Connectivism: the network metaphor of learning

Mohamed Amine Chatti*, Matthias Jarke and Christoph Quix

Informatik 5 (Information Systems), RWTH Aachen University,
Ahornstr, 55, 52056 Aachen, Germany
E-mail: chatti@cs.rwth-aachen.de
E-mail: jarke@cs.rwth-aachen.de
E-mail: quix@cs.rwth-aachen.de
*Corresponding author

Abstract: Connectivism is a new learning theory introduced by George Siemens in 2004 in order to cope with the increasing complexity and fast-paced change of the new knowledge era. This paper addresses the network metaphor of learning, which explains learning in terms of networks. We begin by introducing the connectivism approach to learning based on Siemens' work, and then provide an account of our view of connectivism by discussing the learning as a network (LaaN) perspective. We then present knowledge ecology as a social landscape that mirrors the complex nature and wide scope of knowledge, and continue by contrasting knowledge ecology to popular social forms that have been introduced in the CSCL and CSCW literature. These include communities of practice, knots, coalitions, intensional networks, and ad hoc transient communities. We end by comparing the connectivism/LaaN perspective with dominant learning and social theories. These theories are behaviourism, cognitivism, (social) constructivism, situated learning, activity theory, and actor-network theory.

Keywords: learning; knowledge; connectivism; knowledge ecology; learning as a network; LaaN; CSCL; CSCW.

Reference to this paper should be made as follows: Chatti, M.A., Jarke, M. and Quix, C. (2010) 'Connectivism: the network metaphor of learning', *Int. J. Learning Technology*, Vol. 5, No. 1, pp.80–99.

Biographical notes: Mohamed Amine Chatti has a Diploma in Computer Science from the Technical University of Kaiserslautern, Germany. He is currently working as a Research Assistant and PhD student at the Chair of Computer Science 5 – Information Systems, RWTH Aachen University, Germany. His research interests include web information systems, technology enhanced learning, professional learning, knowledge management, personal learning environments, and knowledge ecologies.

Matthias Jarke is a Professor of Information Systems at RWTH Aachen University and the Director of the Fraunhofer FIT Institute of Applied IT in Sankt Augustin, Germany. In his research, he investigates IS support for knowledge-intensive cooperative processes in business, engineering and culture. He has coordinated several IST projects, served as Programme Chair of leading information systems conferences. Both his university group and Fraunhofer FIT have been involved in numerous e-learning activities, ranging from the high school level to entrepreneurship training. He serves on a number of national and international advisory boards.

Christoph Quix is an Assistant Professor in the Information Systems Group (Informatik 5) of RWTH Aachen University, Germany, where he also received his PhD in Computer Science in 2003. His research focuses on metadata management, data integration, and semantic web technologies. He has about 40 publications in scientific journals and international conferences.

1 Introduction

Drucker (1994) argues that in the emerging economy, knowledge is the primary resource for individuals and for the economy overall – land, labour, and capital. He further argues that improving knowledge worker productivity is the greatest challenge of the 21st century. Knowledge is fundamentally social, personal, flexible, dynamic, decentralised, ubiquitous, networked, and complex in nature (Chatti et al., 2007). Furthermore, there is a wide agreement that the new era is defined by rapid knowledge development. For example, Siemens (2006a) writes: "Knowledge is changing. It develops faster, [and] it changes more quickly... Over the last several decades, more of our knowledge has shifted to soft knowledge. When things change rapidly, many knowledge elements do not have time to harden before they are replaced or amended". In the same direction, Brown and Adler (2008) note: "In the 20th century, the dominant approach to education focused on helping students to build stocks of knowledge and cognitive skills that could be deployed later in appropriate situations. This approach to education worked well in a relatively stable, slowly changing world in which careers typically lasted a lifetime. But the 21st century is quite different. The world is evolving at an increasing pace".

In order to reflect the nature of knowledge and align with the rapid change of the new knowledge intensive era, a new vision for learning is required. Siemens (2005a) argues that we do need to see the power of connections, and introduces connectivism as a new learning theory, which asserts that learning is primarily a network forming process. In this paper, we present the connectivism approach to learning which mainly views LaaN, and discuss the nature of the social landscape underlying connectivism, i.e., knowledge ecology.

2 Connectivism

Downes (2006) introduces the concept of *connective knowledge*, which asserts that "knowledge – and therefore the learning of knowledge – is distributive, that is, not located in any given place (and therefore not 'transferred' or 'transacted' per se) but rather consists of the network of connections formed from experience and interactions with a knowing community". Siemens (2005a, 2005b, 2006a, 2006b) argues that knowledge and learning are today defined by connections. The author stresses that 'know where' and 'know who' are more important today that knowing what and how, and introduces *connectivism* as a new learning theory that presents learning as a connection/network-forming process.

Connectivism principles acknowledge that learning is complex, multi-faceted, messy, and chaotic and consist of (Siemens, 2006a):

- learning and knowledge require diversity of opinions
- learning is a network formation process of connecting specialised nodes or information sources
- knowledge rests in networks
- knowledge may reside in non-human appliances, and learning is enabled/facilitated by technology
- capacity to know more is more critical than what is currently known
- learning and knowing are constant, on going processes (not end states or products)
- ability to see connections and recognise patterns and make sense between fields, ideas, and concepts is the core skill for individuals today
- currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities
- decision-making is learning.

Siemens (2005a) suggests learning that can reside outside the individual learner, is focused on connecting specialised information sets and the connections that enable us to learn more than our current state of knowing. According to Siemens, the main intent of network creation is to enable learners to continue to stay current in the face of rapidly developing knowledge. Siemens (2005a, 2006a) points out that the half-life of knowledge is shrinking. The half-life of knowledge is the time span from when knowledge is gained to when it becomes obsolete (Gonzalez, 2004). Siemens (2006a) writes: "In today's world, knowledge life is short; it survives only a short period of time before it is outdated". Adler (2007) quotes R. Natarajan, the former director of Indian Institute of Technology-Madras, noting that the "half-life of knowledge in many technical areas is now less than four years. Hence, 50% of what students learn as undergraduates will be obsolete by the time they graduate and begin to seek employment". Siemens (2006a) argues that learning networks can then be the solution to meet the challenges of rapidly diminishing knowledge life. The author writes: "learning networks can be perceived as structures that we create in order to stay current and continually acquire experience, create, and connect new knowledge (external). And learning networks can be perceived as structures that exist within our minds (internal) in connecting and creating patterns of understanding".

Connectivism is also the assertion that "the pipe is more important than the content within the pipe" (Siemens, 2005a). That is, the connections that enable us to learn more are more important than our current state of knowing. As Siemens (2006a) puts it: "Our ability to learn what we need for tomorrow is more important than what we know today. When knowledge is needed, but not known, the ability to plug into sources to meet the requirements becomes vital. As knowledge continues to grow and evolve, access to what is needed is more important than what the learner currently possesses".

3 The LaaN perspective

In this section, we will present our own conceptual viewpoint on connectivism by discussing the *learning as a network (LaaN)* perspective, which represents a knowledge ecological approach to learning. The LaaN view is built upon four premises:

- knowledge and learning are two sides of the same coin
- knowledge and learning are fundamentally personal and social in nature
- knowledge is in the network, or even more knowledge is the network
- learning is a matter of knowledge networking within knowledge ecologies.

LaaN views learning from a learner perspective. It starts from the individual learner and focuses on her personal knowledge network (PKN) as the unit of analysis. A PKN is comprised of a myriad of knowledge nodes with complex connections. Different views and theories of knowledge exist (Chatti and Jarke, 2009). Wierzbicki and Nakamori (2005), i.e., discuss diverse possible meanings of the concept of knowledge. A distinction that is often cited in the literature is made between explicit and tacit knowledge. Explicit knowledge (or information) is systematic knowledge that is easily codified in formal language and objective. In contrast, tacit knowledge is hard to formalise, difficult to communicate and subjective (Nonaka and Takeuchi, 1995). To note here that tacit and explicit knowledge cannot be separated and examined independently. Citing Polanyi (1962, 1966), Tsoukas (2005) writes: "tacit and explicit knowledge are not the two ends of a continuum but the two sides of the same coin: even the most explicit kind of knowledge is underlain by tacit knowledge". In Wenger's (1998, p67) words: "it is not possible to make everything explicit and thus get rid of the tacit… It is possible only to change their relations". Consequently, we have two types of interrelated knowledge nodes:

a explicit knowledge nodes are different explicit knowledge assets available in a variety of forms such as texts, images, sounds, videos and captured in distributed information repositories such as blogs, wikis, pod/vodcasts etc.

b tacit knowledge nodes are people performing in diverse, frequently overlapping social domains, who act together and help each other see connections.

LaaN, thus, views learning as the personal networking of knowledge nodes. In order to learn, we extend our PKN with new explicit/tacit knowledge nodes and when needed we activate the nodes that we believe are able to help us in mastering a learning situation. What we are trying to do all the time is either to pull together explicit knowledge nodes from more than one source, apply our personal judgement, reflect, detect patterns, remix and assemble it to form a new explicit knowledge asset or to expand our personal social networks with new tacit knowledge nodes by connecting to different social domains to harness tacit knowledge in a collaborative way, through listening, participation, dialogue, discussion, observation, and imitation.

Within a LaaN perspective, everyone is treated as a knowledge networker, one who has the ability to:

- create, harness, nurture, maintain, and extend her PKN
- identify connections, recognise patterns, and make sense between different knowledge nodes
- locate the knowledge node that can help achieving better results, in a specific learning context
- cross boundaries, connect and collaborate
- navigate and learn across multiple knowledge networks.

At the heart of the LaaN perspective lie knowledge ecologies. In the next section, we will discuss in detail knowledge ecology as a social landscape that reflects the complex nature and wide scope of knowledge.

4 Knowledge ecology

Several researchers, especially in the area of knowledge management, have used the term 'knowledge ecology'. Por (2000), i.e., defines knowledge ecology as "a field of theory and practice that focuses on discovering better social, organisational, behavioural, and technical conditions for knowledge creation and utilisation". According to Malhotra (2002), knowledge ecology "treats knowledge creation as a dynamic evolutionary process in which knowledge gets created and recreated in various contexts and at various points of time". In this paper, we present a more learner-oriented view of knowledge ecology. We define *knowledge ecology* as a complex, knowledge intensive landscape that emerges from the bottom-up connection of PKNs. In the following, we will address the characteristics of knowledge ecology and compare this social landscape to other important social aggregates that have been introduced in the CSCL and CSCW literature. These include *CoP* (Lave and Wenger, 1991; Wenger, 1998), *knots* (Engeström et al., 1999), *coalitions* (Zager, 2000), *intensional networks* (Nardi et al., 2002), and *ad hoc transient communities* (Berlanga et al., 2008).

4.1 Characteristics of knowledge ecology

Some of the key characteristics underlying the notion of knowledge ecology may be deduced from the characteristics of

a knowledge

b ecology.

Although, there is no common definition of the term knowledge, there is a wide agreement that knowledge is social, personal, flexible, dynamic, decentralised, ubiquitous, networked, and complex in nature (Chatti et al., 2007). An ecology is an open, complex adaptive system comprising elements that are dynamic and interdependent (Brown, 1999). Key characteristics of knowledge ecology include: complexity, adaptation, emergence, self-organisation, openness, and decentralisation.

Complexity and adaptation: knowledge ecology is a good example of a complex adaptive system (Holland, 1995). In a complex adaptive system, the behaviour of the whole is much more complex than the behaviour of the parts. Knowledge ecology is complex in that it is diverse and made up of multiple interconnected elements and adaptive in that it has the capacity to change and learn from experience (Holland, 1995, 1998). Knowledge ecology is also a complex system comprising many interacting identities in which cause and effect relationships cannot be distinguished (Snowden, 2002). Knowledge ecology thus has a non-deterministic character; it can evolve in ways that we may not expect or predict.

Emergence and self-organisation: Emergence is central to the theory of complex adaptive systems (Holland, 1998). Goldstein (1999) defines emergence as "the arising of novel and coherent structures, patterns and properties during the process of self-organisation in complex systems". Emergent properties are irreducible. As Lewes (1875) puts it: "The emergent is unlike its components in so far as these are incommensurable, and it cannot be reduced to their sum or their difference". Holland (1998) argues that emergence must be the product of self-organisation, not centralised control (cited in Ryan, 2007). Thus, as an example of a complex adaptive system, knowledge ecology holds emergent properties and includes self-organised entities. Knowledge ecology is co-constructed and maintained by individuals. It emerges naturally and is derived from the bottom-up networking of multiple PKNs. Knowledge ecology houses the learning that occurs in a bottom-up and emergent manner, rather than learning that functions within top-down and hierarchical structures under the control mechanisms of outside forces.

Openness and decentralisation: as with complex systems, ecologies are open and their boundaries are difficult to be determined. And, knowledge is decentralised and ubiquitous in nature. Thus, openness and decentralisation are central attributes in knowledge ecologies.

4.2 Knowledge ecology vs. CoP

As a special type of community, Lave and Wenger (1991) introduce the concept of *communities of practice (CoP)*. Wenger et al. (2002) defines CoP as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis". Wenger (1998) discusses three dimensions of CoP: mutual engagement, a joint enterprise, and a shared repertoire. Knowledge ecologies differ from CoP on all these dimensions.

According to Wenger (1998), the first characteristic of practice as the source of coherence of a community is the mutual engagement of participants. He stresses that the kind of coherence that transforms mutual engagement into a community of practice requires work and asserts that the work of 'community maintenance' is an intrinsic part of any practice. Knowledge ecologies, by contrast, are characterised by independence and diversity coming from lack of mutual engagement. Rather than being forced to interact intensely with other members of a CoP, within knowledge ecology, everyone can rely on her PKN. Often, people turn to their personal relationships in order to learn and get their work done, rather than trying to get access to a well established community of mutual engagement. Consequently, people focus on forming, maintaining, and sustaining their PKNs rather than maintaining the community of practice to which they belong.

Wenger states that the second characteristic of practice as a source of community coherence is the negotiation of a joint enterprise. He notes that CoP is not self-contained entities. They develop in larger contexts – historical, social, cultural, and institutional – with specific resources and constraints. Consequently, the practice of a community is profoundly shaped by conditions outside the control of its members due to external efforts to maintain influence and control over the practice. In contrast to CoP, knowledge ecologies are not positioned within a broader system and are not bound to the control of any external force. They emerge naturally without strong predetermined rules or institutional authority. Knowledge ecologies are thus self-controlled and self-contained entities.

Wenger notes that the third characteristic of practice as a source of community coherence is the development of a shared repertoire. He points out that the repertoire of a community of practice includes routines, words, tools, ways of doing things, stories, gestures, symbols, genres, actions, or concepts that the community has produced or adopted in the course of its existence, and which have become part of its practice. In contrast to CoP, knowledge ecologies lack a shared repertoire and are thus open and distributed domains. The knowledge resources are distributed over all PKNs within knowledge ecology.

4.3 Knowledge ecology vs. knot

Within an activity theory framework, Engeström et al. (1999) note that a great deal of work in today's workplace is not taking place in teams with predetermined rules or central authority but in work communities in which combinations of people, tasks and tools are unique, of relatively short duration. The authors introduce the concept of *knotworking* to describe temporal situation-driven combinations of people, tasks, and tools, emerging within or between activity systems. According to the authors, the notion of *knot* refers to rapidly pulsating, distributed, and partially improvised orchestration of collaborative performance between otherwise loosely connected actors and organisational units. Knotworking is characterised by a movement of tying, untying, and retying together seemingly separate threads of activity. In knotworking, the centre does not hold, meaning that the tying and dissolution of a knot of collaborative work is not reducible to any specific individual or fixed organisational entity as the centre of control or authority. The authors contrast knots to CoP, noting the differences between the two in terms of knots' loose connections, short duration of relationships, and lack of shared lore (Nardi et al., 2002).

Knowledge ecologies are similar to Engeström's knots in that they enable the formation of networks between loosely connected individual actors. These networks have no centre and rely on distributed control and coordinated action between actors. Knowledge ecologies and knots, however, differ in several important points. Knots are constituted by temporary relationships among knots' actors who aggregate to accomplish a specific task and disaggregate immediately afterwards. And, knots' configurations are in a sense predictable due to the well-defined practices of the actors and their predetermined individual roles. Knowledge ecologies, by contrast, are formed by long-term personal relationships among individuals who self-organise in highly flexible, dynamic, and unpredictable networks, without predetermined roles.

4.4 Knowledge ecology vs. coalition

Zager (2002) explores a collaboration configuration called a *coalition* and notes that coalitions are temporary collaborative groups where shared concerns and interests connect constituent individuals and teams. Constituents are part-time members of the coalition, making the coalition loosely bound. At any moment, the coalition's membership is fluid and diffuse, and communications among constituents may be non-existent, hindering coordination of the coalition. The organisation of the coalition is bottom-up, comprising independent participants acting on their own, with little or no reference to the other participants. Nardi et al. (2002) point out that coalitions share many of the characteristics of knots in being temporary, loosely bound, and fluid. The authors further note that while knots and coalitions are similar, it is worth making a distinction between smaller, more discrete knots where certain kind of interactions are possible, and more distributed coalitions. Coalitions differ from knots in that they occur in large distributed organisations where people involved in the coalition are in separate parts of the organisation and often out of communication with one another.

Knowledge ecologies and coalitions are similar in terms of distributivity and decentralisation, but different at the communication level. Zager (2000) notes that coalitions lack communication among their constituent individuals and teams, which leads to many coordination problems. He writes: "In coalitions, conversation is curtailed, and coordination suffers". In knowledge ecologies, however, communication is essential for successful networking and efficient knowledge sharing.

4.5 Knowledge ecology vs. intensional networks

Nardi et al. (2002) note that the most fundamental unit of analysis for computer supported cooperative work is not at the group level for many tasks and settings, but at the individual level as personal social networks come to be more and more important. The authors develop the concept of *intensional networks* to describe the personal social networks workers draw from and collaborate with to get their work done. The authors further use the term n*etWORK* to refer to the ongoing process of keeping a personal network in good repair. Key netWORK tasks include:

1 building a network, i.e., adding new contacts to the network so that there are available resources when it is time to conduct joint work

2 maintaining the network, where a central task is keeping in touch with extant contacts

3 activating selected contacts at the time the work are to be done.

Nardi et al. (2002) compare intensional networks to CoP, knots, and coalitions. The authors note that intensional networks differ considerably from CoP stating that intensional networks are personal, more heterogeneous, and more distributed than CoPs. According to the authors, intensional networks also differ from knots in several ways. First, intensional networks often involve long-term relationships. Second, the joint work may last for long or short periods of time. Third, the knotworking that occurs within established institutions is more structured in terms of the roles it draws upon. In contrast, work that is mediated by intensional networks results in more flexible and less predictable configurations of workers. Fourth, in intensional networks, workers are not

thrown together in situation dependent ways or assembled through outside forces. Instead, work activities are accomplished through the deliberate activation of workers' personal networks that have been carefully cultivated, often over many years. Nardi et al. (2002) further point out that intensional networks differ from coalitions on the dimension of intentionality. An intensional network is a deliberately configured and persistent personal network created for joint work, whereas a coalition is highly emergent, fluid, and responsive to state changes in a large system.

Intensional networks are at the core of our knowledge ecology concept. One of the crucial skills of a knowledge networker within a knowledge ecology is her ability to netWORK; that is build, maintain and activate her PKN to get her work done or learning goal achieved. Knowledge ecology, however, is a more general concept than intensional networks. Intensional networks are the elementary building blocks of knowledge ecologies which, by definition, are derived from the overlapping of different intensional networks. Nardi et al. (2002) admit that joint activity is accomplished by the assembling of sets of individuals derived from overlapping constellations of personal networks. The authors, however, place a heavy emphasis on the netWORKing process, discuss the characteristics of intensional networks as ego-centric networks that arise from individuals and their communication and workplace activity, but do not address the characteristics of the knowledge domains that emerge out of the interacting intensional networks. We referred to these knowledge domains as knowledge ecologies and we characterised them as emergent, highly dynamic, complex, and self-organised social entities.

4.6 Knowledge ecology vs. ad hoc transient communities

Ad hoc transient communities are very close to Engeström et al.'s (1999) knots. They are defined as communities that, whilst being part of a larger learning network, are brought into existence to fulfil a particular request (their ad hoc-ness) and exists for a limited period of time only (their transience) (Berlanga et al., 2008; Kester et al., 2007a, 2007b; Sloep et al., 2007). Ad hoc transient communities have several characteristics. First, the period of time they exist, is limited when compared to the time a typical learner spends in the learning network. Second, the knowledge sharing process is not supposed to be organised by an institution. Third, the knowledge exchanged comes in different kinds. It may be declarative, procedural, or conditional (Berlanga et al., 2008).

Similar to knowledge ecologies, ad hoc transient communities support voluntary, emergent, informal knowledge sharing. And, knowledge sharing is not imposed, it rather arises spontaneously (Berlanga et al., 2008). However, knowledge ecologies differ from ad hoc transient communities in three essential points. First, knowledge ecologies often involve stronger personal relationships than ad hoc transient communities. Second, knowledge ecologies may last for long periods of time in contrast to ad hoc transient communities that exist for a limited period of time only to address a specific learning related goal. Third, an ad hoc transient community is driven by a tutee-tutor interaction. As Kester et al., (2007a) state "an ad hoc transient community always starts with some learner who has a specific request and thus adopts the role of tutee. Depending on the nature of the request, peers have to be found that are suitable for the peer tutor role". In knowledge ecologies, by contrast, a learner relies on her PKN to get support for a particular learning goal. Sloep et al. (2007) acknowledge this negative side of ad hoc transient communities. They note "when users build up [learning] networks of their own,

it becomes gradually less likely that they will make use of the ad hoc transient community as a mechanism to have their questions answered".

5 Learning theories

Having introduced the connectivism approach to learning, discussed the LaaN perspective as our own viewpoint on connectivism, and presented knowledge ecology as the social landscape underlying LaaN, in the next sections, we compare the connectivism/LaaN perspective with dominant learning and social theories. These theories are behaviourism, cognitivism, (social) constructivism, situated learning, activity theory, and ANT.

5.1 Psychological learning theories

Wenger (1998) states that learning has traditionally been the province of psychological theories: *behaviourism*, *cognitivism*, and *constructivism*. In this section, we give a brief overview of these three theories and address their limitations in handling the increasing complexity and rapid change of the new knowledge era.

Behaviourist theories focus on behaviour modification via stimulus-response pairs and selective reinforcement (positive and negative reinforcement). Their pedagogical focus is on control and adaptive response (Skinner 1974; cited in Wenger, 1998). Behaviourists see the mind as a black box (all behaviour can be explained without the need to consider internal mental states or consciousness) and define learning as a change in behaviour in the learner.

Cognitive theories focus on internal cognitive structures and view learning as transformations in these cognitive structures. Their pedagogical focus is on the processing and transmission of information through communication, explanation, recombination, contrast, inference, and problem solving. They are useful for designing sequences of conceptual material that build upon existing information structures (Anderson 1983, Hutchins 1995; cited in Wenger, 1998). Sfard (1998) referred to the cognitivism view, according to which learning is mainly a process of acquiring desired pieces of knowledge, as the acquisition metaphor of learning.

Constructivist theories focus on the processes by which learners build their own mental structures when interacting with an environment. Their pedagogical focus is task-oriented. They favour hands-on, self-directed activities oriented toward design and discovery. They are useful for structuring learning environments, such as stimulated worlds, so as to afford the construction of certain conceptual structures through engagement in self-directed tasks. Learning, therefore, is simply the process of adjusting our mental models to accommodate new experiences (Piaget, 1954, Papert, 1980; cited in Wenger, 1998). How one constructs knowledge is a function of the prior experiences, mental structures, and beliefs that one uses to interpret objects and events (Jonassen, 1991). Rather than attempting to map the structure of an external reality onto learners, constructivists recommend that we help them to construct their own meaningful and conceptually functional representations of the external world (Jonassen, 1991).

Behaviourism, cognitivism, and constructivism, as psychological theories, assume that learning occurs inside a person (Siemens, 2005a). These theories view knowledge as

a property and possession of an individual mind. As Sfard (1998) notes: "The language of 'knowledge acquisition' and 'concept development' makes us think about the human mind as a container to be filled with certain materials and about the learner as becoming an owner of these materials". Instead of knowledge residing in the mind of an individual, connectivism focuses on knowledge that resides in a distributed manner across a network (Siemens, 2006b). In other words, psychological theories emphasise knowledge as a thing/object and the individual mind as a container, whereas a connectivism perspective emphasises knowledge as a network. Within the connectivism perspective, learning is knowledge networking rather than knowledge acquisition, internalisation, or construction.

5.2 Social theories

Connectivism shares with dominant social theories, such as *social constructivism*, *situated learning*, *activity theory*, and *ANT*, a core proposition, that knowledge and learning are fundamentally social in nature. However, the connectivism view of LaaN is quite distinctive.

5.2.1 Connectivism vs. social constructivism

Social constructivism is a theory of learning based upon the learners' social interaction and collaboration. Social constructivist theorists (e.g., Vygotsky) have extended the traditional focus on individual learning to address collaborative and social dimensions of learning. Whereas, Piaget's cognitive constructivism focuses on the individual mind, Vygotsky's social constructivism conceptualises learning as more socially constructed. Vygotsky (1978) argues that all cognitive functions originate in, and must therefore be explained as products of, social interactions and that learning was not simply the assimilation and accommodation of new knowledge by learners. According to Vygotsky (1978), human cognitive structures are essentially socially constructed. Knowledge is not simply constructed, it is co-constructed.

We criticise the social constructivism approach in two ways. First, although, social constructivism takes social interactions into account, it still sees learning as essentially intrinsic (i.e., in the learner's mind) and has thus a primarily psychological perspective. In fact, because knowledge is actively co-constructed by learners, learning depends to a significant extent on the learner's mind to understand and promote the learning process. Unlike social constructivism, connectivism views learning as both intrinsic and extrinsic; it occurs within networks. Second, the theory of social constructivism suggests that learners co-construct knowledge. However, the usage of the word 'construction' makes from knowledge a robust and durable object. As Latour (2005) states: "using the word 'construction' seemed at first ideal to describe a more realistic version of what it is for anything to stand. And indeed, in all domains, to say that something is constructed has always been associated with an appreciation of its robustness, quality, style, durability, worth, etc". Robustness and durability, however, do not apply to knowledge. Knowledge is much more varied and uncertain. As Siemens (2006a) stresses, "in today's world, knowledge life is short; it survives only a short period of time before it is outdated". In connectivism, knowledge is a network rather than an object that can be constructed.

5.2.2 Connectivism vs. situated learning

Situated learning is a model of learning first introduced by Lave and Wenger (1991). This model proposes that learning involve a process of engagement in a community of practice (CoP). Rather than looking to learning as the acquisition of certain forms of knowledge, Lave and Wenger (1991) explore the participation metaphor of learning in which learning is matter of legitimate peripheral participation (LPP) within a CoP. According to Lave and Wenger (1991), in a CoP, a newcomer learns from old-timers by being allowed to participate in certain tasks that relate to the practice of the community. Over time the newcomer moves from peripheral to full participation. It is however argued that, in modern and dynamic knowledge communities, there are not such clear-cut roles for newcomers and old-timers because everyone has to function as a newcomer in a sense of continuously surpassing his or her earlier achievements, and because sometimes new generations develop competencies that are very difficult for older generations to attain (Bereiter and Scardamalia, 1993; Paavola et al., 2002). Wenger (1998) revises his earlier work (Lave and Wenger, 1991) and offers a social account of learning through the negotiation of meaning and identity formation within CoP. While Wenger does not ignore legitimacy and peripherality, it is participation that he extracts as being crucial to the revised notion of a CoP showing it to be the key constituent in the processes of the negotiation of meaning (Hildreth and Kimble, 2002). According to Wenger, participation refers to "a process of taking part and also to the relations with others that reflect this process. It suggests both action and connection". Wenger stresses that learning is social participation and points out that "participation is not tantamount to collaboration. It can involve all kinds of relations, conflictual as well as harmonious, intimate as well as political, competitive as well as cooperative". He further explains that any CoP will then produce objects and refers to this process of giving form to the experience as reification.

Within the connectivism perspective, the notion of LPP, that is the process by which newcomers become included in CoP, is absent. In connectivism, role models are not strictly defined. There is no distinction between 'newcomers, novices, or peripheral participants' and 'old-timers or masters'. Every participant is equally treated as a knowledge networker. Furthermore, the social landscape is quite different within connectivism. Unlike CoP which are characterised by a single movement from the periphery to the centre, in knowledge ecologies, the centre does not hold and the movements occur in unpredictable directions. As we have discussed before, we make a strong distinction between closed, bounded, structured, and hierarchical CoP on the one hand and open, distributed, diverse, emergent, and self-controlled knowledge ecologies on the other hand.

5.2.3 Connectivism vs. activity theory

The cultural-historical theory of activity (activity theory) has grown out of the work of Vygotsky, Leont'ev and other Soviet psychologists. Activity theory approaches human cognition and behaviour as embedded in collectively organised, artefact- mediated activity systems (Leont'ev, 1978; Engeström, 1987). According to Engeström (1999b), an activity system "constantly generates actions through which the object of the activity is enacted and reconstructed in specific forms and contents – but being a horizon, the object is never fully reached or conquered". The classical representation of an activity system is a mediating triangle comprising three central components, namely subject, object, and

mediating artefacts (Leont'ev, 1978; Vygotsky, 1978). Activities are social practices oriented at objects. An entity becomes an object of activity when it meets a human need. The subject constructs the object using mediating artefacts (Engeström, 1999b). Engeström (1999a) notes that the problem with this classical representation is that it does not fully explicate the societal and collaborative nature of the actions. He then expands Vygotsky's (1978) mediating triangle with a social component by including three contextual factors, namely community, rules, and division of labour. Engeström (1987, 1999b) uses this expanded activity system model as the basis for his theory of *expansive learning*. Engeström (1987) conceives the notion of the 'zone of proximal development', initially discussed by Vygotsky (1978), as the cornerstone of expansive learning.

Vygotsky (1978) distinguishes between two developmental levels: The level of actual development is the level of development that the learner has already reached, and is the level at which the learner is capable of solving problems independently. The level of potential development is the level of development that the learner is capable of reaching under the guidance of teachers or in collaboration with peers. The learner is capable of solving problems and understanding material at this level that they are not capable of solving or understanding at their level of actual development. Vygotsky further defines the zone of proximal development as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers". According to Vygotsky, the zone of proximal development defines those functions that will "mature tomorrow but are currently in an embryonic state".

Vygotsky's (1978) zone of proximal development is very close to Lave and Wenger's concept of LPP. Both concepts emphasise that learning occurs best when an expert guides a novice from the novice's current level of knowledge to the expert's level of knowledge. As we pointed out when discussing the weakness of the idea of LPP, the lines became blurred between the expert and novice roles. At each moment the novice can get into the expert role and vice versa. In connectivism, everyone is a knowledge networker and can thus act as a novice in one context and step into the expert role in another context. Moreover, in connectivism, learning takes place in knowledge ecologies rather than within zones of proximal development. Unlike a zone of proximal development which is characterised by a rigid, restrictive, and one-dimensional development (i.e., training the novices within the zone to become competent members of the activity), a knowledge ecology is open and multidimensional. The boundaries of knowledge ecologies are less fixed and can easily be bridged and merged. And, the development within knowledge ecology is never fully predetermined and occurs in unpredictable dimensions.

Within an expansive learning framework, Engeström (1987, 1999b) presents the notion of 'expansive cycle' as the equivalent of Vygotsky's (1978) zone of proximal development. He traces seven actions to be taken in travelling through the zone of proximal development. Together these actions form an expansive cycle or spiral. According to Engeström (1999b), an ideal sequence of actions in an expansive cycle includes:

1 questioning, criticising, and rejecting some aspects of the accepted practices

2 analysing the situation

3 modelling of a new solution to the problematic situation

4 examining the model

5 implementing the model

6 reflecting on and evaluating the process

7 consolidating its outcomes into a new, stable from of practice.

However, in the new knowledge intensive era, it is increasingly evident that knowledge is highly complex and that dealing with knowledge is definitely not reducible to any sequence of actions. The actions which form Engeström's expansive learning cycle are not the only kinds of actions that must be mastered and performed in highly complex knowledge ecologies. The connectivism perspective does not postulate a predetermined sequence of actions; it rather enables a wide range of learner-driven actions that are neither predetermined nor predictable. Moreover, whereas in activity theory the emphasis is on the generated actions within a mediated, object-oriented activity, connectivism rather focuses on the individual learner and her PKN.

5.2.4 Connectivism vs. actor-network theory

Actor-network theory (ANT), also known as the sociology of translation or sociology of associations, proposes a socio-technical account that makes no distinction in approach between the social, the natural and the technological (Callon, 1986; Latour 1996, 1997, 2005; Law, 1992). ANT is based upon the principle of generalised symmetry employing a single conceptual framework when interpreting actors, human and non-human. Latour (1997) writes "an 'actor' in ANT is a semiotic definition -an actant-, that is, something that acts or to which activity is granted by others. It implies no special motivation of human individual actors or of humans in general. An actant can literally be anything provided it is granted to be the source of an action". An actor is also a simplified network. As Law (1992) puts it: "an actor is a patterned network of heterogeneous relations, or an effect produced by such a network... Hence, the term, actor-network – an actor is also, always, a network".

However, ANT has several limitations. Williams (2007) points out that ANT makes a specific link between the person and their environment such that it is not possible that an individual acts within several networks at the same time. As he puts it: "ANTs actor-networks seem to move from one part of an actor-network to another, but do not seem to have the facility or the affordances to move within more than one network at the same time, in a similar way to the way in which one can say that someone acts within several discourses at the same time". In knowledge ecologies, however, an individual can be 'actant' in several, frequently overlapping networks at the same time.

Moreover, ANT explores the ways that the networks of relations are formed, how they emerge and come into being, how they are constructed and maintained, and how they are made more durable over time, or fall apart. It also examines how actors enlist other actors into their world (Latour, 1996). Central to ANT is the concept of translation which is the process of creation of an actor-network and generation of ordering effects (Law, 1992). According to Callon (1986), the translation process consists of four major steps: problematisation, interessement, enrolment, and mobilisation. However, as discussed before, the creation of knowledge networks cannot be dictated by a predefined process. It rather requires self-ordering and self-organisation. Law (1992), while exploring the strategies of translation, acknowledges the self-ordering nature of

knowledge networks. As he puts it: "translation is contingent, local and variable". In contrast to ANT, in the connectivism approach, the creation of knowledge networks is rather undetermined, often unpredictable internal process within the knowledge ecology which is, by definition, a self-controlled, self-maintained, and self-organised entity.

Williams (2007) notes that ANT does not distinguish between complex and complicated systems. He quotes Snowden (2002) who makes a distinction between complex and complicated: "An aircraft is a complicated system; all of its thousands of components are knowable, definable and capable of being catalogued as are all of the relationships between those components... Cause and effect can be separated and by understanding their linkages we can control outcomes. Human systems are complex; a complex system comprises many interacting agents, an agent being anything that has identity... In such a complex system, the components and their interactions are changing and can never be quite pinned down. The system is irreducible. Cause and effect cannot be separated because they are intimately intertwined". According to Williams, ANT (particularly in Latour's work) refuses to make the distinction between human and non-human actors i.e., actors with and without identity; identity in the sense of self-maintaining and self-reproducing identity.

Another point where it also becomes clear that ANT does not make a distinction between the complex and the complicated is the Ant's concern with the way in which the social is constantly reconfigured, or in Latour's (2005) words 'reassembled'. Law (2002) stresses that the core of the actor-network approach is "a concern with how actors and organisations mobilise, juxtapose and hold together the bits and pieces out of which they are composed; how they are sometimes able to prevent those bits and pieces from following their own inclinations and making off; and how they manage, as a result, to conceal for a time the process of translation itself and so turn a network from a heterogeneous set of bits and pieces each with its own inclinations, into something that passes as a punctualised actor". Latour (2005) uses the verb reassemble to describe the same effect. He specifies five major uncertainties:

- the nature of groups: there exist many contradictory ways for individuals to be given identity
- the nature of actions: in each course of action a great variety of agents seem to barge in and displace the original goals
- the nature of objects: the type of agencies participating in interaction seems to remain wide open
- the nature of facts: the links of natural sciences with the rest of society seems to be the source of continuous disputes
- and, finally, about the type of studies done under the label of a science of the social as it is never clear in which precise sense social sciences can be said to be empirical.

Latour argues that if the social is based on layers of uncertainties, then the social needs to be reassembled. However, in the new knowledge intensive era, the relationship between different knowledge nodes or in Law's terms 'heterogeneous bits and pieces' is becoming flexible and is changing rapidly; thus, it cannot be captured through a reconfiguration process. Reconfiguration, or in Latour's terms reassembling, works well for complicated systems in which different components and associated relationships can be identified and managed. Reconfiguration, however, cannot work while dealing with complex

knowledge systems comprising many interacting identities. In the latter case, networking is the solution. In complex knowledge systems, the way the knowledge nodes network with each other results in unpredictable movements in the knowledge ecology. Knowledge ecologies lie at the heart of the connectivism approach.

Furthermore, Latour (2005) claims that it's possible to render social connections traceable by following the work done to stabilise the five controversies specified above and that the role of ANT is to trace actor-networks. To note here that 'network' in Latour's vocabulary means something different. Latour points out that 'network' are an ambiguous word meaning "a string of actions where each participant is treated as a full-blown mediator". To avoid this confusion, Latour suggests using 'work-net' rather than 'network'. He writes: "we should say 'work-net' instead of 'network'. It's the work, the movement, the flow, and the changes that should be stressed". In complex knowledge systems, however, there is no chance to trace social connections, nor is it possible to follow the actors or their actions. Latour himself acknowledges that following the actors themselves is not an easy task since, as he writes, "the actors to be followed swarm in all directions like a bee's nest disturbed by a wayward child". Thus, there is no means to trace actors' actions and connections because their actions are uncertain, unexpected, and often hidden; and their connections are varied, ubiquitous, and open. The role of connectivism is neither to follow actors nor to trace their actions or connections. Its major role is to foster connections between PKNs in order to form a complex, adaptive, dynamic, open, and living entity; i.e., knowledge ecology.

5.2.5 Comparison table

Table 1 summarises how the dominant learning and social theories outlined in the previous sections differ from the connectivism/LaaN perspective. We would like to stress here that different learning theories cannot be considered in isolation. They complement and enhance each other. They interplay with each other, but cannot replace each other. In fact, many the assumptions that underlie connectivism/LaaN are compatible with those of other theories. Connectivism/LaaN is thus not a replacement for other theories that address different aspects of learning. But is does have its own focus and explains specific types of learning. The primary focus of connectivism/LaaN is mainly on the learner and her PKN and complex network learning is the type of learning best explained by connectivism/LaaN.

6 Conclusions

In this paper, we addressed how the growing complexity and constant change of knowledge requires a new approach to learning. Based on Siemens' work, we introduced connectivism as an alternative learning theory for the new knowledge era, and presented our own conceptual viewpoint on connectivism by discussing the LaaN perspective which represents a knowledge ecological approach to learning. By comparing connectivism to influential learning and social theories on the one hand, and knowledge ecology to prominent social infrastructures discussed in the CSCL and CSCW literature on the other hand, our aim was to better explore the scope of the connectivism/LaaN perspective and highlight the nature of the social landscape underlying connectivism, i.e., knowledge ecology.

Table 1 Learning theories compared

	Psychological learning theories			*Social theories*				*Connectivism/LaaN*
	Behaviourism	*Cognitivism*	*Constructivism*	*Social constructivism*	*Situated learning*	*Activity theory*	*Actor-network theory*	
Key concepts	Mind as a "black box"	Schema, sensory, register, short-term memory (STM), long-term memory (LTM)	Mental structures, personal interpretation, prior experiences	Social negotiation, zone of proximal development (ZPD)	Legitimate peripheral participation (LPP), newcomer, old-timer	Activity system, subject, object, mediating artefacts, expansive learning	Actors, sociology of translation/associations, generalised symmetry	Personal knowledge network (PKN), knowledge nodes
How does learning occur?	Change in learner's behaviour	Transformation in internal cognitive structures	Adjusting our mental models to accommodate new experience	Moving from the level of actual development to the level of potential development	LPP	Generate actions within a mediated, object-oriented activity	Actor-network forming process	Connections identification, pattern recognition
Focus	Behaviour modification (intrinsic)	Internal cognitive structures (intrinsic)	Learners build their own mental structures (intrinsic)	Reaching the level of potential development (intrinsic)	Community of practice (CoP)	Activity system	Actor-networks	Learner and her PKN
Core activity	Stimulus-response, selective reinforcement	Process and store information, reorganisation of cognitive structures	Self-directed tasks	Travelling through ZPD	Participation, negotiation of meaning, identify formation	Sequence of actions in an expansive cycle	Translation, i.e., creation of actor-networks and generation of ordering effects	Widen our PKNs to embrace new knowledge nodes
Learner's role	Knowledge acquisition	Knowledge internalisation	Knowledge construction	Knowledge co-construction	Engagement in a CoP	Construction of the activity object using mediating artefacts	Mediator in actor-networks	Knowledge networker
Underlying social entity and its characteristics				Group of teachers and peers, centralised, controlled, top-down	CoP, closed, structured, hierarchical, knowledge-push	Knots, temporary relationships, predictable	Actor-network, heterogeneous	Knowledge ecology, complex adaptive, unpredictable, dynamic, open, distributed, diverse, emergent, self-*, homogeneous, knowledge-pull

Summarising, connectivism addresses the network metaphor of learning, and is a new approach to learning that combines personalised, formal, informal, and lifelong learning within a social context. Although, it occupies common ground with other social theories as it stresses the social nature of knowledge, connectivism is distinguished from all those theories in that it provides a more personalised, open, dynamic, emergent, and knowledge-pull model for learning. At the heart of connectivism lies knowledge ecology which is a complex, emergent, highly dynamic, open, self-controlled, self- maintained, and self-organised entity with the major task to handle the unanticipated changes in the new knowledge intensive era.

Depending on the learners and situation, different learning theories may apply (Mergel, 1998). Different learning theories overlap and each learning theory has its strengths and weaknesses. Constructivism/LaaN presents a relatively young learning theory. The constructivism/LaaN perspective presented in this paper yields general principles of a new vision of learning from which to derive a consistent set of conceptual models and frameworks for understanding and enabling learning in the new-networked world.

References

Adler, R.P. (2007) 'Minds on fire: enhancing India's knowledge workforce', *Report of the 2nd Annual Joint Roundtable on Communications Policy*.

Anderson, J.R. (1983) *The Architecture of Cognition*, Harvard University Press, Cambridge, MA.

Bereiter, C. and Scardamalia, M. (1993) 'Surpassing ourselves', *Open Court*, Chicago.

Berlanga, A.J., Sloep, P.B., Kester, L., Brouns, F. and Koper, R. (2008) 'Ad hoc transient communities: towards fostering knowledge sharing in learning networks', *Int. J. Learning Technology*, Vol. 3, No. 4, pp.443–458.

Brown, J.S. (1999) 'Learning, working & playing in the digital age', *AAHE Conference on Higher Education*, Washington, DC.

Brown, J.S. and Adler, R.P. (2008) 'Minds on fire: open education, the long tail, and learning 2.0', *EDUCAUSE Review*, Vol. 43, No. 1, pp.16–32.

Callon, M. (1986) 'Some elements of a sociology of translation: domestication of the scallops and the fishermen of St. Brieuc Bay', in Law, J. (Ed.): *Power, Action & Belief. A New Sociology of Knowledge?*, pp.196–229, Routledge & Kegan Paul, London.

Chatti, M.A. and Jarke, M. (2009) 'Social software for bottom-up knowledge networking and community building', in Lytras, M.D., Tennyson, R. and Ordóñez de Pablos, P. (Eds.): *Knowledge Networks: The Social Software Perspective*, pp.17–27, IDEA Group Publishing, Hershey, PA, USA.

Chatti, M.A., Jarke, M. and Frosch-Wilke, D. (2007) 'The future of e-learning: a shift to knowledge networking and social software', *International Journal of Knowledge and Learning*, Vol., Nos. 4/5, pp.404–420.

Downes, S. (2006) 'Learning networks and connective knowledge', retrieved on 3 April 2008, available at http://it.coe.uga.edu/itforum/paper92/DownesPaper92.pdf.

Drucker, P.F. (1994) 'The theory of business', *Harvard Business Review*, September/October, pp.95–104.

Engeström, Y. (1987) *Learning by Expanding*, Orienta-Konsultit, Helsinki.

Engeström, Y. (1999a) 'Activity theory and individual and social transformation', in Engeström, Y., Miettinen, R. and Punamäki, R-L. (Eds.): *Perspectives on Activity Theory*, pp.19–38, Cambridge University Press, Cambridge.

Engeström, Y. (1999b) 'Innovative learning in work teams: analyzing cycles of knowledge creation in practice', in Engeström, Y., Miettinen, R. and Punamäki, R-L. (Eds.): *Perspectives on Activity Theory*, pp.377–404, Cambridge University Press, Cambridge.

Engeström, Y., Engeström, R. and Vähäaho, T. (1999) 'When the centre doesn't hold: the importance of knotworking', in Chaiklin, S., Hedegaard, M. and Jensen, U. (Eds.): *Activity Theory and Social Practice: Cultural-Historical Approaches*, Aarhus University Press, Aarhus, Denmark.

Goldstein, J. (1999) 'Emergence as a construct: history and issues', *Emergence: Complexity and Organization*, Vol. 1, No. 1, pp.49–72.

Gonzalez, C. (2004). 'The role of blended learning in the world of technology', retrieved on 10 March 2008, available at http://www.unt.edu/benchmarks/archives/2004/september04/eis.htm.

Hildreth, P.J. and Kimble, C. (2002) 'The duality of knowledge', *Information Research*, Vol. 8, No. 1, Paper no. 142.

Holland, J.H. (1995) *Hidden Order: How Adaptation Builds Complexity*, Addison-Wesley, MA.

Holland, J.H. (1998) *Emergence: From Chaos to Order*, Addison-Wesley, MA.

Hutchins, E. (1995) *Cognition in the Wild*, MIT Press, Cambridge, MA.

Jonassen, D.H. (1991) 'Objectivism versus constructivism: do we need a new philosophical paradigm?', *Educational Technology Research and Development*, Vol. 39, No. 3, pp.5–14.

Kester, L., Sloep, P.B., Van Rosmalen, P., Brouns, F., Koné, M. and Koper, R. (2007a) 'Facilitating community building in learning networks through peer-tutoring in ad hoc transient communities', *International Journal of Web Based Communities*, Vol. 3, No. 2, pp.198–205.

Kester, L., Van Rosmalen, P., Sloep, P., Brouns, F., Koné, M. and Koper, R. (2007b) 'Matchmaking in learning networks: bringing learners together for knowledge sharing', *Journal of Interactive Learning Environments*, Vol. 15, No. 2, pp.117–126.

Latour, B. (1996) *Aramis or the Love of Technology*, Harvard University Press, Cambridge, MA.

Latour, B. (1997) 'On actor-network theory – a few clarifications', *Soziale Welt-Zeitschrift Fur Sozialwissenschaftliche Forschung Und Praxis*, Vol. 47, p.369.

Latour, B. (2005) 'Reassembling the social', *An Introduction to Actor-Network-Theory*, Oxford.

Lave, J. and Wenger, E. (1991) *Situated Learning. Legitimate Peripheral Participation*, Cambridge University Press, New York.

Law, J. (1992) 'Notes on the theory of actor-network: ordering, strategy and heterogeneity', *Systems Practice*, Vol. 5, No. 4, pp.379–393.

Leont'ev, A.N. (1978) *Activity, Consciousness, Personality*, Prentice Hall, Englewood Cliffs.

Lewes, G.H. (1875) *Problems of Life and Mind*, Vol. 2, Kegan Paul, Trench, Turbner, & Co., London.

Malhotra, Y. (2002) 'Information ecology and knowledge management: toward knowledge ecology for hyperturbulent organizational environments', *Encyclopedia of Life Support Systems (EOLSS)*, UNESCO/Eolss Publishers, Oxford, UK.

Mergel, B. (1998) 'Instructional design and learning theory', retrieved on 29 January 2009, available at http://www.usask.ca/education/coursework/802papers/mergel/brenda.htm.

Nardi, B., Whittaker, S. and Schwarz, H. (2002) 'NetWORKers and their activity in intensional networks', *Computer Supported Cooperative Work*, Vol. 11, Nos. 1/2, pp.205–242.

Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University, New York

Paavola, S., Lipponen, L. and Hakkarainen, K. (2002) 'Epistemological foundations for CSCL: a comparison of three models of innovative knowledge communities', in *Proceedings of the Computer-supported Collaborative Learning Conference*, pp.24–32, Erlbaum, Hillsdale, NJ.

Papert, S. (1980) *Mindstorm*, Basic Books, New York.

Piaget, J. (1954) *The Construction of Reality in the Child*, Basic Books, New York.

Polanyi, M. (1962) *Personal Knowledge*, The University of Chicago Press, Chicago.

Polanyi, M. (1966) *The Tacit Dimension*, Routledge & Kegan Paul, London.

Por, G. (2000) 'Nurturing systemic wisdom through knowledge ecology', *The Systems Thinker*, Vol. 11, No. 8.

Ryan, A.J. (2007) 'Emergence is coupled to scope, not level: research articles', *Complexity*, Vol. 13, No. 2, pp.67–77.

Sfard, A. (1998) 'On two metaphors for learning and the dangers of choosing just one', *Educational Researcher*, Vol. 27, No. 2, pp.4–13.

Siemens, G. (2005a) 'Connectivism: a learning theory for the digital age', *International Journal of Instructional Technology and Distance Learning*, Vol. 2, No. 1.

Siemens, G. (2005b) 'Connectivism: learning as network-creation', Elearnspace, retrieved on 24 March 2008, available at http://www.elearnspace.org/Articles/networks.htm.

Siemens, G. (2006a) *Knowing Knowledge*, available at Lulu.com, ISBN: 978-1-4303-0230-8.

Siemens, G. (2006b) 'Connectivism: Learning theory or pas-time for the self-amused?', Elearnspace, retrieved on 24 March 2008, available at http://www.elearnspace.org/Articles/connectivism self-amused.htm.

Skinner, B.F. (1974) *About Behaviourism*, Knopf, New York.

Sloep, P., Kester, L., Brouns, F., Van Rosmalen, P., De Vries, F., De Croock, F. and Koper, T. (2007) 'Ad hoc transient communities to enhance social interaction and spread tutor responsibilities', in Uskov, V. (Ed.): *6th International Conference on Web-based Education WBE 2007*, pp.548–554, Acta Press, Chamonix, France.

Snowden, D.J. (2002) 'Complex acts of knowing: paradox and descriptive self-awareness', *European Conference on Knowledge Management*, Dublin, Ireland.

Tsoukas, H. (2005) 'Do we really understand tacit knowledge?', in Easterby-Smith, M. and Lyles, M.A. (Eds.): *The Blackwell Handbook of Organizational Learning and Knowledge Management*, Blackwell Publishing.

Vygotsky, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*, Harvard University Press, Cambridge, MA.

Wenger, E. (1998) *Communities of Practice: Learning, Meaning and Identity*, Cambridge University Press, Cambridge, UK.

Wenger, E., McDermott, R. and Snyder, W.M. (2002) *Cultivating Communities of Practice*, Harvard Business School Press, Boston.

Wierzbicki, A. and Nakamori, Y. (2005) *Creative Space: Models of Creative Processes for the Knowledge Civilization Age*, Birkhäuser.

Williams, R. (2007) 'Managing complex adaptive networks', *International Conference on Intellectual Capital and Knowledge Management*, Cape Town.

Zager, D. (2000) 'Collaboration on the fly', in *Proceedings of the Academia/Industry Working Conference on Research Challenges*, pp.65–70.

Zager, D. (2002) 'Collaboration as an activity', *Computer Supported Cooperative Work*, Vol. 11, No. 1, pp.181–204.