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Pedagogy with information and communications technologies in transition

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Abstract This paper presents an analysis of ways in which pedagogy with information and communications technologies (ICTs) may need to adapt to accommodate to a major shift in our conceptions of knowledge and learning. A holistic approach to this analysis based on Checkland's "systems thinking" suggested changes in pedagogy needed for 21st century learning and suggested ways of managing the complexity in order to support teachers in developing their pedagogical practices. The examination of how learning is conceptualised while learners are in contact with vast arrays of knowledge through Internet access and how this understanding can be reconciled with current views of knowledge acquisition in formal education suggests a need for rebalancing in most phases of education between individual work and group participation. Furthermore, opportunities need to be increased for learners to develop expertise in their chosen domains and to make links between their formal and informal learning. Examination of scenarios in which people learn through peer interaction rather than any formal teaching suggests a need to recognise and not underestimate young people's capabilities. The paper proposes incorporating opportunities for students to engage with self-organizing social systems into pedagogy. This would complement an emphasis on develosping and understanding both individual and shared expertise.

Keywords Pedagogy · Assessment for learning · Neuroscience · Knowledge society · Internet · Self-organizing social systems

1 Introduction

This paper examines ways in which pedagogy may need to adapt to accommodate a major shift in our conceptions of knowledge and learning brought about by

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technological developments. Recent major changes in our understanding of the nature of learning are illustrated by the following set of terms that have become commonplace in educational discourse: lifelong learning, informal learning, virtual schooling, online learning, blended learning, social networking and M-learning. Internet and mobile technologies in particular have led to radical changes in the ways that young people socialize and learn (Bavelier et al. 2010; Ito et al. 2008; Livingstone and Haddon 2009). Furthermore, studies in the UK (Crook and Harrison 2008), across Europe (Livingstone and Haddon 2009) and in the US (Rideout et al. 2010) have shown that young people spend much more time using the Web outside of school than in school indicating the growing opportunities for informal learning. Therefore substantial shifts in our view of learning have been identified. For example a change to mobility in learning is characterised by Kress and Pachler (2007) as a constant state of contingency, provisionality and knowledge creation brought about by an expectation of immediate access to a world of resources, materials and social interaction. Thus there is a shift in emphasis from teaching to learning (Bauman 2005; Kress and Pachler 2007) in which responsibility is transferred to individual students to manage their learning trajectories (Bauman 2005).

Change in our conception of learning is a reflection of broader social change characterised by the Polish philosopher and sociologist Zygmunt Bauman as a passage from the 'solid' to 'liquid' phase of modernity (Bauman 2000). In this new environment, change is too rapid for social forms to solidify, the future is unpredictable and people are expected to be flexible rather than following rules or using established knowledge (Bauman 2000). For education the changing nature of knowledge is particularly significant:

> Like everything else in the world, all knowledge cannot but age quickly and so it is the refusal to accept established knowledge, to go by precedents and to recognize the wisdom of the lessons of accumulated experience that are now seen as the precepts of effectiveness and productivity. (Bauman 2000 P.154).

Therefore Bauman argued that this need for continual knowledge creation through interaction in socio-cultural settings militates against an education that focuses on building young people's knowledge gradually through a pre-determined sequence of learning as specified in most curricula (Bauman 2005). Furthermore survival in liquid modernity depends on 'individualization' as people are continually forced to make choices through lives consisting of many separate episodes in frail and volatile settings (Bauman 2000).

The changes in conceptualisation of learning outlined above have led to calls for teachers to respond to the needs of twenty first century learners by changing their pedagogical practices to become more learner-centred, to recognise achievements gained outside school, and to make greater use of new technologies (e.g. United States Department of Education 2010; Underwood and Dillon 2011). Analysis of pedagogy and pedagogical practices with ICTs based on a review of research from 1990 to 2003 combined with a study of schools known to be using ICTs effectively to support attainment revealed extensive evidence of ICTs contributing to pupils' attainment (Cox et al. 2004; Cox and Webb 2004; Webb and Cox 2004). However these benefits were dependent upon the ways in which teachers select, organise and integrate the ICT resources into activities in the classroom and beyond. Implementing a range of these pedagogical practices requires broad and deep knowledge and skills so that even in the best practice a teacher would make use of a limited subset of the ICT resources available (Webb and Cox 2004). A major conclusion from this and other research (e.g. Loveless 2011) was therefore that while enabling new affordances and different ways of learning that are beneficial and motivating for students, developments in ICTS were making the roles of teachers much more complex. Furthermore uptake of use of ICTs in schools is generally limited and teachers make use of only a small subset of the technologies that could enable learning (Law et al. 2010).

In order to explore possibilities for managing the complexity of pedagogy with ICTs Whetten's (1989) two criteria for theory building together with Checkland's "systems thinking" were adopted for the analysis presented in this paper. Whetten argued that a balance should be achieved between comprehensiveness (i. e., are all relevant factors included?) and parsimony (i.e., should some factors be deleted because they add little additional value to our understanding?) (Whetten 1989 P. 490). Early stages in the development of a theory or understanding of a situation should be comprehensive (Whetten 1989). This may be achieved by taking a holistic approach to develop a rich picture (Checkland 1981, 2000). Thus in the analysis presented in this paper a broad "systems thinking" approach was adopted, at the outset, in order to achieve a holistic view of pedagogy and how pedagogy is situated in a broader educational context. Then existing purposeful activity systems from important world-views (Checkland 2000) identified from research were examined in order to identify key issues for managing complexity and fruitful areas for future development.

1.1 Overview of the nature of pedagogy in educational practice

The term pedagogy usually refers to the science or theory of educating and needs to be understood within a broad framework of educational practice (Alexander 1992; Somekh 2008; Park and Oliver 2008; Loveless 2011; Cox and Webb 2004; Leach and Moon 2008). Thus pedagogy is culturally situated (Somekh 2008; Leach and Moon 2008) in a setting which includes, for example, not only the curriculum content, the subculture of the subject (Grossman et al. 2004; Entwistle 2005) and the context of educational practice but also the needs of learners and consideration of ideas, values and beliefs in society and the nature of knowledge (Alexander 1992; Hipkins et al. 2010). In any particular educational setting pedagogy exists in a dynamic relationship with the curriculum and assessment regime. Typically this relationship is represented as a triangular model in which the three elements of pedagogy, curriculum and assessment influence each other and are all informed by theories of how people learn (Wilson 2007). The complexity of teachers' pedagogical practices for ICT use is captured in a framework that was developed originally to understand the pedagogical processes that were observed in classrooms (Cox and Webb 2004; Webb and Cox 2004). This earlier framework was revised (see Fig. 1) to accommodate changes in understanding of students' involvement in planning their own learning in the context of assessment FOR learning (Webb 2005; Webb and Jones 2009).

The idea of assessment FOR learning (AfL) has gained in importance in education in many countries (Webb and Gibson 2011) owing to evidence of strong effect sizes

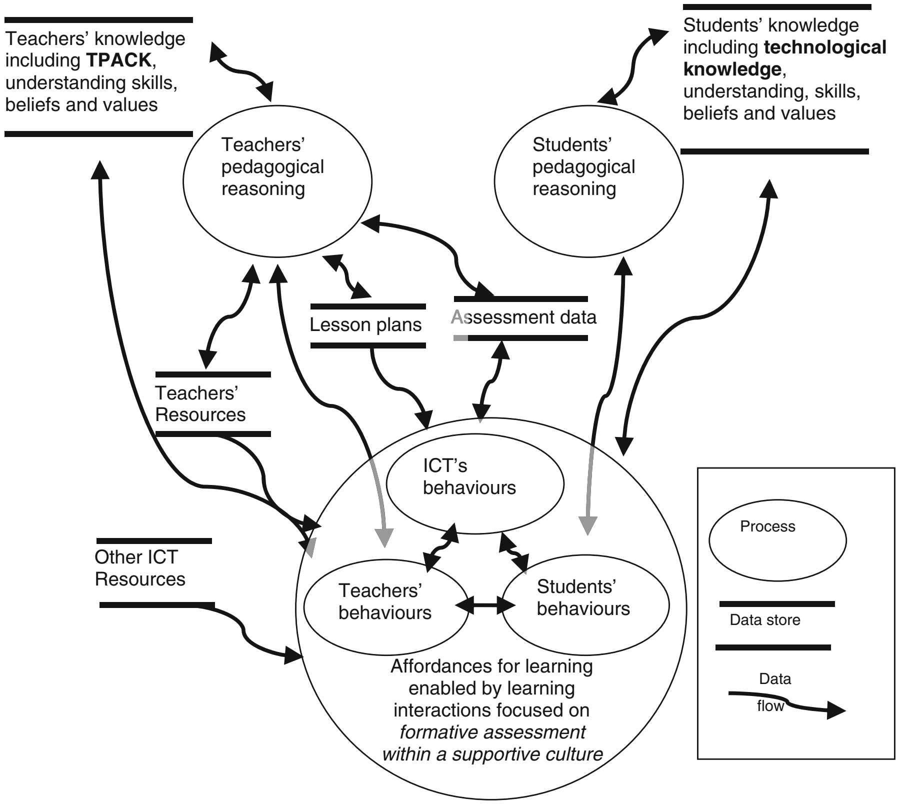

Fig. 1 Revised framework for pedagogical practices relating to ICT-use

for innovations based on AfL (see Wiliam 2011 for a recent analysis). The environment and interactions create affordances for learning and where formative assessment is embedded students act as instructional resources for each other (Wiliam et al. 2004; Webb and Jones 2009).

Teachers' pedagogical reasoning (Shulman 1987) leads to: a) teachers producing lesson plans and schemes of work that incorporate affordances for learning and b) teachers' behaviours during lessons that enable students to benefit from these affordances. Teachers need to have appropriate knowledge including pedagogical content knowledge (PCK) to inform their pedagogical reasoning. Since Shulman's (1987) earlier work the importance of PCK has been recognised widely by researchers and practitioners and has more recently been defined as a complex dynamic phenomenon that arises from teachers' reflection in and on action:

> "PCK is teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment" (Park and Oliver 2008 p. 264).

In the framework presented in Fig. 2, PCK has been expanded to incorporate technological knowledge by introducing the more recent construct: technological

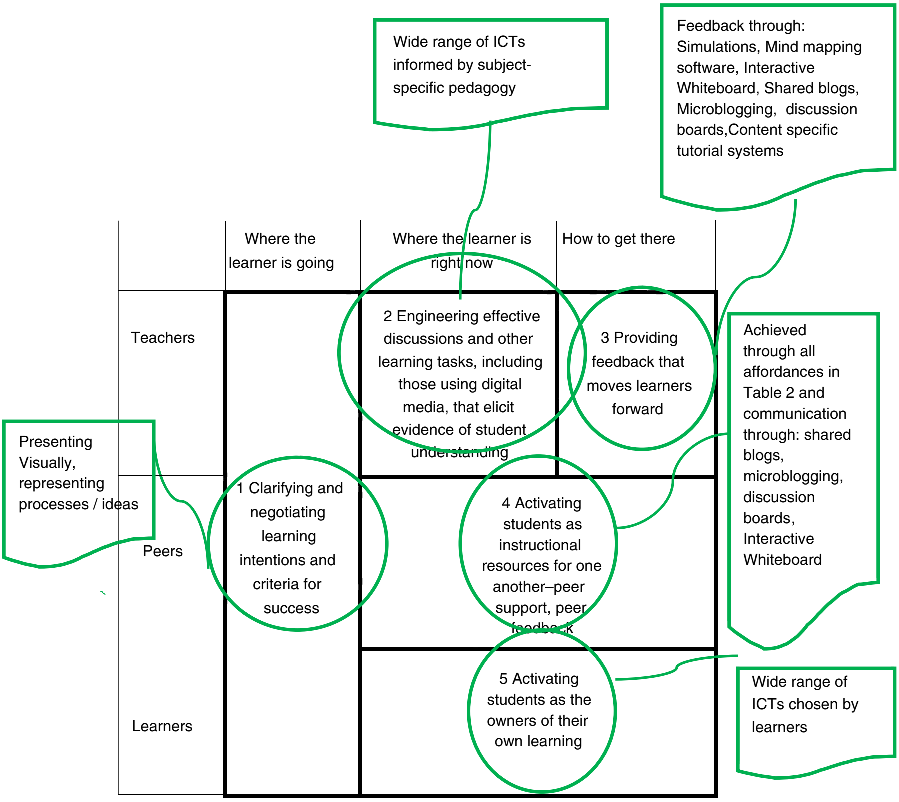

Fig. 2 Aspects of formative assessment and potential uses of ICTs

pedagogical content knowledge (TPACK) (Koehler and Mishra 2005; Mishra and Koehler 2006) which has been discussed widely as a potential framework for knowledge of how to integrate use of appropriate technology when planning lessons and making teaching decisions (Voogt et al. 2012).

The framework incorporates pedagogical reasoning processes of students (Webb 2005, 2011 online pre-publication) which may be developed through peer assessment and feedback which leads to improved self assessment (Black et al. 2003). Thus students may become aware not only of what they do not understand, but also of how they learn and what kind of learning resources they prefer to use (Wiliam 2011; Black et al. 2003). In classrooms where a supportive culture has been established through a philosophy based on assessment for learning (Webb and Jones 2009) students become better able to identify their needs, and hence play a larger role in planning for their learning (Black and Wiliam 2006, 2009). Thus students may be able to participate with their teachers in making decisions about what and how they will learn so the pedagogical reasoning processes are shared with students (Webb 2005). Here the increasing use and awareness of ICTs by young people (Conole et al. 2008) may contribute to shared TPACK. In particular, technological knowledge (Koehler and Mishra 2005) of many students may be better than that of their teachers, enabling students to lead on the use of technologies. Initiatives to develop students as "digital leaders" have emerged, for example see www.digitalleadernetwork.co.uk

In summary, in accordance with system thinking (Checkland 2000), the model in Fig. 1 provides an overview at the top level of pedagogical processes in situations identified by researchers as best classroom practice.

2 Managing complexity of pedagogy with ICTS—identifying potential solutions

From a review of the framework presented in Fig. 1, in the light of evidence of teachers' pedagogical practices in relation to ICTs (Webb 2011 online pre-publication; Cox and Webb 2004; Webb et al. 2008; Hattie 2009; Law et al. 2010; EDUsummIT 2012) a set of potential activity systems with strong potential to influence pedagogy were identified (see Table 1).

In subsequent sections I will examine systems I to 7 in Table 1 and discuss the emerging issues and implications and then synthesise these into some proposals for pedagogy. Other systems (8–10), included in Table 1, were not developed further in the current analysis because their potential for shaping pedagogy, while important, is more limited or less proven than the other systems as explained below.

Learning spaces (Thomas 2010) and 'built pedagogy'(Monahan 2002) are important issues in 21st pedagogy because teachers have to work with and adapt where possible their learning/teaching spaces. However considerations of built pedagogy do not help substantially to manage the complexity of pedagogy except when designing a new school, classroom or virtual learning space. Elements of the TPACK Model were discussed earlier in the initial overview but the full TPACK Model is more complex and comprehensive. A critique of the TPACK Model (Charles 2011) concluded that the model needs further development to create clarity in the TPACK construct definitions and their inter-relationships. Furthermore the model has a high degree of parsimony because TPACK is easy to understand at a surface conceptual level while hiding a deep underlying level of complexity (Charles 2011). In the current analysis I was not trying to hide the complexity but rather to understand and manage it so the TPACK Model is not discussed in depth in the current paper.

Table 1 Activity systems with strong potential to influence pedagogy

1. Instant access to knowledge (Peltokorpi 2008; Sparrow et al. 2011; Bauman 2005)
2. Developments in neuroscience in relation to how people learn (Ansari 2012; Bavelier et al. 2010; Geake 2008; Green et al. 2010; Hills and Hertwig 2011)
3. Learning without teaching (Webb and Jared 2010; Mitra and Dangwal 2010; Jared 2010; Ito et al. 2008)
4. Online self organising social systems (Rideout et al. 2010; Wiley and Edwards 2002)
5. Teachers' decision making processes (Barton and Haydn 2006; Cox and Webb 2004; Hattie 2002, 2009; Valtonen et al. 2011)
6. Identifying the most effective uses of technologies in creating affordances for learning (Cox and Webb 2004)
7. Assessment FOR Learning (AfL)—peer interaction (Wiliam 2011; Webb and Jones 2009)
8. Learning spaces (Thomas 2010)
9. Built pedagogy (Monahan 2002)
10. TPACK Model (Koehler and Mishra 2005).

3 Instant access to knowledge: Implications for pedagogy

Why do we need to know this sir? We could just ask Evi.

Pedagogy needs to provide answers to this question in relation to our understanding of how people learn, in ways that enable teachers to feel confident about how they are teaching. Evi, an app that uses artificial intelligence, is currently evolving as a popular way to interact with the Internet on mobile devices in the UK but we could equally substitute the American-designed personal assistant, Siri, on the i-phone, Google or a plethora of apps that are likely to develop over the next few years to help us to find and make sense of information.

There is evidence that people have already adapted their cognitive strategies to their expection of instant access to information (Sparrow et al. 2011). For example, in experiments where people, with Internet access were solving problems, they recalled less of the information itself but instead recalled where to access it (Sparrow et al. 2011). Sparrow et al. (2011) argued that this phenomenon is an extension of existing transactive memory systems that have already been developed through social interaction in face to face settings. In these transactive memory systems, information and expertise resides in individuals but is used by group members working together because they have shared knowledge of *who knows what* as well as team mental models (Peltokorpi 2008). There is already a fairly extensive theoretical base for transactive memory systems and a developing evidential one (Peltokorpi 2008). What the evidence of the experiment of Sparrow et al. (2011) suggests therefore is that unless people perceive a strong need to retain knowledge, their intuitive behaviour will be to try to remember where to find it rather than to put in the effort and attention to assimilate this knowledge. Furthermore this behaviour has presumably been learned through using computers but is built on hard-wired behavioural mechanisms that have developed over our evolutionary history as social beings (ibid).

The world-view developing as a result of instant Internet access, outlined above, appears to be in tension with current views of how people learn that emphasise deep understanding (Entwistle 2005; Gobet and Wood 1999; Pellegrino et al. 2001). For example, a metaphor for learning, with understanding, that gained wide acceptance among teachers during the last part of the twentieth century was that of a deep versus shallow approach. A deep approach has the potential to develop understanding as students engage with ideas, relate them to previous knowledge and experience, and critically evaluate evidence, whereas a shallow approach remains at the surface of knowledge and focuses on retention of material (Entwistle 1997; Hattie 2002). More recent research has emphasised ‘ways of thinking and practising’ in a subject area to describe the richness, depth and breadth of knowledge developed through engagement (Entwistle 2005). These conceptions of knowledge used in cognition and learning seem to be markedly different from those valued in the liquid modernity of Bauman (2000) creating a potential for tension between education and the needs of business and wider society. Furthermore they appear to fall short in answering the student’s question “Why do we need to know this?” in the context of instant Internet access. A recent analysis of expertise (Kahneman and Klein 2009) that draws on research across several fields of psychology may help to resolve this tension. Kahneman and Klein explain expert decision making using a dual process model in which, intuitive judgments are produced rapidly by System 1 operations, which are automatic, involuntary, and almost effortless but are followed up by System 2 processes which are controlled, voluntary, and effortful. Thus an expert, who needs to make a decision, will make an initial judgment using System 1 operations but will then evaluate this course of action by simulating its effects using cognitive activities of System 2. If the simulation is unsuccessful, System 1 will be called on for a further solution until a suitable one is found. In research with expert fire-fighters the first solution generated was often the only one needed, giving the impression of skilled intuition dependent only on pattern recognition (Kahneman and Klein 2009). However a deep understanding gained through both study and experience underpinned both systems. System 1 generates rapid automatic skilled intuitive responses because experts can match new situations to stored patterns that they have generated from many previous experiences (ibid).

Expertise is not only achievable by professionals. Depending on the domain, anyone can develop expertise in a specific area through a suitable combination of study, practice and effort. Accessibility to knowledge and to experts through the Internet gives people many more opportunities for developing expertise in a domain of their choice. Therefore one way of enabling learners to understand why they need to assimilate knowledge is to allow them to develop expertise in their chosen domain and then to focus specifically on how they make decisions, what knowledge they use and how effective their decisions are. Using these experiences to build understanding of how they learn could add value to students' informal learning and help to bridge the gap to more formal learning. Another pedagogical approach focused on metacognition in relation to expertise would be to examine examples of decision making of experts from various professions. This type of metacognition is similar to an approach taken in medical education where medical experts think-aloud through their decision-making processes to model them to students (Lajoie 2008). These approaches would help to develop understanding and appreciation of how human experts think.

Kahneman and Klein also concluded, from their analysis, that skilled intuitions will only develop in environments of sufficient regularity, which provide valid cues to the situation thus explaining why experts' judgements are not always accurate. This inaccuracy explains why, in some circumstances, computers can outshine experts by using solutions based on relatively simple statistics and algorithms (Kahneman and Klein 2009). Therefore coming to understand how computers process information will also be important for learners so that they can compare, contrast and understand the different advantages of each.

The pedagogical approaches suggested above are not entirely new. Teachers often use real world examples as problem solving activities and at secondary school level and above the importance of understanding the decision making and reasoning processes within the subject culture is well recognised (Entwistle 2005; Grossman et al. 2004) . What is different is an incorporation into pedagogy of a recognition that we need not only to develop awareness of human thinking and reasoning processes but also to evaluate them in comparison to *computational thinking* in order to learn how to make best use of new opportunities provided by new technologies and to develop alongside our machines.

In summary, there is really no conflict between current views of how people learn and knowledge acquisition in learning in liquid modernity. However there are dangers that learners will not engage with education that fails to help them to make sense of how learning occurs and how knowledge is used and shared between people and between people and computers in the world beyond the classroom. Another challenge for pedagogy is how to respond to the potential for changes in people's capacity for learning that may be brought about by brain changes caused by use of new technologies as discussed in the next section.

4 People's capacity to learn in liquid modernity: Implications for pedagogy

Evidence suggests that developing and practising particular skills causes brain changes across multiple parts of the brain and may lead to broad neuronal plasticity (Ansari 2012). For example learning to read effects brain structures associated with speech perception and visual processing as well as those identified as being associated specifically with reading (Ansari 2012). Of even more general significance is the finding that working memory capacity can be increased by training based only on repetition, feedback and often gradual adjustment of the difficulty (Klingberg 2010). In other words this improvement is not an artefact dependent on using tricks for memorising but a real expansion of the memory that humans use for conscious higher thinking processes (Ansari 2012).

Evidence of changes associated with use of new ICTs is building and what is becoming clear, according to the review by Bavelier et al. (2010), is that changes depend on specific aspects of use such as the content, length and frequency of use, context and other aspects of people's lives. Furthermore, some outcomes are clearly beneficial and others are harmful (Bavelier et al. 2010). Effects can be unexpected because brain responses are complex in that changes in one part of the brain are accompanied by changes in other parts. There is some evidence for persistent attentional difficulties (Bavelier et al. 2010) and negative social well-being (Pea et al. 2012) being associated with high levels of multitasking but the evidence is correlational and clear causal links have not yet been established. Beneficial effects, for which evidence of direct causal relationship is accumulating, include enhancements in vision, attention, cognition, motor control and better visual short-term memory associated with playing action video games (Green et al. 2010; Bavelier et al. 2010). Furthermore evidence for a general mechanism to explain these effects based on improved probabilistic inferencing has been found (Green et al. 2010).

In a possible future scenario for the practical use of neuroscience techniques outlined by Geake and Cooper (2003) students regularly wear neuroimaging headsets while they do assessment tasks. Their individual images are statistically analysed by a computer, and teachers use their pedagogical knowledge to review the reports. Where teachers identify specific difficulties associated with brain development they recommend courses that use real-time biofeedback to strengthen specific memory circuits for individual learners. These possibilities may not be realised for many years and will raise a range of ethical issues but they do suggest that as pedagogy continues to adapt to our changing understanding of learning, incorporating findings from neuroscience and determining directions in the newer field of educational neuroscience will be important (Fischer et al. 2010).

In summary there is increasing evidence that uses of technologies are producing persistent changes in children's brains and hence changing their capacity and capabilities for learning (Bavelier et al. 2010). However, although developments in neuroscience are rapid, our understanding of these changes is still very limited. From a review of research Hills and Hertwig (2011), present compelling evidence that excessive expansion of our cognitive capabilities is likely to be at the expense of some other aspect of our cognitive capabilities so there will be limits to such expansion. Therefore there are real potential benefits for some groups of learners, e.g. those whose working memory is relatively small could be improved by specific training, but a one-size fits all approach is unlikely to be beneficial and identifying cognitive side effects is crucial (Hills and Hertwig 2011). Thus the implications for pedagogy with ICTs point to a commonsense approach that variety and balance in learning activities and strategies are valuable and intensive use of any particular type of activity should only be employed where clear evidence shows that such practice will develop appropriate skills without deleterious consequences. Furthermore a good general understanding of neuroscience should be incorporated into pedagogy so that dubious innovations based on neuromythologies (Geake 2008) are avoided.

5 Learning without teaching

Few argue that teachers are not necessary or important for learning. Indeed current educational policy discourse focuses on the importance of good teachers. This view is supported by evidence from meta-analyses that confirms that teachers are a major source of variance in student's achievement, accounting for about 30% of the variance (Hattie 2002, 2009). Learners themselves and the attributes they bring to the learning situation account for 50% of variance (Hattie 2002). However, there are three major reasons for examining the extent to which learning can occur without teaching in a formal sense. First the Internet together with mobile technologies is enabling many more opportunities for learning without formal teaching. For example, the phenomenon of 'geeking out' (Ito et al. 2008), where teenagers pursue specific interests and develop expertise through online engagement, is completely separate from any teaching or schooling in the traditional sense. Second, in many countries opportunities for children to experience good teaching or indeed any schooling, are still limited but Internet access to excellent educational resources through mobile devices is possible even in the remotest locations. Third, in the current climate of austerity, there is a focus on efficiency so teaching is under scrutiny particularly for ways in which the use of technologies may increase efficiency (e.g. United States Department of Education 2010).

An approach to learning that addresses needs of school curricula while overcoming the need for strong involvement by teachers may be seen in the interactions on the AskNRICH online forum (Jared 2008; Webb and Jared 2010). In this forum anyone can ask an 'expert' for assistance with any mathematical problem. Although the forum is monitored by a team of mathematicians (teachers and students) at Cambridge University the expectation is that anyone can seek or offer help and that help will be provided predominantly by peers. Thus there is no clear distinction between students and teachers. Research by Jared (2008, 2010) has shown that school students as users of this forum progress from seeking and receiving help through to becoming able to help others to develop their own mathematical understanding. This pedagogical phenomenon is achieved through a combination of strong motivation on the part of these aspiring mathematicians, a well-structured online environment and clear guidelines for posting, including how to answer questions in a supportive way, that are reinforced by the volunteers who monitor and moderate the forum (Jared 2008, 2010). Thus the forum and its rules have overcome the need for teacher involvement and enabled learning through peer interaction.

Research that may clarify the scope for learning without teaching in the context of the school curriculum is the so called “Hole-in-the-Wall” series of experiments where a public computer facility was provided for Tamil-speaking children in a number of remote Indian villages (Mitra and Dangwal 2010). These experiments have demonstrated that children aged 10–14 years can work together in groups, without teachers, to learn basic molecular biology in English, a new language for them. These students performed better on tests than children who had been taught this material in state-controlled schools (Mitra and Dangwal 2010). In further “Hole-in-the-Wall” experiments where adults, with no subject expertise, supported the students with encouraging comments only, the students’ test results equalled those of their peers in a private urban school (Mitra and Dangwal 2010). In the context of the analysis presented here the “Hole-in-the-Wall” research is important for three main reasons. First it demonstrates a remarkable capacity for students aged 10 to14 to learn in groups with Internet access but without teaching. Second many people have found this phenomenon surprising which suggests that many of us underestimate young people’s capabilities. Third it emphasises that encouragement is very important for maintaining motivation and focus: a truth that has long been known and is evident in expert teachers (Hattie 2002) but is not always emphasised in education in formal settings.

Mitra has termed these situations self organising learning environments (SOLE) or self organising mediation environments (SOME) but provides little information as to how they self organise and what conditions are needed other than that groups of four are advised and that students are motivated by a vague suggestion of possible future gain rather than clear targets (Mitra and Dangwal 2010). A view of self organised learning defined by (Wiley and Edwards 2002) is of online self-organizing social systems (OSOSS) as environments in which large numbers of people interact and participate to accomplish various goals without any central authority. Since OSOSSs were first described, an enormous range of Web-based tools such as blogs, wikis and other social networking facilities including RSS feeds have evolved and provide support for the OSOSS model of learning. Examples from the report by (Ito et al. 2008) showed teenagers geeking out on OSOSSs. Wiley and Edwards suggested that OSOSSs work because large numbers of people with similar interests provide peer support and because there are many users, no-one feels overburdened in providing support (Wiley and Edwards 2002). In some systems online threaded discussions are moderated by community members who meet certain criteria and meta-moderation allows community members to evaluate the appropriateness of moderators’ ratings and comments (Wiley and Edwards 2002).

Incorporating OSOSS into pedagogy should be seen as a priority for several reasons. First students are engaging with these online opportunities from a young age (Rideout et al. 2010) so pedagogy within formal education has a duty to support students in using these facilities and understanding their learning potential and risks. Second, even if the subject matter students are engaging with does not match school curricula, there will be good opportunities for students to reflect on what and how they have learned through these experiences and thus to come to understand the nature of human learning and expertise development as discussed earlier. Third, where students do develop ideas related to the subject matter of school curricula through informal learning, teachers will need to enable students to recognise, evaluate and build on this understanding.

6 Pedagogy with a limited range of the most appropriate ICTs

Whereas the previous three world-views discussed here have focused on learning, this view starts from a consideration of how teachers can choose from the wide range of ICTs. Even if you believe, as I do, that teachers should be highly educated expert professionals, and should be enabled to develop their expertise continually so that they can make use of tools and resources to support learning, there is still a need for principles and guidelines to enable teachers to: a) select from the wide range of ICTs that are proliferating and b) deploy them to provide affordances for learning. Furthermore some priorities and starting points are needed for initial teacher education because studies have shown that beginning teachers, even though they belong to the ‘net generation’, find deploying ICTs for learning very challenging (Valtonen et al. 2011; Barton and Haydn 2006). The main factors that determine teachers’ use of ICTs are their attitudes towards their value for learning and their self-efficacy, which is determined by their skills in using the particular ICT resource (Van Acker et al. 2011). Previous studies identified the enormous time and resources that would be needed to develop teachers’ knowledge and skills in relation to the wide range of ICT uses that could enhance or transform learning and instead suggested that teachers could focus on a more limited range of ICTs that were effective (Cox and Webb 2004; Webb and Cox 2004). Table 2, which is adapted from previous findings (Cox and Webb 2004; Webb and Cox 2004) indicates the wide range of affordances for learning and the types of ICTs that can support them. Affordances for learning are dependent on a combination of the whole environment for learning together with the characteristic of the learner (Cox and Webb 2004; Webb 2005).

In identifying which technologies to use and how to deploy them it is difficult to establish clear criteria based on evidence because meta-analyses of effect sizes shows much variation and no clear patterns with regard to the value of different ICTs (Hattie 2009; Liao and Hao 2008). Instead these analyses confirmed those of other studies (Cox et al. 2004; Cox and Webb 2004) that the value of the use of particular ICTs depends on the specific learning intentions, characteristics of learners and how the ICT resources were deployed alongside other elements of the learning environment. The analyses of effect-sizes of interventions with ICTs (Hattie 2009) did suggest that key attributes leading to highest effects were learner control, peer learning and challenging tasks with well-explained and focused feedback. These findings are

Table 2 Categories of affordances for learning supported by ICTs (adapted from Cox and Webb 2004; Webb 2005)

1. Categories of affordances	2. Learning supported	3. Type of ICTs used	4. Generic or subject specific ICTs
Researching information	Acquiring knowledge, consolidating understanding	Internet, Web browsers, Web cams, Video conferencing, content specific databases	Generic/Subject specific
Preparing presentations and producing materials	Organising ideas, reflecting, reviewing, evaluating, consolidating understanding	PowerPoint, Wikis, blogs word processors	Generic
Presenting	Presentation skills, organising ideas, reflecting, reviewing, evaluating	PowerPoint, Interactive Whiteboard	Generic
Visually representing processes/ideas	Understanding dynamic processes, reflecting, reviewing, comparing, evaluating, consolidating understanding	Simulations, animations, virtual worlds	Subject specific
Feedback	Knowing what aspects need more learning, thinking, predicting, self assessment	Simulations, Mind mapping software, Interactive Whiteboard, Shared blogs, Microblogging, discussion boards, Content specific tutorial systems	Generic/Subject specific
Making a drawing	Thinking about what they already know about composition	Drawing package	Subject specific
Taking turns	Social skills, sharing	Roamer, shared computer	Generic
Broadening experience	Generalising from examples, extending their ideas, clarifying, generating new ideas	Internet, Webs browsers, Web cams, Video conferencing, shared blots, Micro blogging, Discussion boards	Generic
Drawing graphs	Thinking about relationships between variables	Spreadsheets, data-logging packages	Generic
Investigating relationships, Testing hypotheses	Thinking about relationships between variables, reflecting, reviewing, comparing, evaluating, consolidating understanding	Simulations, Spreadsheets, data-logging packages, specific modelling packages, virtual worlds with haptics	Generic/Subject specific

consistent with findings of large effect sizes for AfL (Wiliam 2011). One way therefore of identifying which technologies should be prioritised in pedagogy is to examine their potential for supporting AfL. A framework for AfL (Wiliam et al. 2004) identified 5 strategies for AfL from empirical research in classrooms as:

1 Clarifying and negotiating learning intentions and criteria for success
2 Engineering effective discussions and other learning tasks, that elicit evidence of student understanding
3 Providing feedback that moves learners forward
4 Activating students as instructional resources for one another—peer support, peer feedback
5 Activating students as the owners of their own learning

In Fig. 2 this framework has been modified to incorporate ICT use based on discussions with practitioners, researchers and policy makers at EdusummIT 2011 (EDUsummIT 2012; Webb and Gibson 2011) and overlaid with potential key uses of specific ICTs.

AfL obviously does not encapsulate the whole of pedagogy but it does provide a content-free framework, supported by evidence of very high effect sizes, that can be applied to learning any topic (Wiliam 2011) and thus provides the basis for a principled approach to decision making about incorporating ICTs into pedagogical practices. A teacher referring to this framework to develop their pedagogical practice would need to be asking the question: how might the use of this ICT resource enable this aspect of formative assessment and enhance the experience for learners? For example, many teachers use interactive Whiteboards, to little educational benefit (Smith et al. 2005), but if they were using it to *clarify and negotiate learning intentions and criteria for success* they might use the approach shown in Table 3.

Table 3 shows just one example of how the use of one type of ICT could be used to support one of the AFL strategies. The approach in Table 3 is based on face-to-face teaching but some of the strategies could also be supported by online interactions.

Table 3 Using an interactive whiteboard to clarify and negotiate learning intentions and criteria for success

1. An online test prior to the lesson enables students to self assess and the teacher to identify learning intentions based on curriculum requirements as well as assessment data
2. The teacher writes the learning intentions on an interactive whiteboard at the start of the lesson or module
3. Whole class question and answer where students' self assess in relation to the learning intentions and class results are displayed on a bar chart
4. The teacher and students negotiate their learning intentions, perhaps leading to some changes or differentiation in the learning intentions and to clear statements of the success criteria
5. The revised learning intentions and success criteria are stored in a shared area so that teachers and pupils can refer to easily
6. Students show examples of their work to the class or group on an interactive whiteboard and explain and annotate it to indicate how it meets the success criteria
7. In peer groups students ask each other questions and give each other feedback while reviewing their work on an interactive whiteboard.

7 Conclusions and implications

The findings of this analysis of activity systems for 21st century learning can be summarised in relation to 3 main aspects of pedagogy which are discussed below: 1) learner involvement in managing and controlling their learning and 2) teacher expertise and decision making and 3) managing learning support through sharing knowledge related to pedagogy.

7.1 Learner involvement in managing and controlling their learning

As discussed in this paper, in order to support learners in managing their learning, schools can encourage individualisation and understanding of the nature of learning by enabling learners to follow their own interests for part of their school time. In this endeavour the evidence of enhanced achievement from collaborative learning (see for example Johnson et al. 2000) together with evidence discussed earlier that learners (aged 10–14) can self-organise in groups (Mitra and Dangwal 2010) supports a focus on learning collaboratively. A collaborative learning approach can also support the development of understanding and capabilities for surviving in our networked and liquid world (Bauman 2005). This would not mean that learners would always work in groups but collaborative work would be encouraged and recognised. As learners develop their capabilities for interacting in face to face settings they could be encouraged to engage with OSOSSs with learning potential. This pursuit of their own interests would not only be for the purpose of developing expertise but also for students to understand the nature of expertise, how it can be developed, how human cognition and memory systems support this development and how computational systems can also be harnessed to manage knowledge and support decision making. This approach could also lead to opportunities for understanding and developing shared expertise and transactive memory systems. Furthermore the relationship between these pursuits of individualisation and the pedagogy and curriculum pertaining in the rest of school-time would need to be actively discussed by learners and teachers so that learners understand the need for learning across the range of subjects and can make connections across the domains in terms of their approaches to learning as well as their understanding of subject matter.

7.2 Teacher expertise and decision making

The need to recognise teacher expertise as critical for efficient and effective learning emerges from the current analysis just as strongly as in many previous analyses (Hattie 2009) but with a different focus. The complexities for teachers of making sound pedagogical decisions need to be recognised so that the additional complexity of integrating a plethora of ICT uses into these decisions is appreciated. Proposing the AfL framework as a way of grounding decisions about lCT use is supported by strong effect sizes of innovations based on AfL (Wiliam 2011). However for teachers, becoming effective practioners of AfL is challenging (Webb and Jones 2009). Furthermore the evidence relating to expertise of teachers shows that while expert teachers can make a great deal of difference to students' learning many experienced teachers are not expert (Hattie 2009) so there are grounds for optimism but no room for complacency. The use of the AfL framework provides teachers with a way of thinking about learning first and then considering how to integrate into their plans one or more ICTs that will further the purpose of AfL. Their decision to integrate the ICTs can then be based on a predictive evaluation of whether or not it will add value to the learning experience. As mentioned earlier AfL is only part of pedagogy: other aspects include organisation of the learning environment and student groups; establishing a supportive culture; taking account of learners' overall development of knowledge, skills and expertise. Subject specific aspects of pedagogy include hierarchies of knowledge, subject culture, knowledge representations and terminologies. ICT use can affect all of these aspects of pedagogy but focusing on the AfL framework meets the criterion of parsimony (Whetten 1989) and provides a base for future developments in which we can have some confidence in these changing times.

7.3 Managing learning support through sharing knowledge related to pedagogy

The two pedagogical approaches described above are complementary. The first can be described as *learner-led* and the second as *learning-led*. The learning-led approach fits well with the AfL framework outlined previously. In the learner-led approach, teachers aim to enable learners to discover, explore and pursue their particular interests and to become increasingly independent in their learning within collaborative settings. In the learning-led approach, teachers aim to educate learners according to a curriculum defined by the society and culture in which they live. Crucially there must be movement and information flow between these two approaches so that learners see overall coherence in their learning and development.

These 2 approaches could be supported by sharing of pedagogy. The learner-led approach could involve team teaching: preferably the whole school engages at a set time giving opportunities for vertical groupings and professional development for teachers through collaborative learning while they engage in team teaching. Such teams may use online stores of knowledge about learners or traces from e-assessments but in developing such electronic information it will be important to maintain the high quality relationships and interactions between peers and between teachers and students with accompanying narrative and to resist the narrowing of learning that tends to be associated with a focus on detailed and systematic recording of assessments based on grades or competencies (Torrance 2007). Furthermore methods need to be developed for making output from e-assessment and feedback systems accessible to both teachers and learners in order to support pedagogical reasoning as a shared process between teachers, learners and peers (Webb and Gibson 2011). There is a dearth of studies and little evidence to support the benefits or otherwise of team teaching and this may reflect the rarity of team teaching in schools (Hattie 2009) suggesting a need for research and development.

In conclusion a possibility outlined here is to achieve a balance at all phases of education between developing understanding of the body of knowledge that is considered relevant in the culture and pursuing individual interests and thus developing expertise in an area of choice. Both of these could be achieved through a combination of individual effort and group participation designed to develop both individual study and group skills. Furthermore both could be supported by a range of resources including Internet access. The balance is likely to change as learners progress through formal education but there is no reason to assume that basic knowledge must be acquired before learners participate in knowledge construction. Rather there are benefits in learners engaging in metacognitive reflection as they tackle problems and develop expertise. This reflection should not only develop their information literacy but also evaluate their learning, their approaches to learning and compare and contrast human thinking and computational thinking.

Developments in neuroscience that inform our understanding of how learners' capacities and capabilities for learning may be changed either deliberately or accidentally through their activities with or without technology have been reviewed here briefly because they are likely to be important in our ongoing understanding of pedagogy. However, currently our limited understanding of how brains work means that no great implications for pedagogy can be derived and instead we should remain open to new possibilities as research in neuroscience proceeds.

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