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OECD Work on Technology and Education: innovative learning environments as an integrating framework

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Introduction

The aim of this article is two-fold. First, it presents in succinct summary a selection of the work conducted by OECD in the field of technology and education. This has been an on-going focus since the 1980s and recently, much of this has been carried out under the heading of 'New Millennium Learners'. But the technology focus extends well beyond a single project and includes work on innovation, open educational resources and the development of the digital resources market, as well as ICT use in educational settings, access, and digital competence.

Second, the article considers the assumptions underlying much work on technology in education to propose that a more holistic focus on learning environments, of which technology is only a part, represents a fruitful avenue to help design education for current and future systems. OECD has a project called Innovative Learning Environments (ILE) which has just reconceptualised 'learning environments' in general and 'innovative learning environments' in particular, drawing on 40 case studies in 19 systems (sometimes countries, sometimes regions or states) to illustrate the framework and to refine it iteratively[1]. This article presents this framework to show how technology enters into schooling in very diverse ways. There is neither a single 'technology effect' nor does technology operate by itself, but always in combination with all the other elements, dynamics, contexts, and partners of learning environments.

OECD Work on Technology in Education

There is longstanding work in OECD on 'new technologies', dating back to the 1980s that include analyses on how such technologies might transform the teaching of reading, writing, science and mathematics (OECD, 1986; 1987). In the years that followed, adults were as much in focus as school-age students, and in the early 2000s this resulted in two reports that also had a strong equity focus — one on the digital divide (OECD, 2000) and one on ICT and out-of-school youth and adults (OECD, 2004a). Schools and schooling were not ignored, and the 2001 report 'Learning to Change — ICT in Schools', written under the 'Schooling for Tomorrow' umbrella, arrived at a set of conclusions that maintain a relevance today:

> *Digital literacy is now a fundamental learning objective*, including information-handling skills, and the capacity to judge the relevance and reliability of web-based information.
>
> *Curriculum change is needed in the Internet age:* the open, skills-based, student-centred approaches supported by ICT call for changes in schooling, teaching and learning.

> *Student assessment must be compatible with ICT-enriched learning:* there is a very mixed message being conveyed by expecting young people to be digitally literate and then assessing them in conventional ways.
>
> *Schools must be fully equipped and supported, backed by quality educational software* — in order to get over the 'thresholds' that allow use on demand within classrooms, and to be readily available out of lesson time.
>
> *ICT requires more demanding teacher professionalisms* calling also for appropriate professional development.
>
> *Leadership fully committed to adopting ICT* is needed so that working with ICT in schools becomes integral and unexceptional, and the change is sustained.
>
> *School, home and community have new opportunities for partnership:* ICT encourages — and ultimately requires — a learning environment based on dynamic partnerships between the home and school, what is learnt in school and outside, and between teachers and students (OECD, 2001).

While such conclusions remain fully relevant to many schools and systems, they were cast largely within the conventional parameters of schooling rather than more hybrid arrangements that importantly incorporate non-formal learning. Some of the conclusions also reveal an implicit 'technological determinism' in that the logic was as much about the change needed to obtain the most from the technology as about how to design good teaching and learning and then examine how different technology uses and applications could be brought into play in the service of such designs.

New Millennium Learners

In more recent years, a great deal has been achieved under the umbrella of 'New Millennium Learners' (NML) that concluded with its final publication (OECD, 2012). The NML project focused on young people and their digital experiences and expectations, as well as on progress regarding technology use or application in education. The final 'Connected Minds' publication arrived at what it itself describes as a 'conservative' conclusion: young people's expectations as learners in relation to technology use in formal education seem not to be changing dramatically and they are not always comfortable with innovative educational uses of technology despite the social media and digital practices they otherwise engage in as young people. This is not to say that they want no change, as they do expect technology to be: a) a source of engagement to make learning more interesting and relevant, b) a means to make school work more convenient, and c) a means to make it more educationally productive. There is, in short, a large degree of instrumentalism in young people's expressed opinions — whether they would be less instrumental if the norm they experienced was tech-rich, learning-focused schooling can only be speculated.

NML also contributed to improving basic international data on access to and use of ICT in education, and it launched specific reviews of 1-to-1 computers in classroom schemes (Valiente, 2010) and of ICT and initial teacher education (Rizza, 2011). On the 1-to-1 initiatives, for instance, the messages are mixed. On the one hand, such schemes are seen to have shown some positive impact on ICT skills and writing, and also to help bridge the first digital divide in the access to ICT at home and in school as well, potentially, as the digital divides between developed and developing countries. On the other, there is only very modest evidence

concerning gains in other academic domains such as mathematics and little evidence about the cost-effectiveness of these initiatives or their influence to change teaching and learning strategies (See also Bocconi *et al.* in this issue pp. 113–130).

Developing and managing knowledge about technology in education was a prominent focus for NML. Among the conclusions reached was the need to systematically develop knowledge about technology innovation, with an evolving framework for sustaining both top-down and bottom-up technology-based innovations and appropriate capacity building, and a well-organised, easily accessible, and up-to-date knowledge base. It was argued to supplement investments in technology-based innovations with the necessary monitoring, evaluation and research, instilling a culture of output-oriented innovation, getting value for money, and obtaining feedback on policy measures intended to foster innovation (OECD, 2010a).

As the digital divide defined by technology access, at home or in schools, has tended to fade a second one based on digital competence more stubbornly remains: between those who have the necessary competences and skills to benefit from computer use and those who do not, which competences are closely linked to students' economic, cultural and social capital (OECD, 2010b).

But there has been much work on technology and education at OECD besides 'New Millennium Learners': the widening of student achievement surveys towards digital literacy (2011); reviews of e-learning in higher education (2005), followed by surveys on Open Education Resources (OECD, 2007; Hylén *et al.*, 2012); analyses of technology as one source of educational innovation (2004a), of the digital resources market with special reference to Nordic countries (2009), and more recently of the education patent market (Foray & Raffo). A selection of findings and conclusions from these different strands are summarised next.

International patterns of access and digital literacy

In 2000, nearly 9 in 10 15-year-olds (89%) reported access to the Internet at home as an OECD average, and in 2009 less than 1% of 15-year-old students in OECD countries declared that they had never used a computer. Based on PISA 2009 data, the OECD average for 15-year-olds reporting using computers at home is 93%, compared with only 71% using them in school, with a stronger correlation between educational performance and computer use at home than with its use in school (OECD, 2011). In fact, there remains much work to be done to improve the 'digital literacy' of students in OECD countries. All 16 OECD countries except Korea that were surveyed on this still have significant numbers of students who perform poorly in digital reading (See also Biagi & Loi in this issue pp. 28–42). Contrary to the popular image of 'digital natives' navigating effortlessly in web-based settings, many students could not so operate effectively:

> PISA results show that even when guidance on navigation is explicit, significant numbers of students still cannot locate crucial pages. The digital reading assessment offers powerful evidence that today's 15-year-olds, the "digital natives", do not automatically know how to operate effectively in the digital environment, as has sometimes been claimed. (*ibid*, p.19)

E-learning and Open Educational Resources

The early work on e-learning (OECD, 2005) was able to conclude then that it had not yet revolutionised learning and teaching in higher education systems. The

immaturity of on-line learning was demonstrated by low adoption of content management systems, where electronic content was split into 'learning objects' that could be manipulated and reconstituted for multiple pedagogic purposes. By 2007, a different tone was being adopted:

> An apparently extraordinary trend is emerging. Although learning resources are often considered as key intellectual property in a competitive higher education world, more and more institutions and individuals are sharing digital learning resources over the Internet openly and without cost, as open educational resources (OER) (. . .) Although no definite statistics are available, there is a rapid expansion in the number of OER projects, as well as the number of people involved and the number of resources available. In January 2007 the OECD identified over 3,000 open courseware courses available from over 300 universities worldwide (OECD, 2007, pp. 9, 10).

A more recent survey (Hylén *et al*., 2012) suggests that OER activities are spread much more widely across all educational sectors with primary, lower secondary and upper secondary education as involved as tertiary education, with only post-secondary non-tertiary education having slightly lower levels of activity. Most countries have simultaneously initiated activities in several educational sectors (See also Tuomi in this issue pp. 58–78).

Technology as a Source of Organisational Innovation in Education and the Digital Learning Market

Innovation in a Knowledge Economy, a slim, often-overlooked but seminal volume (OECD, 2004b) identified four sources or 'pumps' of innovation, of which technological advance was one; these in different measures explain most of the innovation taking place in organisations in different sectors of the economy, including education:

- *Modular reorganisation and specialisation:* rethinking the units and dynamics of the organisation and their interconnections.
- *Engaging in and exploiting R&D*, thereby exploiting knowledge, including new knowledge.
- *Networking and sharing knowledge* to move beyond the limitations imposed by the capacities of single professionals or units.
- Exploiting the innovation offered by *different technologies and technological advance*.

The conclusion reached in 2004 was that education in general and schools in particular faced structural and cultural difficulties in exploiting these sources of innovation. This offers a broader view than by looking only at educational innovation by casting the net out to learn from a variety of organisations and sectors. It also identifies four sources or 'pumps' of innovation — technological advance is only one — but the other three also need to exploit technology (e.g. in accessing research knowledge or networking). More recent OECD analysis of educational patents shows that there has been a clear rise over the past 20 years in the production of innovative educational technologies by businesses, typically building on advances in ICT (Foray & Raffo, 2012). While this increase in educational innovations may present new opportunities for the formal education sector, the evidence shows that this emerging industry currently targets non-formal and

tertiary education rather than primary and secondary schooling. The OECD also conducted an analysis of the markets for digital learning resources with particular reference to the Nordic countries (OECD, 2009) (See also Bocconi *et al*. in this issue pp. 113–130).

Widening the Focus from Technology to Learning Environments

It is important in education to know as basic educational data about such matters as how are extensive technological resources available in schools and the different ways in which they are used. We need analyses of how the digital resources market operates if we expect it to be vibrant and high quality, or how teachers or students feel about pedagogies using ICT. We need evidence on these questions as on the myriad others about how well schools are resourced and function. In looking for broader technology impacts on education, however, the evidence often seems less compelling than the descriptive data. The reasons for this, we would argue, come in the apparent paradox that much of this work has been, at the same time, insufficiently focused on learning and not focused enough.

On the one hand, it is 'not focused enough' when it begins with the technology and takes the technological deterministic course, as described by Mayer in his chapter for the OECD volume on *The Nature of Learning*:

> In the technology-centred approach, the focus is on using technology in education through providing access to cutting-edge technology. The main problem with the technology-centred approach is that during the 20th century it has produced several major cycles of big promises, some implementation in schools . . . and failure (. . .) In contrast, in taking a learner-centred approach, we begin with a focus on how people learn and view technology as an aid to human learning. (pp. 182, 183)

If Mayer is correct in suggesting that the long history of approaches grouped as 'technology-centred' have largely failed, then this perpetuates the conviction that investment in ICT in education has not paid off and does a disservice to the educational potential inherent in diverse digital and communication technologies. The problem has lain in thinking that the simple investment in such technology would be the catalyst by itself for radical educational and learning change. This is neither learner-centred nor education-centred.

Much of the work on education and technology is 'too focused' on learning, on the other hand, in being highly concentrated on the micro-level experiences in teaching and learning by small groups or individuals, without a more holistic understanding of learning environments into which the immediate technology-enhanced learning activities fit. The result tends to be the presentation of fragments of teaching and learning possibilities that technology can contribute to without locating that in more convincing wholes that include but go well beyond the innovative episodes. It is to do this that we deploy the concept of 'learning environment' in this article. Neil Selwyn's analysis for the NML project builds on this point to argue that the discussion needs to be cast into even larger perspectives to do with the purpose of education and the nature of society:

> . . . current discussions of Web 2.0 and schools repeat a long-standing tendency in education for exaggerated and extreme reactions to technology that are centred around matters of learning and teaching rather than the wider

> social, political, economic and cultural contexts of education. Specifically, most educational thinking concerning Web 2.0 reflects an implicit "technology-first" way of thinking, where Web 2.0 technologies are imbued with a range of inherent qualities that are then seen to "impact" (for better or worse) on learners, teachers and schools in ways that are consistent regardless of circumstance or context . . . [Moreover] for all its intuitive appeal, the widespread valorisation of informal learning and the technology-empowered individual learner dangerously depoliticises the act of learning (Gorman, 2007), placing far too much emphasis on the disembodied individual learner. Such arguments could be said to present an overly simplistic view of successful education relying merely on groups of like-minded individuals, failing to consider the wider social, economic, political and cultural contexts of the societal act of schooling. (Selwyn, 2010, pp. 31, 34)

We would particularly stress the need to avoid approaches that place excessive faith in learners to create their own learning environments, with all the motivation and expertise that this requires — it is highly individualistic, indeed idealistic; an unsociological and, in Selwyn's words, 'de-politicised' view that runs through much work on technology in education. The Innovative Learning Environments project presented next instead places great store by designing environments that bring learners together in different learning arrangements, rather than relying on motivated individuals exploiting the possibilities opened up by ICT to 'do their own thing' or come together spontaneously in learner networks.

Innovative Learning Environments at OECD

The OECD's Centre for Educational Research and Innovation (CERI) through the *Innovative Learning Environments* (ILE) project is analysing how young people learn and in which conditions and dynamics they might learn better. The three strands of ILE have been broadly sequential: i) 'Learning Research', ii) 'Innovative Cases', and iii) 'Implementation and Change'. They describe the organisation of the project but are much more than this. The design of ILE into these three dimensions reflects the belief that a critical starting point to consider innovative change in the organisation of learning is the close understanding of learning itself. Building on this has involved immersion in what practitioners and innovators have been working with around the world in their own learning environments — 'the Innovative Cases' — and to hold them up against the 'learning principles' developed out of *The Nature of Learning*. This gives a substantial foundation to consider more widespread change strategies towards innovative learning — the third strand of ILE only now underway.

Why the terminology of 'learning environments' and not that of 'schools' or 'classrooms'? First, when our interest is in learning, to start with institutional structures is, in our view, the wrong way round: it conflates the relationships between institutional structures and the organisation of learning when instead these relationships need to be problematised. It discourages consideration of innovations as well as of forms of hybrid or non-formal learning by assuming that the location of learning should predominantly be, now and in the future, schools and classrooms within them. The notion of 'classroom' is seriously reductionist of

the holistic and cumulative nature of learning by focusing on the episodes that take place within the walls of the units so designated.

Learning Environments, Innovative Learning Environments

In ILE, the 'learning environment' is an organisational form that embraces the learning arrangements catering for a group of learners in context and over time. It may be primarily located in a particular institution (for instance, a school) but it is not necessary that it is school-based, whether for some or all of the learning taking place. Engeström (2007) notes that design research in educational sciences has shifted the focus of attention from isolated individuals to entire learning environments or learning ecologies (Akkerman, Bronkhorst & Zitter, 2011). It becomes necessary to consider how the players and parameters of learning can be designed and redesigned, taking account of existing realities, contexts and learners and the perceived impact of the initial designs.

In the new analysis of the innovative cases, we have elaborated the concept of 'learning environment' as bringing together three sets of circles (OECD, forthcoming). These circles provide a framework to analyse any such environment, traditional or innovative; the new report also specifies the terms in which we might judge learning environments to be *innovative*, *powerful* and *effective*.

The Pedagogical Core: These are the elements and relationships at the heart of each learning environment. We understand these are four core elements: *learners* (who?), *teachers* (with whom?), *content* (what?), and *resources* (with what?). The organisational dynamics and choices that relate these elements are the relationships that traditionally have deeply structured schooling — the single teacher, the segmented classrooms, standardised timetable structures, and traditional approaches to teaching and classroom organisation. We have focused on four sources of change in the relationships between these elements of the 'pedagogic core': regrouping teachers, regrouping learners, rescheduling learning, and changing pedagogical approaches and their mix. We conceive the core as a circle as it involves linking relationships between the core elements over time (Figure 1).

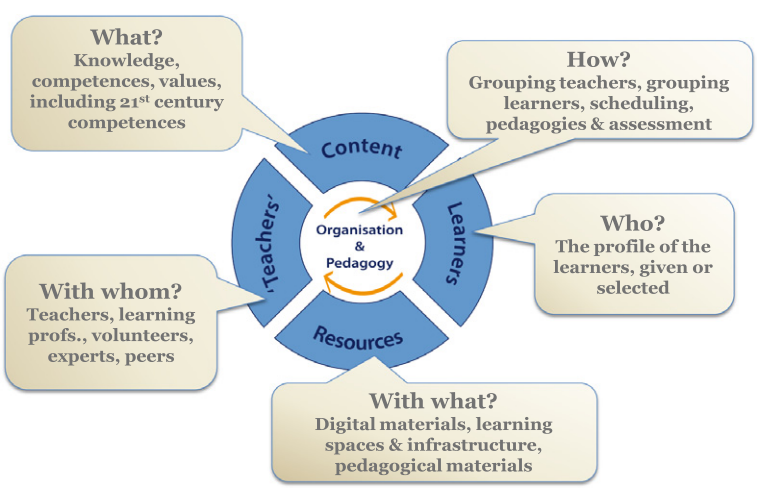

FIGURE 1. The Pedagogic Core — Elements and Dynamics

The Design/Redesign Leadership Circle: As an organisational concept that involves agency and outcomes, the learning environment cannot only be understood as its pedagogic core. How the environment is shaped over time depends critically on the capacity for leadership to design and shape the learning ('learning leadership') and the capacity to digest and act upon the information about the learning taking place that is the result of the inner 'pedagogic core' (Figure 2). The powerful 21st century learning environment will be driven by strong visions of learning objectives and strategy with distributed focused leadership, will be information-rich about the learning taking place, and the information will feed revised strategies for learning and further innovation. Together, this describes a formative organisation constantly engaged in design and redesign of its learning arrangements.

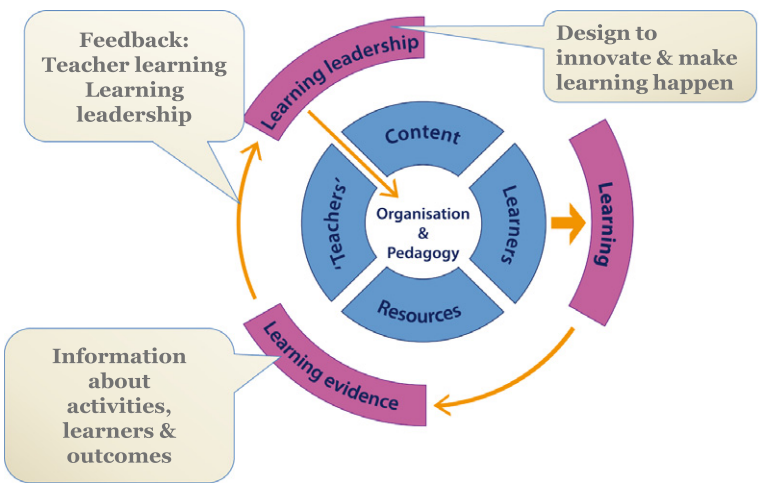

FIGURE 2. The Design/Redesign Leadership Circle

The Partnership Circle: Traditionally, schools have tended to be closed. The contemporary learning environment will instead have well-developed connections with other partners which will extend the environment's resources and learning spaces. Such extensions represent another and wider circle, bringing in, at least, local communities (including families); partnerships with businesses, cultural institutions, and/or higher education; and connections with other schools and learning environments through networks (Figure 3). They impact the pedagogic core by widening the resources, content, expertise, and learning dynamics, while often contributing to the learning leadership that is integral to the second circle.

These circles combine structures and processes. To judge whether particular learning environments are also effective, we argue, involves application of learning principles identified through the first strand of the ILE project and published in conclusion of *The Nature of Learning* (Dumont *et al*, 2010). The 'learning principles' in summary state that, in order to be most effective, environments should meet the following criteria:

- Make learning central, encourage engagement, and be where learners come to understand themselves as learners.
- Ensure that learning is social and often collaborative.
- Be highly attuned to learners' motivations and the importance of emotions.

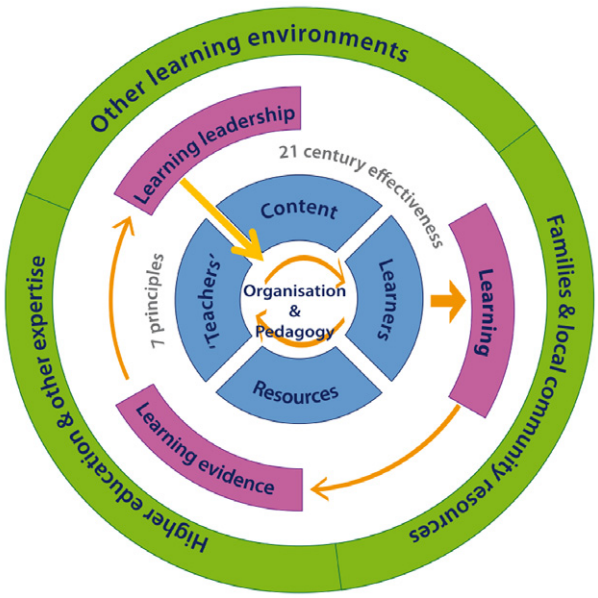

FIGURE 3. The Full Learning Environment Framework, including the Wider Partnership Circle

- Be acutely sensitive to individual differences including in prior knowledge.
- Be demanding for each learner but without excessive overload.
- Use assessments consistent with its aims, with strong emphasis on formative feedback.
- Promote horizontal connectedness across activities and subjects in- and out-of-school.

This set defines already a radical agenda even if each one may be relatively familiar to those knowledgeable of learning research. They go against many practices of conventional schooling — for example, that learning is social rather than essentially private, that emotions are as important in learning as cognitive development, that individual differentiation is needed, and that the traditional segmentation of schooling should be replaced by horizontal connectedness. Even more demanding, we argue that each of the principles should be met if learning environments are to be counted as possessing '21st century effectiveness'.

Rethinking the individual and social balance

There is a fundamental shift in the balance of the social and the individual in these characteristics. The traditional school (in stereotype to highlight the contrast) was defined by a particular combination of the social and individual:

- Unindividualised 'one-size-fits-all' — a shared learning programme where the notion of personalisation has little place, and
- Social in the domination of whole-class teaching.

But

- Private — not social — in schools being largely closed to wider players to define curricula or to be teachers or sources of knowledge, and

- A highly individualised understanding of learning as something done by each individual inside their heads, without collaboration with other learners.

The learning environments examined through the ILE project have deliberately sought to rethink the stereotypical social and individual roles in ways that are very relevant to the role of technology:

- Personalised learning programmes that reject 'one size fits all'.
- Rich mixes of small group, individual research and study, off-site and community work, virtual campuses and classrooms, in with communal teaching and learning.
- Openness to other stakeholders engaged in defining curricula, as sources of knowledge, and as teachers.
- A social understanding of learning, defined by '21st century' content and competences.

Four characteristics of contemporary learning environments

The three circles characterising learning environments and the principles derived from learning research offer four ways for defining what a contemporary learning environment should be aiming to do. It should be:

- *Innovating the 'pedagogical core'.*
- *Engaging the 'Design/Redesign Leadership Circle'.*
- *Widening connections and capacity through partnership.*
- *Promoting 21st century effectiveness.*

This means that ICT and digital resources will enter in numerous ways, at different levels: there is no single technology effect or means through which it might reshape the nature of learning environments.

Technology in Innovative Learning Environments

For some, innovative learning environments are synonymous with technology, though it is clear from the above discussion that this is not our position. We reported the OECD analysis (2004b) that identified that technological advance was only one source of innovation, though the other three — creating and using expert knowledge, reorganisation, and networking — may all be facilitated through ICT. That we do not regard innovative learning environments as synonymous with technology stems also from our conception of 'learning environments' as the whole, through-time structured opportunities and experiences for a group of learners, rather than particular settings or options for a lesson or course for which technology may be essential. And, following Mayer (2010), it derives from our adoption of a 'learning-centred' as opposed to a 'technology-centred' approach.

In this section, we sketch out how technology may contribute to all the different components, relationships, partnerships, and principles that are integral to learning environments as we understand them, to reinforce that there is not a single 'technology effect'.

Technology Redefining the Elements of the Pedagogic Core

Technology may recast all the elements of the *Pedagogic Core*. It may redefine who are the *learners*, for instance, by bringing in excluded learners or by connecting learners who otherwise would be totally unconnected. Technology can redefine who are the *teachers* — the on-line tutor or expert, for instance. The role of digital

resources and ICT in changing *content* is also potentially enormous, by extending materials well beyond textbooks including specialised content that may simply be beyond the reach of most schools. Using technology helps access the so-called '21st century skills', uses the media that are commonplace for learners in their activities outside school, and may enhance equity of access for potential students who might not otherwise have such an opportunity.

The *resources* for learning may obviously be transformed using digital resources, as well as the very notion of a 'learning space': virtual learning environments offer an important extension to the blends of resources and learning options available. In other words, technology can contribute to resetting a number of the standard characteristics structuring education, where it was traditionally assumed that learners were in proximity one to the other, in proximity with their teachers, using materials (books, other materials) that could be held. Distance learning is not a new phenomenon but the ubiquity of powerful inexpensive ICTs, plus increasing sophistication in the design of ways of incorporating those technologies into the learning environment, mean that the scope for breaking with these defining constraints grows constantly. The aim may also be to open up and 'deprivatise' educational spaces, creating visibility and breaking down the close association between a particular learning space and a single teacher (though personalisation may also sometimes call for personalised spaces).

Technology Innovating Core Dynamics

Contemporary learning environments use time more flexibly than was traditionally the case in schools (*rescheduling learning*). Flexibility goes hand-in-hand with individualised learning plans where learners are working on something different at the same time, as well as with educational philosophies determined to make schooling less bureaucratic. Virtual settings contribute to breaking down the notion that learning has to take place in a fixed place and at a fixed time.

Pedagogies obviously represent a fundamental set of dynamics through which the core elements — learners, teachers, content and resources — are related. In many of the examples in the ILE case studies, there is an emphasis on project-based learning, with a shift towards more active and inter-disciplinary learning. But as important, we found that far from reliance on single methods or approaches, there was always a combination of approaches in the learning day or week, including direct teaching. Even in ILEs that have deliberately sought to move away from conventional forms of teaching and organisation, there are particular subjects where more conventional approaches are judged to be the most suitable. The mix may come through the different media and settings used, as when e-classroom work is integrated into the larger menu of teaching and learning options. The mix may come from teacher preferences and choices as part of the wider orchestration of learning. So, even schools and learning environments that are deliberately innovative did not simply replace one approach or methodology with another but, instead, used a battery of approaches, though in largely deliberate ways in line with the broader strategy being followed.

Inquiry-based pedagogies

During the research or inquiry-based projects that feature prominently in the ILE cases, students are encouraged to actively construct their knowledge while practising skills like hypothesis generation, scientific inquiry, self-monitoring and

(sometimes online) literary analysis. While technology is certainly not essential for project-based work, it can be highly facilitating (Groff, 2012):

- In a student-driven, inquiry-based project, technology can provide the *tools* necessary to complete the investigation. Digital cameras and video recorders collect real-time data, for instance, while laptops offer easy access to online searches and mobile computing. The relevant available digital technologies will continue to grow and offer improved means for project-based pedagogies.
- Technology offers the *means* of inquiry-based learning by providing a collaborative working space for progressing the work over time — as individual learners, groups of learners, and as a whole class.
- Technology can offer the *mechanism* on which inquiry-based learning is built. For example, in game-based learning the game is most often not about inquiry but provides the storyline or context upon which the inquiry is structured. Augmented reality games and online simulations are examples of mechanisms for structuring inquiry-based learning in an engaging and relevant way.

Technology Supporting Leadership, Design and Redesign

For the learning environment to be a formative organisation, it needs to be highly informed about the learning taking place within it — *learning evidence*. The contemporary learning environment needs to be 'information rich' and able to use that information to inform further development and direction. The sources of information include learning logs and portfolios, containing detailed records in accessible formats of student learning that can become a basic organisational tool. It includes research on different aspects of the learning environment that is important both for developing teacher professional expertise and for generating crucial intelligence on how well the environment is functioning and suggest potential solutions to problems arising. Data management systems are naturally relevant, and can provide invaluable information about learning, not as an alternative to learning leadership but to inform it.

The role of technology in organising learning data and feedback is obvious. But it may well come into this circle in other ways, too. The distributed learning leadership may very well depend on ICT for communication and collaboration. Teacher learning may depend on on-line materials or social media, as might the expression of learner voice. Strategic options for learning design and redesign may be critically informed by examples and exemplars available on-line, including any necessary support for it to be sustained.

Technology Opening up Wider Partnerships

Creating wider partnerships is a defining feature of innovative learning environments as seen in the ILE analyses: they have an urgent drive to avoid isolation, and an awareness that significant innovation cannot be achieved and sustained by oneself. They look to build and maintain the capital they need as organisations — social capital, intellectual capital, and professional capital — through forging alliances, partnerships and networks, while extending the environment's boundaries, learning spaces and resources.

Technology is often integral to and supports such widening through partnerships, through ICTs powerfully enabling communication and sharing experiences and knowledge. We would particularly single out networking with other learning environments. They often depend on technology to collaborate with others at a

distance, developing active communities of practice and networking. This 'meso' level of learning and organisation is critical if innovative change can move beyond the limitations of particular contexts and go to scale.

The ILE project has also explored the notion of 'hybrid learning environments', in this case with a focus on learning environments that integrate educational and workforce learning with examples taken from vocational education (Zitter & Hoeve, 2012). Over recent years, such informal elements as authentic assignments, project-based learning, and in-school mini-enterprises have been increasingly introduced into school-based learning. At the same time, informal learning has been formalised by means of recognition of prior learning and the use of portfolios (Tynjälä, 2008). This has led to a process of cross-fertilisation leading to new forms of learning that integrate aspects of both formal and informal learning. On this, Zitter and Hoeve have developed the concept of 'hybrid' as the interweaving of learning and working processes to benefit from the strengths of both formal, school-based learning and real-life experience. Technology is an integral part of this interweaving.

Technology in the 'Learning Principles'

We have not singled out technology as defining a separate principle: learning research, as we understand it, does not suggest that ICT needs to be exploited as a condition for learning to be effective. This might appear to diminish our assessment of technology's importance. In fact, its creative and informed application can be seen to enhance all of the principles — far from reducing technology's centrality, the principles reinforce the argument for more and better use of ICT in contemporary education.

- Technology has repeatedly shown its value in engaging young learners (hence, reinforcing the principle 'learner centredness').
- Technology can facilitate collaboration and joint learning, including through use of social media (thus, underpinning 'the social nature of learning' principle).
- Individual differentiation can be greatly facilitated through, for example, more systematic tracking of individual learning paths and performances (principle 'sensitivity to individual differences').
- Similarly, it can support formative assessment and feedback (principle 'use of assessment strategies consistent with expectations') (See also Redecker & Johannessen in this issue pp. 79–96).
- Making connections is a defining aspect of ICT, hence opening numerous possibilities for 'horizontal connectedness'.

The ILE principles of learning are at once a manifestation and result of the practices described in this article and a framework of evaluation in general.

Concluding Remarks

While rejecting a 'technology-centred' approach, it should be clear that we place great importance in the potential of technology to modernise education and to help realise learning environments appropriate for the 21st century. Whatever the discussion over the benefits and costs of technological innovation in education, a fundamental reason to pursue technology-rich learning environments is less open to debate: *we live in a digital world*. The digital transformation is continuing to change the nature of work, social and daily life. Learners in most OECD countries

are currently immersed in it, and this is only likely to continue apace in the future. This also represents a considerable challenge, as raised by Selwyn (2010): how to respond to the fact of living in a digital world in ways that realise the visions and specific agendas that should be peculiar to our education systems, especially for the young? Like Selwyn, we reject the argument that this can be looked after by leaving individuals to their own technological devices in a forest of non-formal learning opportunities or that learning institutions should simply adapt more adequately to available technologies.

Building on the concept of 'innovative learning environments' as outlined in this article provides part of the answer to the challenge (though not to the more fundamental value questions). The very diverse ways that technology enters into shaping learning environments renders highly problematic the search for a specific 'technology impact' on learning — so much depends on how such technology is used and to what purpose, and in combination with everything else that goes to shape such environments. Technology plays an important role in influencing learning from well outside the immediate teaching and learning interface, as the above discussion of the design/redesign and leadership cycle and the wider partnership circle has sought to demonstrate.

It would be almost comic if someone were to question, with the lack of firm evidence to the contrary, whether it is worth investing in books in education. Books are somehow synonymous with schools and school learning. Yet, they are only an alternative technology, albeit a very longstanding, durable and valuable means of reproducing content and transferring knowledge. It is easy to grasp that it is not books *per se* that need to be evaluated, but their contents, how available and used, by whom, for what purposes, with which methods, and in combination with what other technologies. That is the status that the more digitalised technologies have now acquired. The search for impacts on learning must be pursued with at least the same diversity and breadth, indeed with greater breadth as the communicative power of ICT is significantly more wide-reaching.

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NOTE

1. The case studies are available on the OECD website www.oecd.org/edu/ceri/inventorycases.htm.

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