offer these advanced functionalities to its users. For example, the Canvas LMS[10] enables the user to record video and audio inside the LMS through the integration with Kaltura,[11] a multimedia server solution. To achieve this level of interoperability to work, there should be a common way in which the two learning applications interchange information about the users, their needs and their actions.

Even without the existence of any specific standard, several applications have utilized web standards such as HTML, JavaScript and Web Services to integrate different tools in a common user experience. The main showcase for the interoperability between learning applications are the Personal Learning Environments (PLE). These TEL systems enable learners to select their own sets of learning tools from around the web to create a personalized LMS. The ROLE project makes extensive use of Web Services to provide PLEs based on interoperable learning solutions (Govaerts et al., 2011). The level of interoperability in this kind of systems is low, given that the tools are only presented together, so the interchange of information about the learners or their actions is limited.

Several specifications have arisen to enable full high-level interoperability between learning tools. Alario and Wilson (2010) present a comparison between IMS Learning Tools Interoperability, Basic LTI, Apache Wookie and the Group Learning Uniform Environment (GLUE!). All of these are specifications that enable the high-level interchange of information between learning tools. These specifications are very promising, but due to their recent development and the lack of standardization, their support in major TEL systems, such as LMSs, is still in an

[10] Canvas LMS: http://www.canvaslms.com/.

[11] Kaltura Media Server: http://corp.kaltura.com/.

initial or incomplete state. More recently, IMS LTI v2.0 seems to be adopted as the standard for tool interoperability as the IMS certified product directory already lists more than 300 official LTI implementations.

Conclusions

TEL researchers, practitioners and vendors have recognized early on the need to create specifications and standards that enable the scalability and interoperability of TEL systems. While not all these efforts have been successful, as testified by the amount of those specifications and standards that have not been used or have been misused (by subjecting the end-user to unnecessary technical details), all of them have contributed to the understanding on how a TEL system should work and interoperate with others. Current successful implementations of mature TEL systems are based on the lessons learned while developing, testing and deploying standard ways to share content, activities and other relevant information between heterogeneous tools.

The main focus of TEL is to provide better experiences and outcomes to all participants in the learning process. It should be irrelevant for the end-user if the answer to their query is processed by a Federated Search or a Metadata Harvesting infrastructure, or if the export feature of their LMS works with SCORM or Common Cartridge. The important aspect for the end-user is that the system works as desired and that it facilitates their acquisition of new knowledge. The TEL infrastructure and standards should be the workhorse that enables a seamless learning experience, becoming, effectively, invisible.

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Chapter 15
Digital Divides and Social Justice in Technology-Enhanced Learning

Lyndsay Grant and Rebecca Eynon

Beyond the Divide

In contrast to popular opinion, the digital divide is not going away. In fact the inequalities in access, use and experiences of the Internet may be getting wider (Helsper, 2011). The digital divide initially referred to the gap between those who had access to digital technology—particularly the Internet—and those who did not. However, since the early 2000s our understandings of the digital divide as a simple binary distinction between the digital 'haves' and 'have-nots' has shifted to a more complex conceptualisation that takes account of a range of individual and contextual factors in understanding use and non-use of the Internet (Chen & Wellman, 2004; Van Dijk, 2006). This is reflected in the literature where we see a shift away from the term digital divide to digital inequality (DiMaggio & Hargittai, 2001) or digital social inequality (Halford & Savage, 2010). At the same time, research in this area has moved away from more technologically deterministic arguments that assume that if people have access to technology then other benefits will automatically follow, towards a more holistic argument that recognises the complex relationships between technology and society.

Neil Selwyn (2004), in the first selected paper for this chapter, provides a useful critique of limited notions of the digital divide that see it simply in terms of a dichotomy between those who do and those who don't have access to ICT. Firstly, ICT itself is not a homogenous category nor is it limited to the Internet. Secondly, "access" needs to account for gradations in the quality of access and

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individuals' perceptions of access. Thirdly, it is important not to equate access with use; meaningful use is a result of a complex mix of psychological, social, economic and practical factors. Finally, transforming the "have-nots" into "haves" is in danger of mistaking the means of ICT access with the ends of positive social, personal and educational consequences. In this article, Selwyn proposes a more complex hierarchical model that moves from 'formal' access to achieving long term positive consequences from ICT engagement. There still remains the question of explaining why some people are able to move to the top of this hierarchy while others do not step on the first rung of the ladder. Here, Bourdieu's concepts of economic, cultural and social capital (Bourdieu, 1997) are used to encompass the non-technological and non-economic as well as the technological and economic factors. Economic capital is clearly significant for the purchase of ICTs. Cultural capital includes the skills to use technologies, but also the 'know-how', attitudes towards ICT use and socialization into technology cultures that makes the difference between access to ICTs and meaningful use. Social capital describes the remote and face-to-face networks of expertise that people can tap into that provide advice, ideas and links to new technologies, services and ways of using them. This article provides a useful counterweight to overly simplistic notions of a binary digital divide, and provides an important and necessary refocusing of debates towards the outcomes of ICT use rather than simply seeing it as a worthy end in itself.

The second article selected for this chapter, by Mark Graham (2011), considers the subtle gradations of digital divisions in a spatial context within cyberspace itself. The spatial metaphor of moving into cyberspace places Internet use as the latest in a long line of claims about how technologies will overcome distance and geography to bring people together in a single space. Yet Graham shows how people's opportunities for online production and consumption are not completely independent from their offline geographies. Spatial differences such as rural/urban, global North or South, available technological infrastructre and access to networks and education, influence the kinds of online participation available and are not removed by gaining access to cyberspace. Further, cyberspace itself cannot be understood as a single 'place' shared by everyone, but, as Graham puts it, has its own "mappable geographies and uneven topologies" (p. 217). The article reproduces a "map" of cyberspace showing how users' engagement with other people and information is mediated through billions of nodes which are not all well networked with one another, meaning that it is not necessarily possible for everyone to move seamlessly from node to node across the space. Various mechanisms make some parts of the network inaccessible or less accessible to some people. These mechanisms include censorship and blocking from state censorship to parental limits on access and Internet filters; the language of communication makes large swathes of the Internet only accessible to those with fluency in English. The way we find and access information also results in some kinds of information being more visible and accessible than others. Search engine algorithms present search results in rank order in a way that increases the visibility of websites that are well-networked—resulting in websites that are outside powerful social networks remaining less visible. Rather than a single "cyberspace" overcoming geographical constraints, a picture emerges of countless small—but nevertheless often insurmountable—divides within cyberspace itself. Ultimately, we need to consider cyberspace not as a single shared space that transcends geographical distance and inequalities, but as a series of multiple, scattered, disconnected spaces, that retain connections to their users' local physical spaces. Inequalities and divides exist within these virtual topologies, with some people being excluded from the powerful networks and flows of information in ways that can reinforce existing social, economic and political power structures.

These two articles move the debate about the digital divide firmly beyond a single divide between those who have and those who do not have access to ICT. Instead, we need to recognise the multiple ways that existing inequalities play out in individuals' and groups' engagements with technologies, how divisions exist within the connected world and in the outcomes people achieve from their engagement with technologies. However, it is important to recognise, as both Selwyn (2004) and Graham (2011) do, that it is not inevitable that technology use simply replicates existing patterns of inequality; the potential for change still exists and efforts to reduce inequalities need to be tackled with a more nuanced understanding of the causes, nature, and consequences of digital inequalities. Technology-enhanced learning (TEL) plays an important role in these debates, both in terms of designing initiatives that have an awareness of these inequalities and in creating opportunities to address them. To date, much of the research around the digital divide does not consider or speak to the TEL community and vice versa (although see Seale & Cooper, 2010). Here we try to bridge these two areas of important work.

Mapping and Overcoming the Digital Divide

The ways that people use the Internet and other new technologies are not the same, with significant differences in the amount of time, type, and range of activities people engage in online. These differences can be explained to a large degree by differences in demographic, individual and social characteristics that can be categorised into different dimensions of inequalities that try to incorporate people's digital and non-digital environments. For example, DiMaggio and Hargittai (2001) proposed five dimensions of digital inequality: equipment, autonomy of use, skills, social support and purposes of using the Internet.

Thus factors such as age and life stage (Eynon, 2009); skills (Hargittai, 2010; Livingstone & Helsper, 2010; Van Deursen & Van Dijk, 2011); confidence in technology (Eastin, 2005); positive attitudes towards technology (Dutton, Shepherd, & di Gennaro, 2007); quality of access (e.g. home access, personalised access, number of locations of access) (DiMaggio & Hargittai, 2001; Dutton & Blank, 2011); better support networks to use technology (DiMaggio & Hargittai, 2001; Eynon & Malmberg, 2011); the family context (Vandenbroeck, Verschelden, & Boonaert, 2008); and a range of other factors are positively related to uptake of a wider range of online activities.

Underpinning all of these patterns are issues of inequality. Those who are digitally excluded tend to be socially excluded as well. For the most part then, the digital simply replicates or reinforces existing inequalities in society. For example, in the case of learning, access to the Internet has not really increased the number of adults engaging in organised learning opportunities (Barraket, 2004; Eynon, 2009; Selwyn, 2006). In a nationally-representative survey, White and Selwyn (2012) found that those adults who were already taking up learning opportunities in the real world (e.g. night classes, work based training) also took up similar learning opportunities online, whereas those who had never engaged in adult learning were unlikely to re-engage with learning due to the increasing availability of learning opportunities in the online sphere. There is some evidence that the more informal the online learning opportunity, the more factors, beyond social exclusion, that become important (e.g. age, attitudes) but this is an area that is under-researched and needs to be fully explored (Eynon and Helsper, 2011; Warschauer et al. 2012; Thomas et al. 2005).

These patterns of inequalities in use of the Internet are consistent across many countries as demonstrated by the well-known studies by the Oxford Internet Surveys (OxIS) in the UK, EU Kids Go Online and Eurostat data that are collected across Europe, the Pew Internet surveys in the US and other survey data from across the globe that is collected as part of the World Internet Project.[1] Notably for TEL researchers, level of education has consistently been shown to be one of the most important factors in use/nature of use of the Internet, with those who are better off being more likely to benefit. Skills and self-efficacy beliefs about technology often follow as a close second.

However, there is very limited research in the digital divide literature that explores the complex link between use of the Internet and outcomes (Van Deursen, Helsper, Eynon, & Van Dijk, 2016). For example, the online sphere offers a range of opportunities that potentially could lead to learning in the widest sense of the term. These include information seeking (Rieh, 2004), communicating (Hew & Hara, 2006), watching videos, listening to music, blogging, sharing pictures and creating media content (Rollett, Lux, Strohmaier, Dösinger, & Tochtermann, 2007). Such activities may support individuals learning about themselves, about a topic of interest, and as a way to participate fully in social and cultural life in a digital age (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2006). However, taking up these usage opportunities does not straightforwardly equate to learning. We need to better understand what needs to happen for people to achieve meaningful benefits from using technologies in the context of their lives; and to understand this with an awareness of the normative assumptions that are often in play within research in this area (Tsatsou, 2011).

[1] See http://microsites.oii.ox.ac.uk/oxis/; http://www2.lse.ac.uk/media@lse/research/EUKidsOnline/Home.aspx; http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/; http://www.pew.org/; http://www.worldinternetproject.net respectively.

Livingstone and Helsper (2007), in the third selected paper, also stress this point in relation to online opportunities. In their analysis of nationally representative data of 9–19 year olds they present the 'gradations' rather than 'divides' in young people's Internet use, and discuss the possible implications of such use for young people's everyday life. They note that Internet use is never static and needs to be considered over time. Importantly for digital inclusion research, their analysis highlights that young people tend to start using the Internet for only a couple of activities and tend to take up more online opportunities as they become more experienced. Thus, supporting "basic" or "popular" uses may act as a gateway to more "complex" and perhaps more "capital enhancing" online activities such as learning.

The fourth selected paper, (Van Dijk, 2006) highlights the kinds of inequalities that are important in digital divide research. He suggests these are: immaterial (life chances, freedom), material (economic, social and cultural capital, resources); social (positions, power, participation) and educational (capabilities and skills). He argues that digital divide research requires more developed theoretical frameworks in order to determine precisely what is new about inequalities in access and use of the Internet and related technology compared to other resources in society in order to ascertain the real life outcomes related to differences in Internet use. He suggests that, if one considers information as a core resource in society, then new disadvantages are occurring due to a lack of access to information, inability to use information effectively, and reduction in power in the network (Van Dijk, 2006). Such considerations help to develop a more nuanced understanding of the meaning of Internet use on learning and everyday life.

While the outlook is not particularly positive, there are a significant minority of people who are socially excluded but are to some extent digitally included (Eynon & Helsper, 2011; Helsper, 2008). Thus, there is for some a form of "digital choice" in operation (Haddon, 2004; Wyatt, 2003). While "choice" is a somewhat problematic concept, as any choice is made within people's existing social structures (Eynon & Helsper, 2011), it is quite useful conceptually as it moves us away from a deficiency model that sees non-use or low use of the Internet as inherently a deprivation (Selwyn, 2004). It also suggests that successful intervention is possible.

How Might Education Respond to Digital Inequalities?

Aside from questions about how to conceptualise and measure digital inequalities, there is the question of what can be done to reduce the effects of such inequalities. There are several ways that educational institutions might be thought to play a role in reducing such digital inequalities, including providing a point of access to the Internet, supporting young people in their development of their digital skills (Eynon & Geniets, 2015; Eynon & Malmberg, 2011), and providing students with a good understanding of the range of opportunities that may be available to them online. Jenkins et al. (2006) also emphasise the potentially important role of schools in ensuring all young people are able to fully engage in online participatory cultures, not only those who have the necessary resources and support at home.

The extent to which schools actually can and do provide such opportunities varies between schools and, in general, schools in better off areas tend to use the Internet and digital technologies in more sophisticated ways and give students more access and support (Lee, 2008; Warschauer, Knobel, & Stone, 2004). Of course, some schools in deprived areas do provide more innovative approaches. However, most schools can only go so far in providing access and support for online learning and participation as they usually limit the time young people can spend online and the kinds of content and services they are able to engage with—particularly in terms of restricting access to sites where social interaction is possible or entertainment, video, games and music can be accessed (Dresang, 2005; Ito et al., 2008; Lee, 2008; Sharples, Graber, Harrison, & Logan, 2009). Educational institutions are often criticised for not using new technologies in significant and meaningful ways and teachers are often accused of lacking skills and having negative attitudes in this domain. Schools and teachers should not be singled out for blame in this regard without understanding the wider demands placed on them however, as limited use of technology in education can be a very rational choice given the formal systems and structures in place (Crook, 2002; Eynon, 2008). There are many reasons why schools limit children's online engagement, including the availability of technology and supervisory resources, time needed to cover curricular content, the educational priorities of the school, as well as concerns about online misbehaviour, privacy and e-safety (Sharples et al., 2009). Young people may therefore find their use of technologies at school is not able to overcome restricted opportunities at home. For example, in a qualitative study in the UK of young people who did not have Internet access at home the most notable implications were a feeling of being left out socially, of not being able to do homework as thoroughly as they would like and not being able to simply "do their own thing" online. It appeared that in qualitative terms at least a lack of home access was tending to reinforce and compound existing social inequalities (Davies & Eynon, 2012). Similarly, in the US Robinson (2009) demonstrated how a lack of access to home computers led to an instrumental approach to using technology that had implications for confidence and ways of using technology for learning.

How Might Technology-Enhanced Learning Support Social Justice?

Digital inequality is a social injustice itself, but some research also explores how technology-enhanced learning might offer opportunities to address other social inequalities. Of course, as discussed above, the idea that digital technologies can in themselves comprehensively address social injustices overlooks the complex individual, institutional, economic, political, cultural and societal factors that give rise to inequalities in the first place and the correspondingly complex ways these inequalities need to be addressed. No form of technology-enhanced learning can therefore be seen as a sure-fire route to overcoming social injustice, but there may be some ways in which it can play a supporting role when it is developed with an understanding of, rather than assumptions about, the particular people the intervention is aiming to support.

If we think of overcoming digital inequalities as achieving meaningful and beneficial consequences from engaging with digital technologies, then similarly we can ask how technology-enhanced learning might support participation in society in terms of social, economic, political and cultural benefits. Exactly how such participation and outcomes are defined, however, is something to be determined with technology-users themselves rather than pre-determined by researchers, governments or other organisations, though approaches such as user-centred or participatory design (see Light & Luckin, 2008).

Research in this area is dominated by case studies of particular initiatives and so it is difficult to draw general conclusions about the role or "effectiveness" of technology-enhanced learning in furthering social justice. There are, however, several themes in which researchers have focused their attention on how technology-enhanced learning might have something to offer.

Access to Education

Technology-enhanced learning has been seen as providing access to educational content by those who otherwise would be excluded from education, particularly in areas where access to formal education and educational resources are limited. The use of mobile technologies to support learning in African countries where wired infrastructure is not available has been claimed as on the "tipping point" of becoming a major area of research, practice and policy (Traxler & Ng'gambi, 2012) while others have seen technology-supported learning as offering potential in situations where many children are unable to attend school (Unwin, Tan, & Pauso, 2007). However, technology-enhanced learning still faces challenges of scalability and sustainability as well as challenges of providing appropriate cultural and context-specific content and approaches and its success remains dependent on the enthusiasm and dedication of learners and teachers (Traxler & Ng'gambi, 2012). Local technology-enhanced learning initiatives can usually only address some specific needs; for example, Unwin et al. (2007) found that the street children they worked with would have preferred to attend mainstream school but their parents could not afford to keep them there. A technology-enhanced learning approach providing access to educational content may in this case provide some alleviation of inequalities but is unlikely to be able to make inroads on the broader inequalities in these young people's lives.

Two of the most well-known initiatives using technology to support learning opportunities to low-income children and countries include the One Laptop Per

Child initiative which offers low-cost laptops to children in low-income regions[2] and the Hole in the Wall project which provided opportunities for self-directed learning via computers accessible through street kiosks (Mitra & Rana, 2001). Both these projects have received their fair share of critique however, for an overly technocentric approach that underplays the importance of appropriate content (in terms of language, culture and educational content) and the role of teachers and the wider community in the use of technologies for education (Warschauer, 2002; Warschauer, Cotten, & Ames, 2012).

More recently, technologies have supported wider access to education through the sharing of Open Educational Resources (OERs) and distance participation in Massive Open Online Courses (MOOCs). Much of the impetus behind OERs and MOOCs is driven by a desire to use technologies to provide access to education—or a different kind of education—than would otherwise be possible. For example, OER Africa aims to build educational capacity and support access to education across the continent.[3] As OERs and MOOCs become integrated within the business models of universities and commercial producers of educational resources, questions of who gets to access these opportunities and the consequences of participation remain to be answered. However, based on the current evidence, it seems that those who are most likely to participate in such initiatives are well educated people from well-off countries (Ezekiel, 2013).

Recognising Learning Outside the Mainstream

The consequences of not doing well in formal education are serious and long-lasting and there is evidence that children from lower socio-economic status households tend to achieve less highly than their more privileged peers. Yet the same young people may be engaging in informal learning activities outside school that are not recognised in mainstream education. Some research has explored how digital technologies might support informal learning outside school and the potential of digital tools to capture and represent such learning to enable reflection on learning by the learners themselves as well as formal educational institutions (e.g. Walker, 2008).

Some research has particularly focused on broadening the kinds of learning and achievements that we value and give credit to beyond the traditional academic standards measured by schools. For example, the Badges for Lifelong Learning project explored how skills developed through online participation could be recognised and accredited.[4] Assessment of learning that takes place in digital communities can connect learners to knowledge communities well beyond what they would experience in school and may enable more kinds of learning to be recognised as valuable.

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[2] http://one.laptop.org/.

[3] http://www.oerafrica.org.

[4] https://www.hastac.org/collections/badges-learning-research.

While digitally capturing and accrediting diverse kinds of learning may allow a wider range of skills and talents to be recognised, its ability to contribute to more socially just forms of education needs to be balanced against the skills and qualifications that are valued by society more broadly and employers in particular.

Education for Citizenship and Political Engagement

The capability to engage in political and civic life is an important aspect for full social participation and can be conceptualised as engaging with others to work for improvements from the local to global level and engaging with a diverse range of perspectives. Some fear that online communities allow us to limit our encounters with others to those who share our own perspectives, but large scale quantitative research has found that when US young people encountered others' perspectives online they encompassed a diverse range rather than simply those that confirmed their own opinions (Kahne, Middaugh, Lee, & Feezell, 2011). Some young people however did not encounter very many perspectives of any persuasion at all. Where young people had experienced digital media literacy education this was associated with greater exposure to diverse perspectives as well as deeper political engagement online. Kahne and colleagues (Kahne, Feezell, & Lee, 2012; Kahne, Ullman, & Middaugh, 2011) make the point that online engagement can foster civic and political engagement, but that this does not automatically happen for everybody and digital media education is needed to ensure that all young people can take advantage of this opportunity.

Future Challenges for Digital Divide Research

The more complex and nuanced understandings of the digital divide bring with them new theoretical and empirical research challenges. Most of the research that maps the changing contours of digital divides is quantitative and therefore tends to measure the frequency and breadth of use but does not capture the diverse meanings or consequences of technology use for individuals, and how these are shaped within the wider contexts of their lives (Mehra, Merkel, & Peterson-Bishop, 2004; Thomas, Haddon, Gilligan, Heinzmann, & de Gournay, 2005; Tsatsou, 2011). Similarly, while we now have a better understanding of the ways that different forms of digital inequalities and social inequalities inter-relate we need to segment Internet users into better defined groups to understand the differences between them and the different kinds of support they might need (Eynon, 2009; Eynon & Malmberg, 2011). The use of more participatory designs and practices within this area of Technology Enhanced Learning (TEL) could also be particularly valuable. Indeed, research that aims to understand the ways that TEL might support greater social, economic, cultural and political participation tends to be case study based; further research is needed to situate promising initiatives within a broader understanding of pervasive inequalities for particular individuals and groups to draw conclusions about any potential role for TEL in furthering social inclusion.

We hope here to have made some useful connections between research into digital inequalities and research into technology-enhanced learning. Ultimately, we need to bring together efforts to tackle digital inequalities and digital approaches to tackling social and educational inequalities within a broader programme of policy and practice that commits to tackling inequalities at every level of society.

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