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The Future of Learning in the Knowledge Society: Disruptive Changes for Europe by 2020

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1 Executive Summary

In the next fifteen years, European citizens will have access to advanced information and communication technologies that will profoundly change the ways we use, create and learn information, knowledge and skills. We will be able to package material objects in virtual layers of software and information, turn them into extended and informationalized artifacts, and link them to the ubiquitous global net. Our physical spaces will blend material, informational and communicative structures and functionality. Work will become increasingly knowledge-intensive, and productive activities will both concentrate in new geographical regions and, at the same time, become globally distributed. The established institutions of learning will struggle to adapt to the new social and economic order, and new institutional forms of education and learning will emerge.

The rapid and sustained change in information and communication, media, and transport technologies has already reorganized the world. As a result, our concepts and practices of learning will undergo fundamental change in the coming years.

This paper describes the ongoing socio-economic transformation, presents scenarios for future educational settings, and reviews examples of innovative uses of information and communication technologies in education and learning. It tries to open the discussion on the future of educational institutions. For example, we have to ask, why do we learn and whether learning will be interesting also in the future. This requires that we revisit and make explicit some assumptions that underlie our educational institutions, theories and practices.

Debates on the proper objectives of learning will become increasingly visible in the future knowledge society. To an important extent this is because existing educational institutions need to find new ways to justify and legitimize themselves. As workers increasingly have to process up-to-date knowledge and mobilize socially and geographically distributed resources to get their job done, knowing becomes an increasingly dynamic and social phenomenon. Knowledge is reproduced, created, and recombined in fast cycle-times and in problem contexts that are difficult to imitate in educational institutions. Rote learning of facts becomes redundant when everyone has access to ubiquitous networks of information. Learning and knowledge-creation skills become increasingly important for work performance, and educational certificates become increasingly irrelevant. Learning opportunities accumulate fast for some, creating social differences and digital divides, and education institutions and policymakers struggle to combine innovation, creativity and equal opportunities.

To outline the emerging landscapes for learning, as they will be seen from inside educational institutions, we develop short scenarios for a fictive International Standard Classification of Education, for the year 2020. The International Standard Classification of Education (ISCED) was designed by UNESCO in the early 1970's to serve as an instrument for assembling, compiling and presenting statistics of education both within individual countries and internationally. The present classification, ISCED 1997, aims to cover all organized and sustained learning opportunities. Within the framework of ISCED, the term education is taken to comprise all deliberate and systematic activities designed to meet learning needs. Due to its institutional focus, ISCED implicitly categorizes and describes learning institutions where professional teachers work. We therefore use the ISCED classification as a handle to the current systems of education, and try to see how the structures of education will change from their internal point of view.

Educational systems are extremely difficult to change. This has little to do with an abstract tendency for "resistance to change." Change and innovative learning are often against prevailing interests and existing institutional arrangements. As educational institutions are facing the demands of the knowledge society, it is important to understand where, exactly, are the sources of inertia in educational systems. To develop better educational systems we have to understand how educational institutions learn and why learning is difficult in educational organizations.

The paper also describes a number of innovative applications of information and communication technologies and discusses the different ways in which ICTs will be used in future learning environments. We introduce some illustrative examples of new technologies and also propose some new generic application categories for future learning technologies.

The paper then ends with a short concluding section.

The Future of Learning in the Knowledge Society: Disruptive Changes for Europe by 2020

In the next fifteen years, European citizens will have access to advanced information and communication technologies that will profoundly change the ways we use, create and learn information, knowledge and skills. We will be able to package material objects in virtual layers of software and information, turn them into extended and informationalized artifacts, and link them to the ubiquitous global net. Our physical spaces will blend material, informational and communicative structures and functionality. Work will become increasingly knowledge-intensive, and productive activities will both concentrate in new geographical regions and, at the same time, become globally distributed. The established institutions of learning will struggle to adapt to the new social and economic order, and new institutional forms of education and learning will emerge.

The transformation towards the knowledge society is driven by complex interactions between technical, social, economic, and human factors. The developments are not deterministic. Instead, the ongoing transformation is being pushed by forces that at each present configuration find their next direction of gradual evolution. At each point of time, the society, embedded in its material past and the world around it, moves towards the possible and the promising, without simple linear causality.

Although this complex process of co-evolution cannot be described using deterministic causal models, it is possible to describe fundamental trends that will generate new possibilities and promising avenues for development. We don't have to guess the future. We can simply look around us and realize that advances in information processing technologies have already changed the world. Even if technical advance in ICTs would end tomorrow, the diffusion of current technologies will fundamentally change the way we live, work and learn in the 2020. We have created radical technologies but the revolution is still ahead of us. In many ways, we simply have to make current technical opportunities real to change the world.

At the same time, we are creating new technologies that will enable new technical architectures and applications. Due to their important social and economic impact, educational applications of information and communication technologies will be key drivers in this process.

Educational institutions—for reasons described below—have been relatively slow in adopting information and communication technologies. Great expectations about computer-based learning and the rapid growth of educational software markets have in recent years given way to skeptical attitudes concerning the role of technology in learning. To a large extent, this has been because technology has often been used simply to computerize classical learning models. In practice, private firms have often been leaders in experimenting with new learning models and integrating information and communication technologies into their competence development and knowledge creation processes.

As Linné noted in Philoshopia Botanica, “natura non facit saltus.”[1] Discontinuous and disruptive change is something that, strictly speaking, we invent ourselves. At some point in time, we start to think the world has become different enough that the old reality does not exist anymore. We look at a picture and see a rabbit where we earlier saw a duck, and we look to the sky and see the sun at the center of the universe instead of being there ourselves. This is the prototypical paradigm shift, made famous by Thomas Kuhn.

Paradigm shifts, however, are not purely mental events. The reality is deeply rooted in social institutions and material constraints. We can see a rabbit and a duck in the same picture partly because they are only two-dimensional drawings on paper. In the picture, the rabbit does not quack like a duck, and the duck does not make jumps. We can relatively freely imagine one or the other, and our imagination does not really matter much in practice.

In real life, our imagination is constrained in many ways. In particular, our imagination is constrained by the imaginations of others and the real practical characteristics of our material environment. Technical and material artifacts have some affordances and functional capabilities and not others. Human imagination is, in turn, constrained by routines that constantly reproduce and regenerate social institutions and stocks of socially shared knowledge. Socially important change, therefore, is slow, and revolutions can often only be described in retrospection.

Disruptive change becomes real when our collective imaginations change and reorganize our world and our interactions with others. When important trends interact, we may have to reorganize our views of the world in fundamental ways. Such “tectonic” disruptions occur in the foundations on which we build our everyday life. They require that we rethink what already was obvious. The rapid and sustained change in information and communication, media, and transport technologies has already created such tectonic tensions and reorganized the world. As a result, our concepts and practices of learning will undergo fundamental change in the coming years.

This paper, therefore, aims at laying out some characteristics of the ongoing socio-economic transformation. It tries to open the discussion on their implications for learning. We have to ask, why do we learn and whether learning will be interesting also in the future. This requires that we revisit and make explicit some assumptions that underlie our educational institutions, theories and practices.[2]

2 Models of learning

“Protagoras answered: Young man, if you associate with me,
on the very first day you will return home a better man than you came,
and better on the second day than on the first,
and better every day than you were on the day before."

[1] “Nature makes no leaps.” Also commonly used since the 16th century in the form Natura non facit saltum, often translated as “nature does nothing in jumps.”

[2] The paper refers to a number of learning theories which are reviewed in a separate Appendix.

Learning, in the conventional definition, is the process of acquiring knowledge, skills, attitudes, or values, through study, experience, or teaching. To be counted as learning, it has to lead to long-term changes in behavior potential; in other words, it has to generate new capacity for alternative behaviors of an individual in a given situation in order to achieve a goal. Learning may be viewed as a change in activity, in the structure of behavior, and in a person's mode of engagement in social practices (Packer, 1993:264). It is change in mind—metanoia, as Senge (1990) calls it—but also change that is reflected in action.

During the last century, learning has been studied in the contexts of behaviorism, cognitivism, constructivism, connectionism, distributed cognition, socio-cultural theory, and organizational studies on innovation and knowledge creation. Behaviorism focused on externally observable change, cognitivism on mental representations and processes, and constructivism on active interpretation and sensemaking. More recently, studies on distributed cognition have moved the focus from individual human mental processes towards the interactions between human cognition and its social and material environment. This move has partly been influenced by the rediscovery of socio-cultural and cultural-historical theories of learning.

Many variations exist on these research traditions. In general, behaviorism adopted a positivist epistemology, where learners adapt to given external conditions of a learner-independent reality. Cognitivism shared this positivist epistemology, viewing learners as processors of external signals and information. Constructivism, in turn, made knowledge and the reality two sides of the same coin, studying, in the words of Jean Piaget, how "the mind organizes the world by organizing itself."[3] The cultural-historical and socio-cultural research traditions, inspired by Lev Vygotsky and his students, have put this constructivist epistemology in social and semiotically mediated contexts, effectively starting from the assumption that—although meaningful reality and knowledge about it are actively constructed by learners—accumulated social, cultural and material resources both embed and constrain this process.

3 The objective of learning

In these theoretical traditions, learning has often been viewed as a process of adaptation and generation of problem solving capability. Both Piaget and Vygotsky were centrally focused on the question how advanced forms of thinking and mental operations emerge during individual development. For these authors, the fundamental question was not about acquiring knowledge; instead, the question was how we learn to think. In the Vygotskian tradition, for example, conceptual systems were understood to be important—not because they would accurately reflect the facts of the world—but because theoretically advanced conceptual systems make advanced forms of thinking possible. In this tradition, the ultimate goal of learning mathematics, therefore, would not be viewed as learning to know mathematics. Instead, the capability of using mathematical concepts enables us to efficiently think abstract and

[3] Cf. von Glasersfeld, 1995:57.

complex thoughts. The goal of theoretical learning, therefore, is not to make the learner able to provide the answer to a given theoretical problem; instead, it is to develop the learner's capability to think.

These theoretical approaches are descriptive and they typically produce models of how children mature into competent adults. To put it simply, they start from the problem of how children learn that putting a finger in fire hurts. Learning thus becomes seen as a phenomenon of individual development. The normative question of why should we learn, often remains secondary and peripheral.

As a consequence, the objectives of learning are sometimes described as external motives that legitimize learning. For instance, learning is often associated with socio-economic advances. It is frequently pointed out, for example, that education increases economic productivity, which is important for national competitiveness; or that education has substantial private returns for the learners, thus being a rational investment. Such arguments easily lead to discussions about whether it is possible to scientifically prove that education actually has economic impacts, or whether human capital is measured accurately and conceptualized in theoretically sound ways.[4] On the other hand, such economic arguments can also easily be reversed. Lester Thurow (1975), for example, argued in the 1970s that about half of the educational costs should be counted as defensive costs that people have to pay to avoid economic losses. In Thurow's job queue model, educational certificates are valuable because they allow individual jobseekers to jump the line and by-pass other jobseekers in the labor market. In this model, it really does not matter much what people have studied, as long as their educational certificates put them in the front of the queue.[5] As job offers are given to people who are in the front of the queue, successful jobseekers have to be better educated than average jobseekers.[6] The economic function of education may therefore be less about acquisition of knowledge than it is about gaining socially respected educational certificates. Perhaps half of the investment in education, therefore, may generate economically productive competences; the other half is spent because people have to accumulate certificates in an attempt to try and avoid falling back in the queue. This is, of course, just one theory. In economic growth indices that correct GDP by economically positive but socio-economically harmful outcomes such as crime, pollution-induces diseases, and environmental

[4] The social learning models discussed below, as well as a careful analysis on conventional productivity measurement frameworks show that strong or generic statements about the economic impacts of learning are not theoretically very strong or empirically generally valid. Without entering a discussion on the economics of learning, one may note that the current economic models do not well capture socially distributed, context-dependent, historically path-dependent, and innovative characteristics of learning, competence development, or knowledge creation. For a more detailed discussion, see Tuomi, 2004.

[5] In practice, of course, there are multiple queues and a variety of criteria for ranking jobseekers. A Ph.D. in theoretical philosophy may advance in a labour market queue less than a M.A. in computer systems if the queue is for a job on Web portal design. At more advanced skill-levels, however, it often does not matter much whether a job seeker has a Ph.D. in philosophy, linguistics, quantum theory or computer science and they all are, indeed, common in information systems and artificial intelligence research, for example. In the specific case of Web designers, formal educational certificated mattered very little when the profession emerged in the 1990s. For the evolution of professional skills, credential-bestowing institutions and job markets in Web design, see Kotamraju, 2000.

[6] In some job categories, jobseekers perhaps now need to be in the top quintile before they are considered to be potential candidates. Below that cut-off educational achievements matter little.

degradation, education, however, is now counted partly as a positive growth and partly as a negative cost.[7]

In practice, the normative aspect is of great importance in education. Education has traditionally been perceived as a means to civilize people and make young people useful and productive members of the society. Much of the current discourse on education centers on the need to produce competent workers for the needs of the economy. At the same time, learning is also understood in the enlightenment context, where individuals become liberated and realize their true potential by acquiring knowledge and by freeing themselves from superstitions.[8] One way to manage this paradox has been to separate vocational education from enlightenment education, and to understand the former as instrumental and the latter as driven by the quest for knowledge and wisdom. This demarcation, of course, has now to some extent become outdated, as also non-vocational education is often legitimized through its impact on economic growth and competitiveness.

Debates on the proper objectives of learning, however, will become increasingly visible in the future knowledge society. To an important extent this is because existing educational institutions need to find new ways to justify and legitimize themselves. As workers increasingly need to process up-to-date knowledge and mobilize socially and geographically distributed resources to get their job done, knowing becomes an increasingly dynamic and social phenomenon. Knowledge is reproduced, created, and recombined in fast cycle-times and in problem contexts that are difficult to imitate in educational institutions. Rote learning of facts becomes redundant when everyone has access to ubiquitous networks of information. Learning and knowledge-creation skills become increasingly important for work performance, and educational certificates become increasingly irrelevant. Learning opportunities accumulate fast for some, creating social differences and digital divides, and education institutions and policymakers struggle to combine innovation, creativity and equal opportunities.

A natural reaction to extend the instrumental view on education is to include subject matters such as “social skills,” or “skills for personal priority setting” in the educational curriculum. In the knowledge society, however, we need to go deeper and revisit the traditional debates on education. In Plato’s Meno, for example, the starting point was the question whether it is possible to teach virtues. At the first sight, this question contrasts with the instrumental views on education and learning. Socrates argues that it is as impossible to teach virtues as it is to put knowledge into someone’s head. We cannot give a generic definition of virtue or knowledge, and—as we do not know what they are—we cannot teach them. Learning, therefore, can at best be a process where we recall knowledge that we already knew in some unarticulated form, or where we uncover our pre-existing latent virtuousness.

In the modern world, it is useful to recall Socratic dialogues because they pose essential questions that we now have forgotten. Modern educators rarely ask, for example, whether it is possible to teach virtues. In the emerging global and culturally diversified world, such questions, however, have important practical consequences.

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[7] See, e.g., Daly & Cobb, Jr., 1989.

[8] This paradox of socializing people into existing conventions and beliefs and making them free of these conventions and beliefs becomes particularly visible in adult education (Jarvis, 1992).

In the Confucian Daxue[9] virtue is described as a style of being that cannot be gained by simply imitating virtuous behaviors. The Confucian concept of learning was originally meant to be an unending process of widening of one's horizon. In practice—and somewhat paradoxically—aspiring civil servants in China had to memorize Daxue to pass their public examinations. This, again, illustrates the dual nature of education, as a process that potentially creates revolutionary new knowledge and as a process that socializes the learners as well-educated and well-behaving citizens. In practice, the Confucian widening of horizons has often degenerated into rote book-learning. This is now perceived as the major challenge facing Asian educational systems, and a major competitive advantage of American research universities, which now aim at providing global educational services.

In the modern global context, it is useful to note how the Confucian virtues have their foundation in knowledge and research, and how their ultimate motivation is peace and harmony in the State. The first chapter of Daxue clearly states the objective of learning as the illumination "with shining virtue all under heaven." It explains that this objective can be achieved by first establishing order in the state. This requires order and harmony in the family, which can only be achieved by cultivation of persons, which occurs by rectifying the mind. This, in turn, happens when people verify their opinions, by expanding knowledge through investigation of things. Research leads to knowledge, knowledge leads to right opinions, right opinions lead to harmony in the family, harmony in the family leads to orderly states and orderly states, according to Daxue, lead to "peace all under heaven."

The disciplines of Confucius assumed that there is only one truth. In this—as well as in his quest for the perfect order of the State—Confucius joins his younger contemporary Plato. This basic assumption, however, would have found strong opposition from Heraclitus and Protagoras; first because according to Heraclitus contradiction and crisis is the source of all development, and second, because according to Protagoras, wise men never agree as truths are many, and because wisdom starts when we realize this fundamental fact.

Both Plato and Confucius would also have faced opposition from the sceptics. They pointed out, for example, that the establishment of truth always requires facts, which, in turn, have to be justified by facts. This leads to infinite regression.[10] The project of finding the solid foundation of knowledge that would allow Platonists and Confucian civil servants to build order in their minds, lives, and states, therefore, was futile.

The modern institutions of learning reflect the ideas of Plato and Confucius. In contrast, Heraclitus outlines well the characteristics of modern innovation and knowledge based economy. In the view of Heraclitus, the world is a process of constant change and a stage of creative destruction, where crisis and conflict provide the stable source of true knowledge.

[9] The Great Learning, perhaps more accurately translated as "Self-Development of Adults." This is one of the Confucian classics, written probably in the 3rd century BCE.

[10] Infinite regression is one of the Pyrrhonian "modes of scepticism" (cf. Barnes, 1990).

When we use the modern definition of learning as the acquisition of knowledge, skills, attitudes and values that leads to persistent change of behavior potential, such a definition remains quite unclear or tautological unless we define what we mean by knowledge, skills, attitudes, and values. The definition is easily read as a description of a process that leads to improvement. Today it is often taken for granted that learning leads to progress. The definition, however, also allows for the case where people learn wrong knowledge, dysfunctional skills, bad attitudes and disgraceful values. Although the definition looks universal and value-neutral, the implicit idea is that at least when learning results from teaching, we learn accurate knowledge, useful skills, right attitudes, and proper values. Instead of asking the question that started Menon's dialogue with Socrates: "Can virtue be taught?" the modern discourse often starts from the assumption that learning is a virtue in itself. Thus the question what and why should we learn is often considered to be redundant. This fundamentally ethical and political question is then reduced to an analysis of "skill gaps" that need to be filled to match human capabilities with the demands of industrial production. The pre-industrial question that Socrates posed to us, however, remains highly relevant in the post-industrial age, where productive skill sets are highly transient, socially embedded and networked, and where education cannot function as a means to manufacture pre-defined skills as inputs to the economic machine. Today, children may learn to avoid burning their fingers in fire but they may also download detailed recipes for chemical weapons from the Internet and learn how to build a transportable nuclear warhead. In this knowledge-based world, ethics of learning is not only a historical curiosity; instead, it has important practical and social consequences.

In the European tradition, philosophy starts by questioning the conceptual nature of common beliefs. In this vein, Socrates might have explained that he does not really understand the view that knowledge is located inside the human brain, and needs to be transported there. Modern educators might help him out by carefully explaining to Socrates that neurophysiology has now revealed that the brain consist of neurons, which store knowledge in the incredibly complex system of axons and synapses, barely visible to the human eye. No wonder Socrates could not understand this, without a microscope. Inspired by science fiction classics such as William Gibson's Neuromancer, Blade Runner and Fred Hoyle's pioneering Black Cloud, they could go on and tell Socrates how information technology soon will make it possible to beam knowledge directly into the human mind, in an ultrafast blast of images that show how the world really is.

Socrates would then have replied with amazement and wonder. What an interesting philosophical view on the nature of knowledge! But shouldn't we also read James Gibson, not only William Gibson? Can knowledge really be represented as irrelevant facts, independent of human action and contexts of knowing? Is knowledge something that can be moved from outside to inside human brains, or conveyed from one brain to another via electric signals and images. Should we ask, as James Gibson argued, "not what is inside our head, but what our head is inside of?"[11]

The conventional definition of learning becomes inappropriate in the knowledge society for a number of reasons. Strictly speaking, it is broad enough to include

[11] Cf. Gibson, 1950, and Mace, 1977. Gibson focused on ecological psychology, asking what are the environmental conditions of human perception.

almost all human mental and physiological processes. The requirement of "long-term change" makes sense only relative to some definite and objective time-scale, and it is easy to see that it is important only to the extent that it makes behavior predictable to others. The distinction between short-term and long-term change does not have much to do with the processes of learning, per se. It is a social criterion. Also, to be able to make the crucial analytical distinction between change in behavior and change in "the situation" there has to be an external observer capable of perfectly knowing the world and its situations. In practice, also this criterion is essentially social: we perceive learning in others when from our point of view the situation is unchanged and someone's behavior is not. Constructivist theories of learning, for example, may paradoxically describe learning as internal change of mental representations, at the same time as such change could equally well be described as a change in the situation. The distinction between internal and external change was perhaps practical in a world where professions, tools, skills, social institutions and economic relations were relatively stable, and change in the environment was perceived as an exception. In reality, the learner, however, always perceives her situation through what she knows and has learned. Methodologically speaking, therefore, we can never know whether the situation for the learner has in fact changed. The distinction between the unchanging situation and the changing behavior is therefore methodologically and epistemologically void. What matters are the pragmatic consequences: in learning we attribute change to an acting agent instead of the environment. This has practical consequences for our own action, and for allocation of agency and responsibility, for example. The conventional scientific definition of learning builds on an unarticulated social and ethical foundation, which needs to be made explicit when we try to understand how learning and education will change in the coming years.

The idea that we "acquire" knowledge, represented in the standard definition, at least implicitly carries with it the assumption that knowledge is already "out there" and can be moved into the brain of the learner. Although some constructivists may interpret knowledge acquisition as the production, generation or creation of knowledge, the term has its roots in classical positivist thinking. As will be seen below, the idea that we internalize knowledge by acquiring it has important consequences for the ways we organize and facilitate learning in the future networked environments.

Indeed, the basic characteristic of the conventional definition becomes explicitly visible if play devil's advocate and define learning as the process of acquiring errors, incompetence, prejudices, and vices. Although the standard definition claims to describe a process, it, in fact, only describes the outcome: a change in the internal state of the learner. As the process of learning itself remains fully obscure, there is no way to tell, for example, what is the impact of new technological means on learning.

To open the black box of learning, we have to move beyond static definitions of outcomes and characterize the processes that underlie and constitute learning. This will allow us to talk about different pedagogical approaches and the potential roles of technology. A number of such process models are described in the Appendix.

The pedagogic approach of the early Socratic dialogues, including Meno, indeed represents a quite advanced and useful model of learning. The Socratic dialogue fits well with the constructivist conception of learning, where knowledge acquisition is understood as an active and ongoing process towards knowledge. The dialogical model of learning is also well suited for adult learning, where the goal of learning cannot simply be to indoctrinate or inform ignorant students to the true order of reality. The Socratic claim was that we cannot put knowledge into anyone's head. Instead, the learner has to create the knowledge herself using already available resources and knowledge. Socrates does this by asking questions that make Menon think, and the end result of this thinking is that Menon knows something that he did not know before. Vygotsky had a similar approach. He moved, however, beyond the Socratic method by showing that we can build scaffolds in thin conceptual air and reach knowledge that no one has known before. Learning, therefore, is not only about revealing pre-existing truths; instead, it can be truly creative, and lead us to new forms of social and individual thinking and action.

Plato, of course, believed that eternal knowledge lurks in the heaven of ideas waiting to be discovered. Pragmatists would say: Forget eternal ideas. Learning, in any case, is based on making mistakes. Get on with the real work.

We start this by sorting the complex institutions of learning, trying to see what they do, what they think they are doing, and what they could be doing in the next fifteen years.

4 Institutions of education in 2020: "ISCED 2020"

The International Standard Classification of Education (ISCED) was designed by UNESCO in the early 1970's to serve as an instrument for assembling, compiling and presenting statistics of education both within individual countries and internationally. The present classification, ISCED 1997, aims to cover all organized and sustained learning opportunities. Within the framework of ISCED, the term education is taken to comprise all deliberate and systematic activities designed to meet learning needs. ISCED includes a variety of programmes and types of education, such as regular education, adult education, formal education, non-formal education, initial education, continuing education, distance education, open-education, life-long education, part-time education, dual systems, apprenticeships, technical-vocational education, training, and special needs education. ISCED does not cover activities that are not specifically aimed at producing learning, and it adopts a clearly institutional—more accurately, programme-based—view of learning. In other words, it focuses on education and not on learning, per se. Learning that is considered to result as a by-product of other activities is excluded. For example, organizational knowledge creation and learning that occurs in new product development, research, or business intelligence is not covered. Self-organizing and self-organized learning are also excluded. Examples include competence development within open source communities, self-learning among web home page designers and digital photographers, or, for instance, cognitive and motor skill development among computer gamers or garage band players. Some learning-oriented organized and sustained systems, such as public libraries, popular science magazine publishing and television documentary channels are also excluded. Also substitutes for individual learning such as expert services, knowledge networks, or intelligent products are not covered.

Due to its institutional focus, ISCED, however, implicitly categorizes and describes learning institutions where professional teachers work. As ISCED is aimed for international comparisons, it also abstracts these institutions from country and culture specific forms. We can therefore use the ISCED classification as a handle to the current systems of education, and try to see how the structures of education will change from their internal point of view. This is important because the current institutions of learning both structure discussions about the transformation of education and act as major sources of institutional inertia. In principle, the needs of actors within educational institutions are indirectly connected with the learning needs of individual citizens, business firms and the society at large. In practice, the possible routes for change depend on the interests of the people currently working in organized educational settings, as well as the established legal and institutional agreements that regulate working in these settings. In this section I will therefore take the current ISCED definitions of different levels of education, and highlight emerging demands and forms of education that could require reconsideration of the current institutions of education. Basically, we try to see how a revised version of the standard classification, "ISCED 2020," could look like in the next fifteen years, given the current practices and emerging opportunities and needs. Due to the complexity of the varied educational structures in different countries, I only highlight some potentially disruptive developments, for further discussion.

The key concepts underlying the ISCED are communication, learning, organized, and sustained. These are defined in the following way:[12]

- COMMUNICATION: a relationship between two or more persons involving the transfer of information (messages, ideas, knowledge, strategies, etc.). Communication may be verbal or non-verbal, direct/face-to-face or indirect/remote, and may involve a wide variety of channels and media.
- LEARNING: any improvement in behaviour, information, knowledge, understanding, attitude, values or skills.
- ORGANIZED: planned in a pattern or sequence with explicit or implicit aims. It involves a providing agency (person or persons or body) which sets up the learning environment and a method of teaching through which the communication is organized. The method is typically someone who is engaged in communicating or releasing knowledge and skills with a view to bringing about learning, but it can also be indirect/inanimate e.g. a piece of computer software, a film, or tape, etc.
- SUSTAINED: intended to mean that the learning experience has the elements of duration and continuity. No minimum duration is stipulated, but appropriate minima will be stated in the operational manual.

The ISCED classification consists of six levels. Several of the levels include subcategories that separate, for example, vocation-oriented education from education that aims at preparing the learner for the next-level education. Below, I only outline the main characteristics and contrast these with the imagined ISCED 2020.

[12] ISCED 1997. http://www.unesco.org/education/information/nfsunesco/doc/isced_1997.htm

4.1 Level 0 – Pre-primary education

Current
Programmes at level 0, (pre-primary) defined as the initial stage of organized instruction are designed primarily to introduce very young children to a school-type environment, i.e. to provide a bridge between the home and a school-based atmosphere. For a programme to be considered as pre-primary education, it has to be school-based or centre-based. These terms are used to distinguish activities in settings such as primary school, pre-schools and kindergartens from services provided in households or family settings. Such programmes are designed for children aged at least 3 years, as programmes destined for younger children do not normally satisfy the educational criteria in ISCED. This level includes organized instruction for children with special needs education.

2020
ISCED 2020, level 0, will increasingly emphasize basic cognitive capabilities that underlie learning, as well as social collaboration skills. The need to prepare very young children to a traditional school-type "knowledge-transfer" environment will decline. Research on learning disabilities (e.g., dyslexia) will lead to new applications of learning technologies intended for children under 3 years of age. Early-age "cognitive repair" that builds the basic capabilities for learning will be perceived as an important investment in the knowledge society.

4.2 Level 1 – Primary education

Current
Programmes at level 1 are normally designed on a unit or project basis to give students a sound basic education in reading, writing and mathematics along with an elementary understanding of other subjects such as history, geography, natural science, social science, art and music. In some cases religious instruction is featured. The core at this level consists of education provided for children, the customary or legal age of entrance being not younger than five years or older than seven years. This level covers in principle six years of full-time schooling. Throughout this level the programmes are organized in units or projects rather than by subjects.

2020
Immersive computer-based environments will be widely used at ISCED 2020 level 1. They include simulation and game applications for multiple participants that aim for simultaneous development of social and cognitive skills. With ICT support, learners can combine classroom learning with learning at home. As learning will partly move to home, parents will be given the opportunity to become active facilitators and participants in the learning process. This potential of ICTs will be realized particularly in families in the higher socio-economic groups, increasing differences in student performance across socio-economic groups. As technology allows effective remote learning, parents will also increasingly enroll their children to remote schools that provide the best learning services, or where the curriculum is value-based (e.g., religious, individual creativity, ethical, ethnic).

4.3 Level 2 – Lower secondary education

Current
The contents of education at this stage are typically designed to complete the provision of basic education which began at ISCED level 1. In many, if not most countries, the educational aim is to lay the foundation for lifelong learning and human development. The programmes at this level are usually organized on a subject-oriented pattern using specialized teachers. The full implementation of basic skills occurs at this level. The end of this level often coincides with the end of compulsory education where it exists. Level 2 programmes are subdivided into three categories: general education, pre-vocational education, and vocational education. The last one aims directly at providing the learners with practical skills that enable them to access employment.

2020
Computer-supported problem-based learning becomes the dominant learning mode at ISCED 2020 level 2. Learning teams extend across several schools and connect students from different regions and countries. Children are able interact with students in other countries to get contextualized knowledge on issues such as cultural practices, history, and environment. Teachers act as translators and facilitators, supported by ICTs such as computer-mediated communication and collaboration platforms, VoIP, and Video over IP. Cognitive learning objects, with the capability to support the learning process and guide the learner through the "zone of proximal development," become important in vocation-oriented education. Classroom learning will be complemented by parent participation at home and—where the possibilities for this are limited—, for example, by virtual grandparents, i.e. elderly people who are willing to remotely support children in their learning process.

4.4 Level 3 – Upper secondary education

Current
This level of education typically begins at the end of full-time compulsory education for those countries that have a system of compulsory education (15-16 years). Teachers are typically more specialized and qualified than at ISCED level 2. The educational programmes included at this level typically require the completion of some 9 years of full-time education since the beginning of level 1 for admission, or a combination of education and vocational or technical experience and the completion of level 2 or demonstrable ability to handle programmes at this level.

2020
ISCED 2020 level 3 will include problem-based assignments with links to the world outside the learning institutions. For example, students may analyze social, economic and environmental problems, develop proposals for their solutions, and introduce the proposals to relevant authorities, policymakers, and business organizations. Pedagogic approaches at level 3 will on one hand focus on building critical and systematic knowledge on subjects such as science and mathematics and, on the other hand, shift from "know-that" to "know-who" and "know-where," and action-oriented knowledge. Level 3 will move towards the classical trivium (grammar, rhetoric and logic) and

quadrivium (arithmetic, music, geometry, astronomy). Grammar studies will include several different languages and genres. Rhetoric will include electronic communication skills, as well as cultural knowledge needed to operate various culturally different linguistic genres. Logic will include reflective learning of theoretical systems of scientific concepts, as well basic innovation and creativity skills. Arithmetic and geometry is learned using cognitive objects and simulation environments. Music is bundled with visual arts and crafts, for instance, to collectively create audiovisual works in distributed bands and for reconstruction of historical performances.

4.5 Level 4 – Post-secondary non-tertiary education

Current
ISCED 4 captures programmes that straddle the boundary between upper-secondary and post-secondary education from an international point of view, even though they might clearly be considered as upper-secondary or post-secondary programmes in a national context. ISCED 4 programmes can, considering their content, not be regarded as tertiary programmes. They are often not significantly more advanced than programmes at ISCED 3 but they serve to broaden the knowledge of participants who have already completed a programme at level 3. Typical examples are programmes designed to prepare students for studies at level 5 who, although having completed ISCED level 3, did not follow a curriculum which would allow entry to level 5, i.e. pre-degree foundation courses or short vocational programmes. This level includes adult education. For example, technical courses given during an individual's professional life on specific subjects such as computer software can be included in this level.

2020
ISCED 2020 level 4 will grow rapidly and split into two different strands. One will focus on learner-centric self-development in various arts, crafts and conceptual sciences, including philosophy. The other will focus on reintroducing people back to formal education. The majority of ISCED 2020 level 4 activities will be in the former, as middle-aged and aging demographic groups start to improve the quality of their lives by acquiring meaningful skills and knowledge in non-work related areas. In this learner segment, educational certificates will have limited value and learning will be perceived as a value in itself. Information and communication technologies are used in innovative content-specific ways. Level 4 programmes will extend towards level 3 and gain importance in integrating immigrants to formal education and worklife.

4.6 Level 5 – First stage of tertiary education

Current
Level 5 consists of tertiary programmes having an educational content more advanced than those offered at levels 3 and 4. Entry to these programmes normally requires the successful completion of ISCED level 3 or a similar qualification at ISCED level 4. Normally these programmes must have a cumulative theoretical duration of at least 2 years from the beginning of level 5. Level 5 programmes do not lead directly to the award of an advanced research qualification (level 6). Level 5 includes "first degree"

programmes giving access to professions with high skill requirements, and programmes for specific occupational and technical education. ISCED level 5A programmes are tertiary programmes that are largely theoretically based and are intended to provide sufficient qualifications for gaining entry into advanced research programmes and profession with high skills requirements. They have a minimum cumulative theoretical duration (at tertiary) of three years' full-time equivalent, although typically they are of 4 or more years. The teaching faculty typically has advanced research credentials. Qualifications in category 5B are typically shorter than those in 5A and focus on occupationally specific skills geared for entry into the labour market, although some theoretical foundations may be covered in the respective programme. Level 5B programme has a minimum of two years' full-time equivalent duration but generally is of 2 or 3 years or equal credit accumulation. This level includes all the research programmes which are not part of a doctorate, such as any type of Master's degree. In some countries, students beginning tertiary education enrol directly for an advanced research qualification. In this case, the part of the programme concentrating on advanced research (e.g. the "third cycle") should be classified as level 6 and the initial years ("first-cycle" and "second-cycle") as level 5. Adult education programmes equivalent in content with some ISCED 5 programmes can be included at this level.

2020
Learning at ISCED 2020 level 5 programmes move away from purely individualistic "knowledge internalization" models and is increasingly based on collaborative creation of knowledge. The underlying pedagogic models will be based on experimental (Dewey) and action (Engeström) learning, and on knowledge creation models (e.g., Nonaka cycle) which embed individual knowledge construction with social learning (for a discussion on these different models, see the Appendix). Knowledge construction will increasingly occur within specially designed ICT-enabled environments that support information access, knowledge externalization and modeling, hypothesis testing and simulation-based evaluation. Educational institutions compete for learners internationally at this level, and global educational brands emerge. ICTs will be used to provide mass-customized learning for large student populations. National level 5 programmes will be reorganized to respond to the competitive pressures created by the emergence of multinational educational corporations.

4.7 Level 6 – Second stage of tertiary education

Current
This level is reserved for tertiary programmes which lead to the award of an advanced research qualification. The programmes are devoted to advanced study and original research and are not based on course-work only. They typically require the submission of a thesis or dissertation of publishable quality which is the product of original research and represents a significant contribution to knowledge.

2020
ISCED 2020 level 6 is increasingly perceived as an entry qualification for high-status jobs in the knowledge society. Learning paths become multidisciplinary, combining domain specific advanced knowledge with generic research and knowledge

acquisition and analysis skills. The explicit goal of building and participating in global knowledge networks becomes integrated in level 6 programmes. Level 6 programmes are also used to attract global talent. Brand value and access to globally acknowledged thought leaders and future decision-makers becomes an important selection criterion for paying students. Large multinational service providers will be complemented by small personalized programmes that focus on student interaction and high-end ICT learning support. ISCED 6 institutions and large corporations will jointly run new programmes and manage institutional arrangements, including next-generation corporate universities, that combine competence development, worker renewal, and certificates that improve worker career paths and employability. Jobseekers will increasingly look for working environments where they can effectively maintain and improve their competences. Policymakers will align social, tax and educational policies so that they facilitate effective learning in these new programmes. Policymakers will also launch initiatives aimed at creating learning partnerships and networks that support learning in small and medium-sized enterprises.

4.8 ISCED 2020 Level 7 (Continuous informal learning)

Current:
Excluded from ISCED 1997

2020
Education will increasingly be based on facilitation of informal learning and recognition of accumulated competences and skills. Continuous learning becomes dominant in the knowledge society where work, personal interests, identity construction, consumption and non-economic production will require constant upgrading of skills and acquisition of new skills. Social learning on ICT-enabled communities becomes the dominant source of education in areas where new practical knowledge emerges rapidly and has a short lifetime. Learning on demand is supported at workplace and by product designers, who incorporate learning support in product functionality. Level 7 pedagogic models, and the capability to integrate them in products and services, becomes an important source of competitive advantage for business firms.

5 The tectonics of educational change

The above outline of the future learning landscape highlights some major macro-level changes in the educational systems. In particular, this change is driven by the ongoing global socio-economic transformation, where information, knowledge, and innovation are emerging as the main sources of economic growth and employment opportunities. Innovation, in turn, is becoming increasingly networked, multidisciplinary, and problem-oriented. Innovators need good social, cultural and communication skills, as well as capabilities to move between conceptual systems and interpretative horizons. Organizations and business managers need new frameworks for managing innovative activities at all organizational levels and across business networks. Societies need to develop new structures, institutions, and policies to facilitate and support innovation and effective knowledge use. National systems of education and knowledge creation become linked to global knowledge networks in real time. As a consequence, educational systems will be redesigned for the production of new skills, utilization of new knowledge technologies, and for cost-efficient delivery of services in the global competitive market of education. Education and learning will be integrated across the full lifetime of individual learners and demographic change will shift its focus to adult education.

Detailed micro-level descriptions and scenarios at the different levels of ISCED 2020 would reveal a large number of innovative uses of advanced ICTs in education. To get the overall picture right, it is, however, important to understand that technical advances do not, in itself, drive social or institutional change. In the first approximation, technology is used to respond to social demand. Changes in demand indirectly reflect emerging technological opportunities; developmental paths, however, are almost always articulated as practical solutions that release tensions already existing in the present. The increasing pressure to reconsider education is no exception. Education is one of the main social subsystems in the modern societies, and its change is to a large extent driven by other subsystems that already have changed.

Educational systems are extremely difficult to change. As educational researchers often note, it is often easier to move a graveyard than to change the educational system. In both cases, there is resistance from outside and limited support from inside, and in the latter case there is also active dragging of feet. This has little to do with the mythical psychological tendency for “resistance to change,” and it is critically important to understand what, exactly, are the sources of inertia in educational systems. To develop better educational systems we have to understand how educational institutions learn and why learning is difficult in educational organizations.

There are many reasons for institutional inertia in the educational system. Education represents in many countries one of the most important paths for social progress. Independent of the competences and knowledge accumulated in the learning process, education generates valuable certifications, reputations and social capital. Changes in the educational system can often destroy large amounts of such capital. This happens, for example, in countries where educational attainment in specific institutions is used to signal memberships in important social groups. European examples include, for instance, the highly-regarded French Grandes Ecoles, which produce some 60 percent of managers in the top 100 French companies and the majority of high-level public administrators and policymakers. Changes in the social position of Grandes Ecoles would not only impact their present and future students, but also a large and influential population of alumni of these schools. By default, social elites would find it natural to resist educational change if that would, for example, make social distinctions based on enrolment in elite schools irrelevant.

In some Asian countries, enrollment to the leading university practically guarantees the access to top-level positions in public administration and private companies. In the U.S., access to Ivy League universities is a major source of social, political and economic capital. Similarly, professions with restricted access, such as lawyers and doctors, tend to react negatively to proposals that would widen and broaden the access to their profession. Educational change, therefore, is not only about optimal engineering of educational practices and about adapting them to the requirements of the emerging knowledge society. Successful change requires that educational institutions, themselves, become learning institutions, where change management is an important objective of management and leadership.

Systemic inhibitors of change in education also include historically accumulated institutional agreements. For example, when the working conditions and performance criteria of teachers are defined using indicators such as chapters of text-books specified in the course requirements, it may be difficult to teach the same content using computer-based methods where books are not used. Teachers sometimes claim that their employment contracts make it extremely difficult to move from traditional lecturing to team-oriented and problem-based learning models, for example. As employment contracts have been negotiated in the context of traditional pedagogic approaches, in practice they make some advanced or innovative learning methods illegal or disconnect them from teacher performance evaluation.

In private business organizations, change in work practices often starts by changing measurement and incentive systems. In public institutions this is often difficult, as their work practices are tightly regulated, standardized, and at least indirectly specified in educational laws.

The increasing pressure to develop creative, innovative and critical skills also implies that the traditional course-based lecturing model needs to be replaced by student-focused learning models. Psychologically, teacher's job description is, therefore, changing radically. Whereas in many traditional settings the teacher had social authority and his or her views were rarely questioned, in the modern settings teacher's knowledge and competences are continuously questioned. Teachers, who, for example, have chosen their profession based on their own historical perceptions on the nature of teaching and the social position of teachers, may have difficulties in adjusting to the changing educational settings. Anecdotal evidence indicates that some teachers have moved from teaching to research and administration when problem-based learning methods have been introduced. Traditional teacher training has rarely well prepared teachers for the facilitation and support roles that are required in problem-based learning.

Furthermore, teachers who have successfully lectured the same topic over years and accumulated methods and material tailored to their courses easily lose all this accumulated capital when new pedagogic approaches are introduced. Such hidden costs are, economically speaking, a major source of return of investment for teachers. These costs are rarely compensated or considered when, for example, ICT is introduced in classrooms.

Insufficient resources for teacher training are often given as the root cause for the slow and difficult change of educational practices. In many cases, teachers would need time to develop and test new pedagogic materials and methods. The underlying problem, however, is often more about learning and innovation than about inadequate training. Innovation requires slack resources, experimentation and time. The adoption and development of new pedagogic methods requires absorptive capacity that extends beyond individual teachers. If the organizational and institutional context does not support new working methods, no amount of teacher training will be enough to change educational practices.

The dynamics of institutional and organizational change are important. Organizational change is always risky for the agents of change because social change is inherently revolutionary and because it creates conflicts. In private businesses, organizational learning requires organizational culture and management practices that strongly support organizational change agents and which facilitate experimentation and risk taking. Learning organizations, therefore, are qualitatively different from bureaucracies that fundamentally aim at regular implementation or processes and procedures grounded in law. Particularly in institutions of public education, change is therefore often against the deep structures of organizational culture and the modes of operation. This makes typical educational institutions socially conservative and limits the possibilities to introduce new work practices, manage change, and support organizational change agents. In such settings, organizational learning often occurs only through crisis.

One way to improve learning capability in the educational system, manage change and avoid unnecessary crises is to create realistic visions about the future. Such visions can then become the imagined reality where future needs and requirements can be discussed and articulated. Such visions can be used to analyze and discuss the emerging opportunities and challenges, and to develop capabilities and processes that make change possible. In short, scenarios on the future of education will, therefore, be key elements in national and regional knowledge society strategies.

6 New learning technologies: some examples

6.1 Experiential learning in immersive environments

In many important learning models, learning starts when the learner experiences practical or cognitive dissonance.[13] Routine action breaks down, the learner realizes that active sensemaking is needed, and the world needs to be reconstructed. The reconstruction may require reorganization of meaning and also reconfiguration of the material environment.

In classroom settings, this learning process can be simulated by problem-based learning situations. The student is presented with a specific construction of the world, for example using a textual description, and the dynamics of the world is shown to lead to a contradiction or a problem that needs to be solved. Students may also collaborate in solving the problem, for example, by taking different roles and presenting different interpretations of the situation.

Such problem-based learning settings can be enhanced by immersive information environments where the learner can effectively experience cognitive dissonance and where problem-solving resources are readily available (cf. Dede, 2005). A simple example of such a learning environment is the River City MUVE (Multi-user Virtual Environment) developed at Harvard Graduate School of Education.[14] In the River

[13] See the Appendix for a discussion on different learning models.

[14] http://muve.gse.harvard.edu/muvees2003/

City MUVE, student teams use computer-based avatars to explore a historical town, collect notes on their "Lab Notebooks," study virtual water samples of the river, share data with other students, and analyze the reasons for local health and environmental problems. At the end, students write to the mayor of River City describing the health and environmental problems they have encountered, suggesting ways to improve the life of the inhabitants. Learners are engaged in a "participatory historical situation" in which they can apply tools and knowledge from both the past and the present to resolve an authentic problem. In this "back to the future" situation, students' mastery of 21st century classroom content and skills empowers them in the 19th century virtual world.

Less pedagogically motivated but yet effective learning environments include Massively Multiplayer Online Role Playing Games, such as Lineage[15] and EVE Online.[16] The latter is set in an unknown part of the universe, and includes several thousands of solar systems, many of which are settled by the players. The players can inhabit worlds, create organizations and alliances, accumulate wealth and build economies, much as they would operate in a simulated real world. The system provides a persistent and continuously evolving world that runs on servers in London. In October 2005, the system recorded 17,032 simultaneous players. Although MMORPGs are not aimed for learning, they are to a great extent driven by quest for skill development. This is a feature of games and performance-oriented activities, in general. Professional football players learn their skills by playing football, golfers learn by playing golf, and rock guitarists by playing guitar. At present, American football, for example, is teached using 3-dimensional immersive virtual reality environments where the student can engage in the game without actually throwing the ball.[17] Golf and guitar playing can also be learned using computer support integrated with physical objects and movement. Individual physical sports, such as karate, are now studied using interactive virtual reality simulation.[18] Immersive simulation systems have also been widely used in flight training and in military training applications. At present, commercial PC-based flight simulators are used to build systems that closely resemble professional multimillion-dollar cockpit simulators.[19]

6.2 Experimental learning with simulated worlds

The Deweyan experimental learning model emphasizes the generation and testing of hypothetical problem solutions. This model, therefore, can be supported by computer-

[15] http://www.lineage.com

[16] http://www.eve-online.com

[17] The University of Michigan Virtual Reality Laboratory has developed the concept for such a "Virtual Football Trainer." It uses the Cave Automatic Virtual Environment where the user is immersed in 3-D computer-simulated world with real-size players (http://www-vrl.umich.edu/project/football/index.html).

[18] Kick Ass Kun-Fu is an immersive game installation that transforms computer gaming into a visual, physical performance like dance or sports. The gamer can fight and defy gravity like kung-fu movie actors - only there's no wires or post-production needed, thanks to the real-time embodied interaction and virtual set technology (http://mlab.uiah.fi/animaatiokone/kungfu/en/)

[19] Such a PC-based multiplayer simulation environment is used, for example, by Flightline, at Irvine, California, which markets 747 and multiplayer F-16 simulations for corporate events and bachelor parties: http://www.flightlineusa.com/.

based tools that facilitate simulation and "what-if" analyses. Computer-based simulation has been used extensively in organizational settings. In fact, although it has not always been explicitly noted, many historically important uses of computers fall into this category. A prototypical example is the use of computers to design buildings and bridges, where the designer learns whether specific designs are structurally stable. Computations are in this setting used to test alternative designs, and when a working and satisfying solution is found, the structure is implemented in the real world. Another example is the use of executable knowledge representation systems to diagnose the impact of alternative business strategies on competitive positions.[20] Quantitative and qualitative what-if analyses are now commonly supported by management accounting software, and process simulations have been common, for example, in business process design. Software that supports system dynamics modeling and simulation is also frequently used to develop conceptual models and test their implications as a part of real-world learning processes.

Historically, computer-based simulation has been most visible outside classrooms. The reason is simple. Two decades ago, state-of-the-art simulation systems often relied on specialized computer architectures, such as Lisp machines and parallel vector processing. In areas where simulation was important for the actual work—as in structural stability and aerodynamic computations—computer-based simulation tools entered the classroom mainly as the objects of study. The students were taught how to use simulation and modeling tools as competent use of these tools comprised important professional skills that student would need in their actual work practice. Partly this was, however, because the tools were so complex and expensive that their use could practically only be learned in educational institutions or in special courses provided by the software vendor. Today these simulations can be run on standard PCs.

In the future, simulation tools will provide platforms for the construction and testing of conceptual and dynamic models. This will require modular software, open interfaces, and, for example, message-passing programming architectures. Such environments can be used in learning settings ranging from real-life problem solving to primary education.

6.3 Pedagogic veils

I shall call "pedagogic veils" layers of pedagogic knowledge that can be "thrown over" extend material and informational objects. The underlying theoretical concept can be described as an implementation of Vygotskian scaffolding in the object of learning itself. In other words, pedagogic veils are system functionality that provides a novice learner scaffolding that facilitates the learning of competent use of the object.

In the traditional Vygotskian scaffolding, support for learning is provided by a competent adult who skillfully guides a child in the process of competence development. As commercial products become augmented and extended by information technology and bundled with services, pedagogic veils can be implemented in an increasing number of product categories. In a relatively

[20] An example of an AI-based structural simulation environment is Stratex, which was used in multinational corporations to design organizational structures (Paajanen & Tuomi, 1992). The system was also to analyze future skill demands and their match with university-based education in Finland (Tuomi, 1992).

straightforward implementation, products will incorporate their operating manuals and real time communication to expert users and support services. In more advanced implementations, products will be simultaneously designed as material and cognitive artifacts that support dynamic scaffolding. Yet another way of implementing pedagogic veils is to use virtual augmented reality to overlay material objects with information and images that help the learner to skillfully operate and use the object. Pedagogic veils have educational implications, for example, as learning becomes integrated with the actual use of products and services. In such a world a hammer can tell the user how to drive a nail, and adaptive pedagogically designed user interfaces can produce competent computer users. This has educational implications, for example, because learning moves out from classrooms and becomes part of the product itself.

6.4 Intelligent learning objects

A specific variation of the idea of pedagogic objects are objects that are specifically designed for learning. Examples of such pedagogic objects include the LeapPad products developed by the LeapFrog.[21] The LittleTouch LeapPad is an interactive book for children of ages 6 to 36 months with a touch interface and audio feedback. The applications include soundscapes that according to LeapFrog simulate early brain development, and word plays and interactive rhymes that build early language skills. For older kids, the LeapPad system includes, for example, a pen interface that can be used to write on specifically designed interactive books.

The newest LeapFrog product is a "pentop computer," a pen that has an inbuilt processor, video camera, audio, and plug-in program modules.[22] The pen can be used to draw on special micro-dotted paper, which enables the pen to track movements. The user can, for example, draw a calculator or a piano keyboard and drums, which then become active and can be used to make calculations or to play music. The user can also write block-letter words and hear what they have written, or translate written words into a different language. The users can also download from the net interactive content that they can print on their own printers. For example, the system now interfaces with a database of some 200,000 test questions for commonly used middle school textbooks.

6.5 LearningPod

PodCasts and audio books are at present rapidly growing markets, with clear implications for education. Memory storage and audio compression technologies have become so cheap that small iPods and MP3 devices can carry tens of thousands of high-quality music pieces and hundreds of hours of video.[23] It is now possible to wirelessly download one hour of audio in six minutes using commercial services, such as Audible Air. As the current devices can be easily carried and linked to PCs and networks, their educational use can be expected to expand rapidly. Content such as language courses have traditionally been provided on disks and cassettes, but as the

[21] http://www.leapfrog.com/

[22] http://www.flypentop.com/

[23] Apple's 60 gigabyte iPod stores 15,000 songs. It can also store 25,000 photos or 150 hours of video. It weighs 157 grams.

usability and interactivity radically improve with digital devices, learning becomes mobile.

6.6 Cognitive repair and support

Some neurological and cognitive problems can become major obstacles for learning. For example, dyslexia is a major handicap for learners throughout their life, as modern educational settings often require understanding of text. Early intervention and special training of pre-school children can sometimes repair such learning deficiencies. In particular, computer-based techniques have been used to cure dyslexia in children at a very early age. It has also been proposed that one of the most important social benefits from interactive digital television could be learning applications aimed at pre-school children. As the cumulative effect of cognitive repair and efficient learning strategies is large across the human lifetime, early-age educational applications could become important in the future knowledge society.

Similarly, cognitive support for aging people gains importance as the society becomes increasingly knowledge-based and as the population ages in the European countries. As Vygotsky noted, we use material artifacts and symbol systems as parts of our cognition. The wide availability of digital devices will allow us to offload increasing amounts of cognitive tasks to these devices, effectively redesigning the architecture of our cognition. As the division of cognitive labor changes between humans and their environment, learning needs to be redesigned as well. Education aimed at the oldest demographic groups, in particular, will use cognitive support systems extensively in the future. For example, cognitive technologies will be used to compensate the effects of aging and this will create new learning opportunities for aging people.

7 Conclusion

The ongoing socio-economic transformation towards the knowledge society will have a profound impact on educational institutions and the processes of learning. Information and communication technologies will become increasingly integrated into our everyday life. Individual knowledge workers and learners will use information and communication technologies as natural extensions to their cognition, and the line between material, informational and mental environments will become increasingly difficult to draw. New division of labour will emerge between ambient intelligence technologies and human intelligence. At the same time, it will become commonly understood that the human intelligence always was extended and distributed between material and social actors.

Learning is the key factor that distinguishes the knowledge society from the information society. Learning, innovation and knowledge creation, therefore, are at the core of the emerging socio-economic order. In this emerging global, multicultural and networked world, it is increasingly difficult to understand the function of education as transfer of pre-existing knowledge and specific cultural systems of knowing. In the future, the adaptive and civilizing role of education needs to be combined in new ways with the developmental, creative, and transformative roles of learning, and we also have to ask what, exactly, we mean by development in this context. Institutional change, however, is difficult. A key to success in the ongoing socio-economic transformation is that educational systems, themselves, become learners, and that policymakers make this possible. This is perhaps the main challenge facing educators in the next fifteen years. To face this challenge, we need to imagine a world where educational institutions are well aligned with the requirements of individual citizens in their different phases of life, as well as with politically debated goals of social and economic development. Information and communication technologies will change both the demand for learning and the processes of learning. Radical new opportunities are emerging. Innovative scenarios and critical reflection are needed to avoid unnecessary crises and to benefit from the emerging opportunities. This paper suggests some first ideas along these lines. Theoretical and conceptual work is important, but for real impact, action and leadership are also required.

8 Appendix: Individual and social learning models

Learning is so obvious that—to paraphrase Augustinus—we only realize how mysterious it is when we have to say what it is. To open the black box of learning in a way that allows us to discuss the impact of technology, it is therefore useful to briefly review a number of influential models of learning. The conventional definition of learning, as acquisition of knowledge, skills and attitudes that lead to long-term change in behavioral potential, tries to define what learning is. For practical purposes, a more interesting question is how learning happens. We may try to decompose the learning process into its constituent factors and try to see where information and communication technologies might play a role. The following section focuses on individual learning, and presents several variations of well-known process models of learning. The section that follows will then expand the discussion to social learning models. Finally, I will briefly present the 5A model that tries to combine state-of-the-art in both individual and social learning.

In reading this appendix, the reader may be guided by a simple question: If this is how learning happens, where could information and communication technology enter the picture? Due to space limitations, this question is not explicitly discussed in the text. It however, underlies the discussion, which draws on my earlier work (Tuomi, 1999: ch.10-11).

8.1 Cycles of learning

The process of learning is often described as a cycle. This is because the modern concept of learning implies adaptation and adjustment of behavior. Most clearly this can be seen in system-theoretic models where learning is explicitly associated with cybernetic feedback.

8.1.1 Bateson, Argyris and Schön: correction of system error

In his “Logical Categories of Learning and Communication,” Bateson (1973:279-308) proposed a system-theoretic model of learning based on classification of different types of error that need to be corrected through learning. According to Bateson, we have to distinguish four different types of learning. *Zero learning* happens when a specific response occurs that is not subjected to correction. *Learning I*, in turn, is characterized by change in response when a new response is selected from a set of available ones. *Learning II,* which Bateson also called “deutero-learning” and “learning to learn,” occurs when the set of the available alternatives is changed. *Learning III*, in turn, occurs when the process underlying Learning II is changed. According to Bateson, Learning III occurs sometimes in religious conversion, therapy and in other sequences where there is a profound reorganization of character. Modern psychologists could perhaps call Learning III “reframing” and historians of ideas could call it—at a more macro-level—as “paradigm shift.” Finally, *Learning IV* would be change in the process of Learning III. According to Bateson, such learning probably does not occur in any adult living organism.[24]

Bateson's classification of types of learning may look quite behavioristic and remote from the common sense view where learning implies internalization of knowledge. It is also epistemologically ambiguous, as it assumes that we can somehow define "errors" that learning then corrects. Such "error-based" learning does not look very innovative or creative. One may compare this model with the Piagetian model where learning consists of accommodation and assimilation. Assimilation is the process of adjusting to the current situation, whereas accommodation happens when the current situation is reinterpreted and when the cognitive model that is used in the interpretation is changed. In the model of Argyris and Schön (1978), direct adaptation is called "single-loop learning" and accommodation is called "double-loop learning." This model is depicted in Figure 1. Argyris and Schön used this model to describe organizational learning, and in particular dysfunctional routines that are harmful for organizational performance. Argyris and Schön, therefore, also pointed out that learning new things requires unlearning of old things.

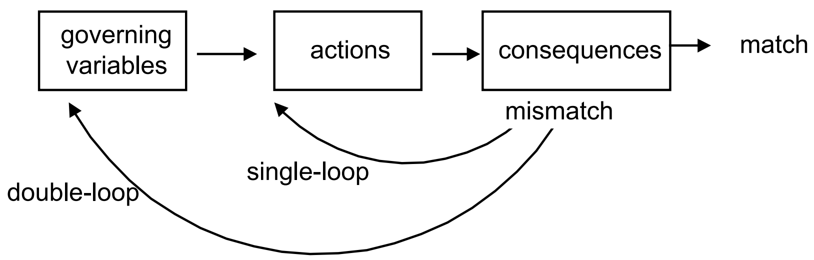

Figure 1. Learning as correction of system error.

8.1.2 Kolb: Experiential learning

Although learning, in principle, could also be described as a process of creative destruction of old knowledge, the standard approach is to focus on learning as a process of accumulation.[25] Learning is therefore often described as an ongoing cycle, where the outcomes of previous learning provide the starting point for further learning. Such an influential and simple model has been proposed by Kolb (1984). Kolb calls this mode the "experiential learning model." In the model, shown in Figure 2, learning occurs through a sequence of phases where concrete experiences generate

[24] According to Bateson, the combination of phylogenesis with ontogenesis may, however, achieve Level IV. The idea of Learning IV reflects Bateson's belief that the human mind is inseparable from its physical and evolutionary context, and that mind can only be understood as a part of ecological relations. The emergence of knowledge-based society (or more accurately, "knowledge-intensive" society) could, however, be understood as Level IV learning. Bateson focused on the relations between individuals and their environment, so that he did not consider this possibility. Bateson's system-theoretic models of learning have become influential in problem-centric and family therapies, highlighting the close linkage between therapy and learning.

[25] For practical purposes, the pedagogy of unlearning, indeed, could be very useful. This has been pointed out especially in the context of organizational and social learning, for example, by Hedberg (1981).

an opportunity for observation and reflection. This, in turn, leads the to creation of new concepts and models that are then tested in novel situations.

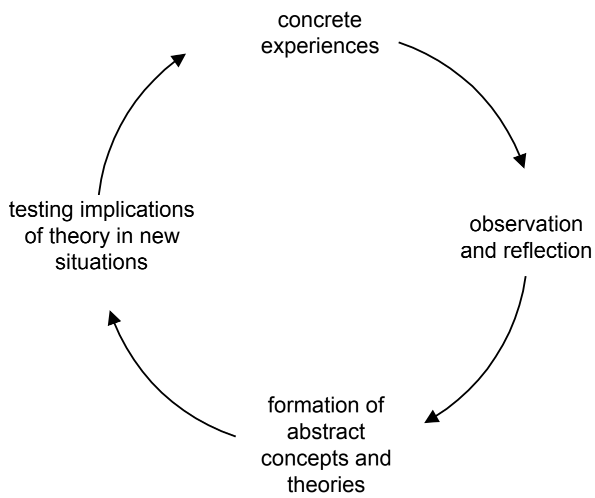

Figure 2. Kolb's learning model.

According to Kolb, learners need four different types of skills to make the learning cycle effective. They have to be able to engage openly and without prejudgement in new experiences, reflect and observe their experiences from many perspectives, create concepts that integrate observations into logically sound theories, and, finally, use these theories in decision making and problem solving (Kolb, 1984:30).

8.1.3 Dewey: Experimental learning

Kolb has argued that his model is based on the learning theories of Dewey and Lewin, which according to Kolb take experience as their starting point.[26] In Dewey's model, learning starts when unconscious routine breaks down, and when a problem emerges that needs to be solved. This leads to problem definition and conceptualization, a working hypothesis, a thought experiment where the hypothesis is tested, and experimental action, where the hypothesis is confirmed. In Dewey's pragmatist thinking, experience is closely related to practical action. Dewey's model, as reconstructed by Miettinen (1998), is shown in Figure 3.

In Dewey's interpretation, concrete practical activity may create "errors" when it does not lead to expected outcomes. Most of the time world works as we expect. Sometimes, however, the reality surprises us and we have to reinterpret the world. Learning consists of this process where a new working reinterpretation is generated. Whereas Bateson outlines a recursive typology of increasingly abstract processes of correcting errors, Dewey describes a sequence of qualitatively different activities that need to be completed for learning to occur. Dewey's model also specifically integrate imagination and creativity as components of the learning cycle.

[26] Strictly speaking, the connection between Kolb's model and Dewey's conception of the learning process is rather loose. Miettinen (1998) has compared these models in detail, and argues that Kolb's model is, in fact, incompatible with Dewey's model, and that Kolb's model is actually an eclectic collection of theoretically unrelated concepts.

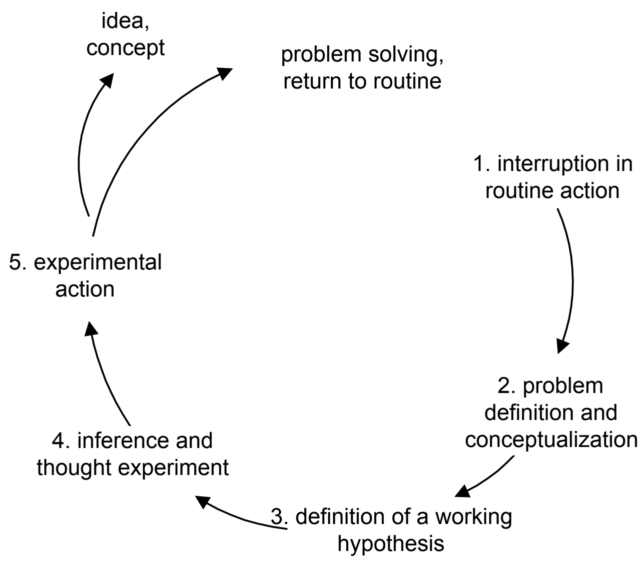

Figure 3. Learning cycle according to Dewey.

8.1.4 Engeström: reflective learning activity

Starting from the Vygotskian cultural-historical activity theory, Engeström (1999:383-4) has described a learning cycle that can be related to Dewey's ideas. In Engeström's model, the first step is similar to that in Dewey's model. A problem emerges that requires a solution. In the next step, the problem is analyzed. Based on the created understanding of the problem, a solution model is produced, its characteristics are studied, and a promising solution is implemented. These steps map closely with Dewey's model. However, Engeström adds an intermediate evaluative step of reflection between experimental action and consolidation of the new practice. This, for example, makes it possible for the learners to learn about their successes and failures in learning, and to improve their capability to learn.

Engeström's model also incorporates the idea that learning is not something that occurs only inside an individual mind. It is a social process that develops new forms of social activity and practice. It therefore does not consist of fixing given errors in individual behavior. Instead, learning becomes in this model a creative and innovative process that changes current practices and habits, thus also changing the social reality. In Engeström's words: "The expansive cycle begins with individual subjects questioning the accepted practice, and it gradually expands into a collective movement or institution" (1999:383). I will discuss the implications of this social characterization of learning in the next section, which focuses on social learning models. Engeström's learning cycle is depicted in Figure 4.

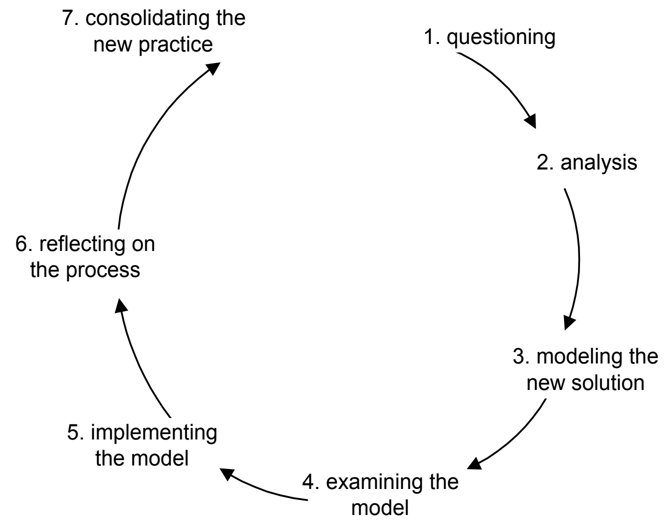

Figure 4. Engeström's learning cycle.

These cycle-models look rather similar. Their underlying theoretical assumptions are, however, quite different. They also have different units of analysis. The learning subject in Dewey's model is an individual. In Engeström's model learning is understood in the context of the Vygotskian cultural-historical activity theory that puts individual learners within culturally accumulated systems of social practice and division of labour. In comparison, Kolb's model is theoretically a rather straightforward schematic common-sense description of learning. Perhaps for that reason, it has become highly popular in individual, team, and organizational contexts.

8.2 Social learning

Traditionally both pedagogical and theoretical learning models have focused on the individual learner. Human activity, however, is inherently social. When we conceptualize learning, we should therefore be careful in defining the subject that learns. In the conventional view, the subject is an individual person who has the capability to acquire knowledge. Social learning models, in contrast, emphasize social interaction as the source of learning and social change as the outcome of learning. This has led to the revival of the Vygotskian cultural-historical research tradition, which starts from the observation that learning is fundamentally an interpersonal and social process, embedded in cultural, historical and material contexts.

8.2.1 Vygotsky: social learning in the zone of proximal development

Vygotsky explained the dynamics of social interaction in the development of child using the concept of *zone of proximal development* (Vygotsky, 1978:84-91). This has several interpretations, which Lave and Wenger classify in three categories (Lave & Wenger, 1991). First, the zone of proximal development may be characterized as the distance between problem-solving abilities exhibited by a learner working alone and when the learner is collaborating with more experienced people. This is the so-called "*scaffolding*" interpretation, where a parent or teacher provides support that is necessary for the learner during the initial learning phase, but which becomes unnecessary and can be removed as soon as this phase is over. The second interpretation is a "*cultural*" interpretation. It construes the zone of proximal development as the distance between the cultural knowledge provided by the sociohistorical context and the everyday experience of individuals. In this interpretation the distance between understood knowledge and active knowledge defines the zone of proximal development. The third interpretation views the zone of proximal development in a "*collectivistic*" perspective. In this context, the zone of proximal development is the distance between everyday actions and new forms of social action that can be collectively generated. The first two interpretations, therefore, focus on an individual learner in a social context, whereas the third focuses on collective learning.

Lave and Wenger argue that learning involves the whole person, not only in relation to specific activities, but also in relation to social communities. In their view, learning only partly implies becoming able to be involved in new activities, to perform new tasks, or to master new understandings:

> Activities, tasks, functions, and understandings do not exist in isolation; they are part of broader systems of relations in which they have meaning. These systems of relations arise out of and are reproduced and developed within social communities, which are in part systems of relations among persons. The person is defined by as well as defines these relations…To ignore this aspect of learning is to overlook the fact that learning involves the construction of identities. (Lave & Wenger, 1991:53)

8.2.2 Lave and Wenger: Communities of practice

For Lave and Wenger, development of human knowing happens through participation in an ongoing social world. Learning is not acquisition of knowledge, but increasing participation in a community of practice. Knowledge is not something that can be found in abstract "knowledge domains" of facts and know-how. Instead it is mastership of practice within a community that defines what this mastership means. Learning involves changing membership status in these communities of practice, from entrance as a novice newcomer, to being an expert old-timer, and eventually being replaced by new newcomers. The idea of learning as "internalization" of knowledge is therefore misleading. Knowledge in a community of practice is constantly negotiated in the community, and the identity of a member in the community, the membership status, and "expert" community practices are mutually constitutive.

One way to think learning, therefore, is as the historical production, transformation, and change of persons (Lave & Wenger, 1991:51). Lave and Wenger introduced the concept of *legitimate peripheral participation* to explain this process of learning. Legitimate peripheral participators enter the community of practice as newcomers, and through their engagement in community practices learn the skills of masters of this practice. Legitimate peripheral participation refers to both the development of knowledgeable skilled identities and to the reproduction and transformation of communities of practice.

Lave and Wenger introduced the concept of community of practice to describe how apprentices become experts. This process has also been called cognitive apprenticeship (e.g., Collins, Brown, & Newman, 1989; Rogoff, 1990; Orr, 1990; Teles, 1993). Cognitive apprenticeship sees learning as enculturation, and attempts to promote learning within the nexus of activity, tool, and culture that they jointly define. Brown, Collins, Duguid (1989), for example, highlighted the close relationship between technical and cognitive tools with concepts shared by specialized communities:

> To explore the idea that concepts are both situated and progressively developed through activity, use should abandon any notion that they are abstract, self-contained entities. Instead, it may be more useful to consider conceptual knowledge as, in some ways, similar to a set of tools…The community and its viewpoint, quite as much as the tool itself, determine how a tool is used. Thus carpenters and cabinet makers use chisels differently. Because tools and the way they are used reflect the particular accumulated insights of communities, it is not possible to use a tool appropriately without understanding the community or culture in which it is used.

The process of becoming a competent expert within a community may be represented as in Figure 5. This simple model has important consequences, for example, when skill development and training is perceived as a process where novices become competent practitioners and experts. Partly because of this, the community of practice model has become extremely popular in recent years. It has been used as a basis for organizational innovation management (Brown & Duguid, 1991), for studies on work practice development (Wenger, 1998), for strategic management of organizational core competences (Tuomi, 1998), and, for example, to study skill development in open source software communities (Tuomi, 2002).

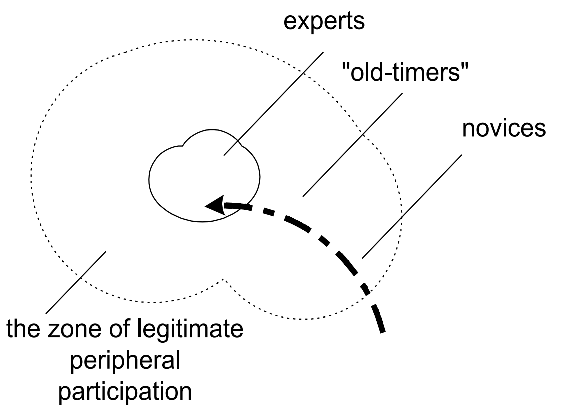

Figure 5. Trajectory of learning in a community of practice.

8.2.3 Davydov: learning through theoretical kernel concepts

In the context of school-learning, Engeström (1996) has compared three approaches to learning that share the focus on practice, culture, activity and tools. One of these is the Davydovian model of learning by formation of theoretical concepts. A child learns, with the teacher's help, to analyze the content of the curricular material and identify a primary general relationship in it. When the child continues the analysis, he or she finds out that this primary relationship is manifested in many different particular relationships in the curricular material, and develops a generalization of the subject under study. As this process goes on, the child eventually is able to develop a "kernel" concept that subsequently serves the child as a general principle that can be used in orienting within the multiplicity of factual curricular material.

Underlying the Davydovian model is the Vygotskian idea that scientific concepts are fundamental in the development of advanced mental functions. Although the Davydovian model may at first look like a method for making children little scientists through acquisition of abstract theories about laws of nature and society, the model actually views teaching as a method to help a child to develop advanced mental functions. In this sense, the Davydovian approach tries to make children more intelligent. In contrast to everyday spontaneous concepts, scientific or theoretical concepts are systems that profoundly change thinking. As Vygotsky notes:

> Scientific concepts, with their hierarchical system of interrelation, seem to be the medium within which awareness and mastery first develop, to be transferred later to other concepts and other areas of thought. Reflective consciousness comes to the child through the portals of scientific concepts. (Vygotsky, 1986:171)

Although Vygotsky used the term "scientific concepts," they can be seen as theoretical concepts that embody systems of cultural development. This contrasts with the view implicitly adopted in much of school learning where, instead of enculturation, the focus typically is on empirical facts, description, and classification of phenomena (Engeström, 1996:160). In the Davydovian model, the goal of learning is the development of thinking.

In the Davydovian model, the goal is not the acquisition or internalization of knowledge embedded in a textbook. Instead, it aims at construction of an open *context of discovery* through practical actions by the students. In contrast, according to Engeström, Lave and Wenger focus on the *context of practical social application*. These interpretations lead to different pedagogical models and school organization:

> The Davydov solution to the encapsulation of school learning is to create such powerful intellectual tools in instruction that students can take them into the outside world and grasp its complexities with the help of those tools…The legitimate peripheral participation approach would break the encapsulation the other way around, by creating genuine communities of practice within schools or perhaps by partially replacing school learning with participation in such communities of practice outside school. (Engeström, 1996:168)

8.2.4 Engeström: learning by expanding

According to Engeström, these modes of learning can be integrated in a learning model that is based on *learning by expanding*. This requires that the learners have an opportunity to analyze systematically and critically the learning activity itself. This was the reflective step represented in Figure 4. It provides *the context of criticism*, and generates a meta-level understanding of the subject under study, including its relations to other communities of practice. The object of learning is the relationships between the context of criticism, the context of discovery, and the context of practical social application (Engeström, 1996:165). In this view, school learning could be integrated in networks of learning that transcend the institutional boundaries of the school in a process of self-organized social transformation.

Those researchers who have focused on social practice as the foundation of knowing have conceptualized also individual learning as inherently social, even questioning the nature of identity of individuals. For example, Engeström uses the concept of zone of proximal development in analyzing changing work practice. His interventionistic and developmental approach could be characterized as a theory of "generating and negotiating best practices" in a context where these practices are tightly bound to a system of activity and the underlying communities of people. Engeström emphasizes also the role of collective generation of new behavior:

> Our concept of zone of proximal development may be provisionally defined as the distance between the present everyday actions for the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the inner contradictions embedded in the everyday actions. (Engeström & Engeström, 1985:214)

In line with Vygotsky, who was inspired by Marx's theory of cultural and cognitive development, Engeström argues that the originary form of human activity is work. In other words, human activity that can properly be called human, and which distinguished humans from other animals, is socially accomplished production. Production requires division of labor and distribution of the results of production. As a driver for production, consumption therefore emerges as the core of human activity. In addition, Engeström—again following Marx—argues that there is a third dominant aspect of human activity, that of exchange, which Engeström also describes as communication and social interaction. Combining the categories proposed by Marx, and the analysis of animal forms of activity by Lewontin, Engeström ends up depicting the structure of human activity as in Figure 6. The core claim of Engeström is that when we talk about human activity, we have to talk about a complex that includes all the elements of the figure. Learning, understood as a change in meaningful and inherently social activity mediated by cognitive and technical tools, requires change in all of them.

Each triangle in the figure can become an activity in itself in a complex society. However, within any such relatively independent activity system, there exists the same internal structure that comprises production, consumption, distribution, and exchange. According to Engeström, this has the important implication that there is no activity without the component of production. In the terminology of A.N. Leont'ev, those components of activity that do not have their own productive aspect can not be called activities; instead, they are actions. There is, however, constant development and reconfiguration of the relationships among activities and between activities and actions. In the course of historical development, actions, therefore, may acquire the characteristics of activity, and new activities may emerge.

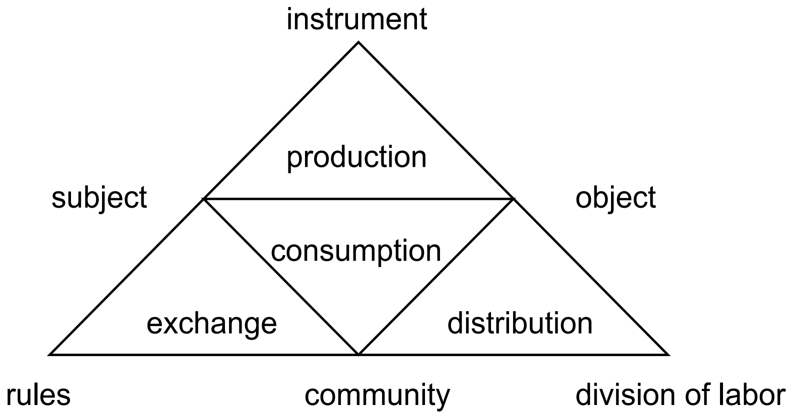

Figure 6. The structure of activity according to Engeström

According to Engeström, this model of activity is the smallest and most simple unit that still preserves the essential unity and integral quality behind any human activity. Using the model, activity can be analyzed in its inner dynamics and historical change. Activity is in this model also represented as a contextual and ecological phenomenon. Finally, activity is also presented as a mediated phenomenon, where both cognitive and concrete instruments and tools become irreducible elements in the relation between the acting subject and the object of activity.

A specific characteristic of Engeström's model is that it can be used to analyze the reasons why learning and change are difficult. The reason, to put is simply, is that change of activity systems creates both internal and external conflicts. According to Engeström, the primary contradiction in modern capitalist socio-economic formations is the inner conflict between exchange value and use value. Secondary contradictions are those appearing between the elements of the Figure 6. The existing structure of division of labor and the demands of new production instruments is an example here. A tertiary contradiction appears when a culturally more advanced form of activity is introduced that interferes with an existing form of activity. For example, kids may go to school in order to play, but the teacher may try to convert play into study of skills needed in modern society. Or business managers may introduce improved management accounting systems and forget that access rights to the old system were an important source of organizational power and prestige. Finally, there are also quaternary contradictions that emerge as activity systems interact with their "neighbor" activities. For example, change in the focal activity may require change in the activities that produce tools for it.

8.2.5 The structure of learning activity

In analyzing the transformation of learning, Engeström's model is interesting, as he has used to model to describe the historical evolution of learning activity. According to Engeström, learning can be understood through describing the evolution of three activity systems: the activity of school-going, the activity of work, and the activities of science and art.

Written language is the first truly generic context-free instrument that can be used to reproduce knowledge and skills. Its relative independence of any specific application generates the activity of school-going as a separate socially institutionalized activity. Although written text enables completely new advanced forms of thought, in practice school learning has often remained reproductive. Knowledge acquisition has become understanding of texts written by authorities. Learning becomes "imitatio," and assimilation of pre-existing canons. Engeström maintains that the general transition to modernity and public schooling has not been a qualitative breakthrough into learning activity, and the seemingly endless stream of literature on the crisis and obsoleteness of school learning should be taken as a symptom of this.

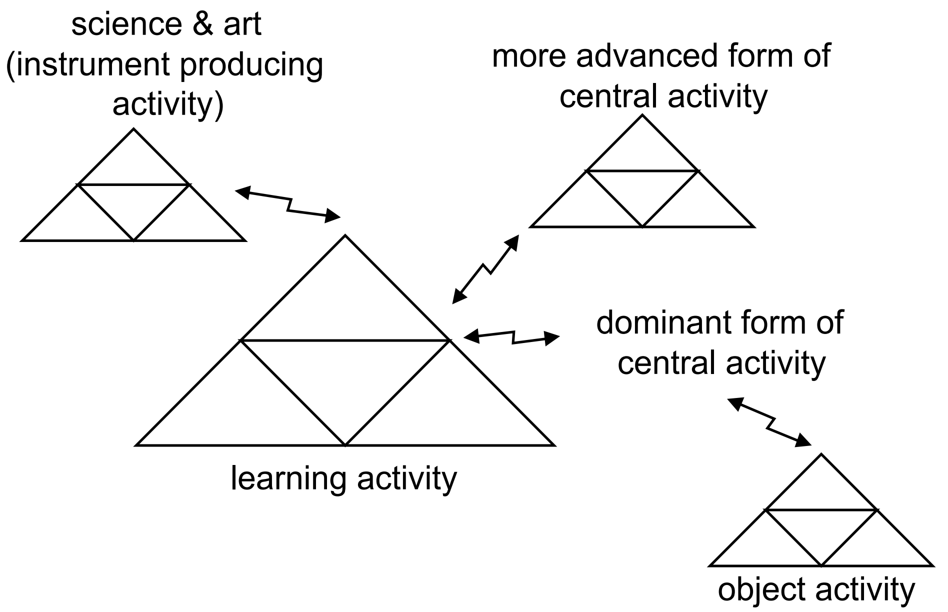

Figure 7. Learning activity in the network of human activities.

Engeström argues that learning should be a developmental activity where the contradictions inherent in the focal activity are overcome. Thus, learning activity needs to become an activity that produces societally new forms of activity. This, however, requires that we have to reconsider the object of school-going. Mastery of given texts needs to be replaced by mastery of advanced forms of thinking. Following Vygotsky, Davydov, and Sylvia Scribner and Michael Cole,[27] Engeström argues that a key to such advanced forms of thinking is in the development of conceptual systems that are externalized and developed into theoretical systems, for example using written text.

In expansive learning, the object of learning is the societal productive practice, or the social life-world, in its full diversity and complexity. Learning activity makes the interaction between historically earlier and more advanced forms its object of activity. Thus, in expansive learning, learning is not assimilation and internalization of pre-existing knowledge. Instead, it is creation of new knowledge and its articulation as a

[27] E.g., Cole & Scribner, 1974.

new social practice. This makes expansive learning also theoretically relevant for innovative learning, as it occurs in the society and in business organizations.

8.2.6 Nonaka: innovative learning in organizations

As business organizations are becoming increasingly dependent on innovation, also learning has in the recent years been increasingly been studied as a process that creates new knowledge, new concepts, and new technologies and products. This has produced a large body of literature on organizational learning. Much of this literature has framed organizational learning as a problem of effective skill management and human resource development. Others, for example Argyris and Schön, have focused on managing dysfunctional learning that decreases organizational efficiency. One of the most influential organizational learning models is the one introduced by Ikujiro Nonaka. As it adds important conceptual elements to discussions on learning, I will briefly describe it below.

Following Polanyi, Nonaka bases his model on dynamic interaction between two types of knowledge. *Tacit* knowledge, according to Nonaka and his collaborator Takeuchi, is personal, context-specific, and therefore hard to formalize and communicate. *Explicit* knowledge, in contrast, refers to knowledge that is transmittable in formal, systematic language (Nonaka & Takeuchi, 1995:59). According to Nonaka, tacit knowledge includes cognitive and technical elements. The cognitive elements include mental models, such as schemata, paradigms, perspectives, beliefs, and viewpoints, and they help individuals to perceive and define their world. The technical elements, on the other hand, include concrete know-how, crafts, and skills.

The central idea in Nonaka-Takeuchi model is that new knowledge is created in articulation of tacit mental models, in a kind of "mobilization process" (1995:60). In this process, tacit knowledge is converted into explicit form. Although new knowledge is, strictly speaking, created only by individuals according to Nonaka and Takeuchi, knowledge creation does not happen within a single individual:

> Our dynamic model of knowledge creation is anchored to a critical assumption that human knowledge is created and expanded through social interaction between tacit knowledge and explicit knowledge…It should be noted that this conversion is a "social" process *between* individuals and not confined *within* an individual. (1995:61)

The transformation of knowledge between different forms is a bi-directional process. Tacit knowledge becomes explicit, but explicit knowledge also becomes tacit. Corresponding to the four possible types of knowledge conversion, there are four conversion modes. Tacit knowledge transforms to tacit knowledge through *socialization*; tacit knowledge transforms to explicit knowledge through *externalization*; explicit knowledge is converted to explicit knowledge through *combination*; and explicit knowledge transforms to tacit knowledge through *internalization*. Nonaka refers to this knowledge creation model as the SECI model (Nonaka & Konno, 1998). Innovative learning and knowledge creation is in this model understood as conversion of tacit knowledge into explicit forms where it can be combined, followed by an internalization process where this new combined knowledge becomes a part of the learner's knowledge structure. This model is shown in Figure 8.

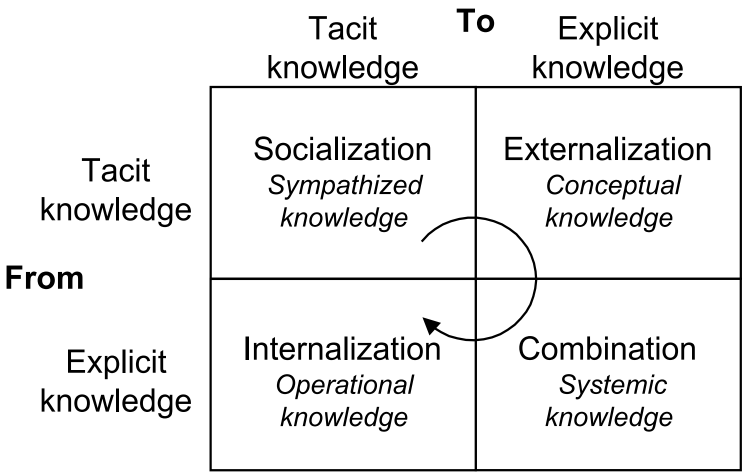

Figure 8. Nonaka-Takeuchi learning cycle.

According to Nonaka and Takeuchi, an individual can acquire tacit knowledge directly from others without using language (1995:62). This socialization process happens through observation, imitation, practice, and shared experience. Externalization, on the other hand, is a process of articulating tacit knowledge into explicit concepts. In that process, tacit knowledge takes the shape of metaphors, analogies, concepts, hypotheses, and models. These we—more or less successfully—try to express using language. Among the various forms of knowledge conversion, "externalization holds the key to knowledge creation, because it creates new, explicit concepts from tacit knowledge" (1995:66). The third mode of knowledge conversion, combination, is the process of systemizing concepts into a knowledge system, and it integrates different bodies of explicit knowledge. This includes such activities as sorting, adding, and categorizing explicit knowledge. According to Nonaka and Takeuchi, knowledge creation carried out in formal education and training at schools usually takes this form (1995:67). In organizational contexts, one of the main roles of middle management is to create new concepts through combining various sources of knowledge (Nonaka, 1988). Internalization, the fourth conversion mode, is a process of embodying explicit knowledge into tacit knowledge. Experiences through socialization, externalization, and combination are "internalized into individual's tacit knowledge bases in the form of shared mental models or technical know-how," and therefore become valuable assets (1995:69).

Organizational knowledge creation is a continuous process where the different modes of knowledge conversion interact. Nonaka and Takeuchi describe this dynamic process as a knowledge spiral. In this spiral of knowledge creation, the socialization mode starts with building a "field" or "space" of social interaction (Nonaka & Takeuchi, 1995:70; Nonaka & Konno, 1998). After such a social interaction field exists, externalization is triggered by meaningful dialogue that sustains collective reflection. As a result, the combination mode is triggered by networking and integrating the newly created knowledge with existing stocks of explicit knowledge.

Finally, “learning by doing” triggers internalization. The different phases of knowledge conversion lead to different knowledge contents:

> Socialization yields what can be called “sympathized knowledge,” such as shared mental models and technical skills…Externalization outputs “conceptual knowledge”…Combination gives rise to “systemic knowledge”…Internalization produces “operational knowledge”…” (1995:71)

Based on these considerations, Nonaka and Takeuchi propose a five-phase model of the organizational knowledge creation process. The first phase consists of *sharing tacit knowledge* within the organizations. The “rich and untapped knowledge that resides in individuals must first be amplified within the organization” (1995:84). In the second phase, tacit knowledge that is shared, for example, by a team within an organization, must be made *explicit*. In the third phase, this explicit knowledge must be *justified*, so that the rest of the organization can determine if the new concept is worthy of pursuit. If the organization gives a “go-ahead” for the new concept, it then has to be converted into an *archetype*, for example, a prototype or an operating mechanism. The last phase extends the knowledge created across the organization. Such *cross-leveling of knowledge* may involve also outside constituent such as customers, distributors, sub-contractors, and other stakeholders.

The Nonaka-Takeuchi model can be represented as in Figure 9. This representation makes also visible the close similarity between Engeström’s and Nonaka and Takeuchi’s models. However, as Engeström (1999) has pointed out, in the SECI model the initial problem that starts the cycle is implicit. More generally, one can say that the Nonaka-Takeuchi cycle differs from Dewey’s and Engeström’s learning cycles as there is no concept of motive, need, or problem integrated in the model (Tuomi, 1999). Therefore, also a criterion for success in learning comes from outside the learning process. In practice, learning in this model has been successful if there is a profitable product out in the market.

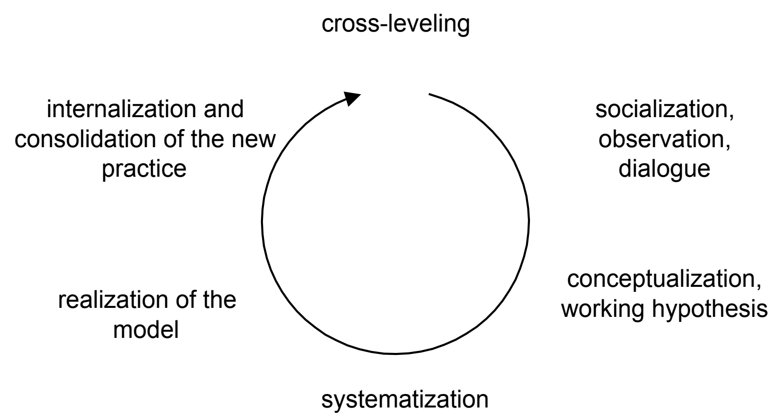

Figure 9. A reconstructed Nonaka-Takeuchi model.

8.3 The 5A-model

The different models of learning allow us to ask how information technology could be used to support and facilitate different phases of learning processes. Strictly speaking, to answer this question, we have to study learning as an ongoing process and as an element of intelligent human action. This leads to learning models that combine elements of the above models using a non-positivistic, socially constructed, and culturally, socially and historically grounded epistemology. Elements of such a model have been discussed by Tuomi (1999), which proposed the “5-A model of learning” as a practical starting point for managing organizational learning and knowledge management. We briefly point out some of the main characteristics of this model, to highlight the potential impact of information and communication technologies.

According to Tuomi (1999) the learning process can be triggered by three different sources: the environment, the society, or the learning unit itself. More specifically, we can distinguish three modes of knowledge generation, which we may call *articulation*, *appropriation* and *anticipation*. We may have a model of a world which suddenly breaks down and surprises us. This tension between our anticipation and observed world may produce new knowledge. We might call this type of learning as “Dewey learning.” Learners can also produce knowledge by appropriating knowledge that exists in the society. For example, systems of “scientific concepts” and language can be learned by acquiring them in a joint effort by the learner and a more competent tutor. On might call this “Vygotsky learning.” Third, knowledge can also be generated by articulating and reconfiguring meaning relationships within the meaning system available for the learner. This could be called by various names, such as “Polanyi learning,” “creative learning,” or, more etymologically, “poiesis.” These processes are schematically depicted in Figure 10.

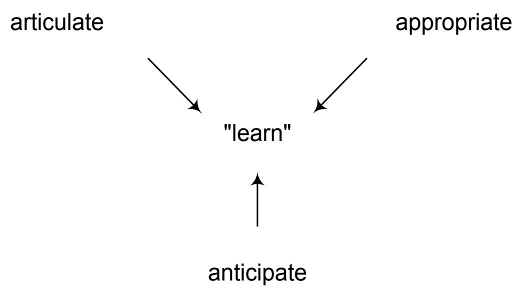

Figure 10. Three sources of ontogenic knowledge.

These dynamic processes transpire within a context of accumulated meaning structure and knowledge. Learning is always incremental, and possible only if there is memory.[28] Therefore we need to add to the Figure 10 the process of *accumulation*.

[28] Although learning in itself is necessarily and incremental process as a result of its accumulative character, its manifestations can be radical. When some central nodes in the meaning structure become reorganized, many meaning relations change. This can be seen as accommodative learning in Piaget’s terms, double-loop learning in the terms of Argyris and Schön, or Learning III in Bateson’s classification.

Moreover, as intelligence, knowledge and cognition can fundamentally only be described in the context of effective action, we should also add to Figure 10 this process which grounds the rest of our constructs. The resulting model of knowledge processes is shown in Figure 11. I shall call it the “5-A model” of knowledge generation, for short.

Articulation and anticipation generate knowledge that can be new to the society. Appropriation, in contrast, generates knowledge that is available within the society but which is new for the focal learner. For example, a child learns language by appropriating linguistic knowledge and clusters of meaning packaged into concepts. After becoming a proficient language user, he or she may also articulate new linguistic structures or concepts, thereby creating new language for others to appropriate. In this linguistic domain, the etymological origin of “poietic learning” is clear. One could also note that theoretical science, as a knowledge-creation mode, is a form of poetry. Both express and articulate something that exists and makes sense, potentially, but which no one said before.[29]

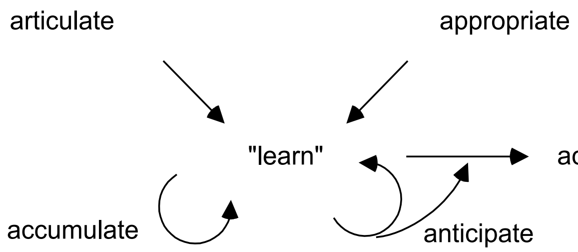

Figure 11. The "5-A model" of knowledge generation.

The generic model shown in Figure 11 should be further refined by considering its manifestations within the different units of analysis, including communities, societies and cultures (cf. Tuomi, 1999: Ch. 11). Here it suffices to point out just a couple of examples of the ways in which information and communication technologies enter the learning process.

Acts in Figure 11 can mean both internal and external action. “Internal action” corresponds to reflective thought. Information technology can facilitate and support reflective thought, for example, by computational simulation and cognitive augmentation.

External action, in turn, comprises two integrated kinds of behavior: communication and production. All human action is mediated and symbolic action that has both communicative and productive aspects, in an analytically inseparable package. The

[29] Postmodern scholars in literature studies might, of course, find the idea that poetry (or language) can be created through references to non-linguistic realities somewhat problematic. Reference to reality, however, does not necessarily imply naive realism or trivial empiricism. The 5A-model, in particular, rests on a rather elaborate analysis of phenomenological, constructivist and socio-cultural epistemologies.

communicative dimension of action is related to the meaning of action, and the productive dimension to its transformative function. In other words, whenever we do something, we both produce external effects that become material facts that other's can try to make sense of and which constrain the practical actions of others, and, at the same time, we try to accomplish some meaningful result. To give a concrete example, when I take soup from a kettle, I both take food and leave the kettle less full of soup. Moreover, all action emerges in the context of activity. For example, when I take soup from a kettle, I participate in a complex social and cultural activity of "eating," regulated by norms, historical traditions, available technologies, the temperature of the soup, expectations about food poisoning, beliefs about purity of specific types of meat, and so forth.[30] All these elements spice the soup so that food becomes a profoundly cultural and communicative phenomenon, independent of the transformative fact that after I take some soup, there is less of it in the kettle. All action, in other words, has meaning within the social context, and action, in itself, always implicitly coordinates social behavior. All action also produces change as a transformation of some aspects of the world.[31] Information and communication technologies enter this process when they are used to produce things and also because they provide a medium for social meaning processing.

Accumulation and memory underlie all meaning processing. In some cases, accumulation is based on physiological change in the cognitive system. In some cases such change can be "purely" cognitive, in the sense of being a change in the configuration of self-referential meaning relations. This type of accumulation occurs, for example, when a cluster of meanings is crystallized into a concept. In other cases, accumulation may happen by utilizing external cognitive tools and auxiliaries. In addition to serving as mediated means to augment meaning processing, these external artifacts may also be used to organize social practice.

A more detailed picture of the knowledge generation process could then be represented as in Figure 12.

[30] "Action" is here used in the activity theoretic sense, as a action directed towards solving a specific goal in a sequence of actions that implement a specific form of social activity or practice. We are therefore here talking about actions that rely on "advanced mental functions" in Vygotsky's sense, i.e., actions that are irreducibly social and knowledge-based. The argument is that, for well developed thinkers and learners, no action remains that would be independent of socio-cultural inheritance. For a young child, the situation may be different.

[31] In some cases, of course, production itself may be communication.

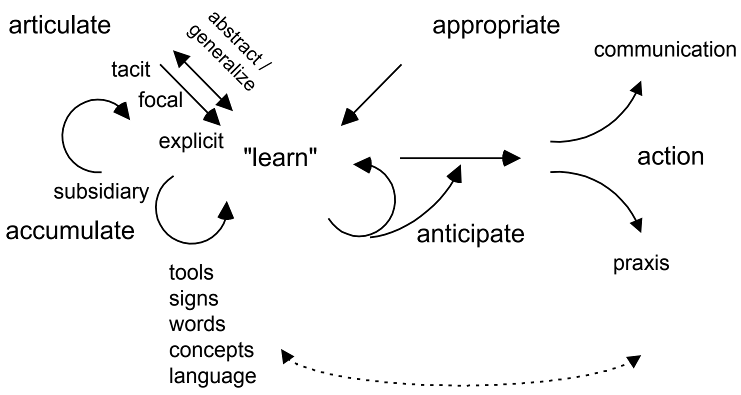

Figure 12. Detail structure of the 5-A model.

Knowledge exists in context and it emerges as plans, anecdotes, language, habits, models, practices, and institutions that guide action. Information and communication technologies can be used to represent all these.

Articulation underlies anticipation as the basis for explorative action and generation of plans. Appropriation of knowledge happens through acquisition of externally generated knowledge that is articulated in communication, tools or action. Most important, accumulation of knowledge requires concept formation, combination of knowledge, and for example, explication of knowledge in language. Although accumulation does not necessarily require representation, when knowledge is represented, meaning processing can use such representations to develop qualitatively new forms of advanced thinking. Representation also enables symbolic communication and collective meaning processing, either through sharing meaning references, or by sharing knowledge artifacts. As a result, knowledge about knowledge becomes possible.

Accumulation of knowledge produces artifacts that can become objects of action. These can be viewed as cognitive tools, in the sense of Vygotsky, by which some meaning processing is off-loaded to the environment. Commonly distinguished articulation processes include abstraction, categorization, combination, explication, refining, visualization, and reflection. Knowledge structures are articulated as concepts, tools, metaphors, images, models, and stories. These in turn, accumulate as practices, languages, designs, integrated histories, and organizational culture, for example. Finally, with written forms of language, some of these accumulated knowledge structures may be represented as documents.

Documents, therefore, can be viewed as attempts to articulate some aspects of underlying accumulated stocks of knowledge in written linguistic form. In most cases, textual representations are only minor parts of the full underlying knowledge structures, and their interpretation always requires knowledge about culture, practices, and language specific to the focal organization and the community of practice. For this reason, also the common idea that knowledge is created by structuring data into information, which is then interpreted to produce knowledge, is not a very useful starting point for understanding knowledge creation or for designing information systems for knowledge-based activities (Tuomi, 2000). In practice, we have to turn around the conventional data-information-knowledge hierarchy when we design, for instance, collaboration or organizational memory systems.

It is impossible to discuss the implication of the above-presented models in any great depth in this Appendix. Detailed learning models are, however, important when we try to understand the changes in learning activity. They represent learning in a way which is abstract enough that we can see the stable core of learning, and they allow us to describe the historical forms of learning that are now undergoing transformation. For example, the above learning models abstract away specific cultural and technical artifacts, such as textbooks. Using the presented concepts, we may therefore "deconstruct" learning and study how, exactly, new technologies enter the learning process. They, for example, allow us to avoid the common error of interpreting new information and communication technologies as means to implement traditional institutional forms of organized learning. For example, it is now generally understood that many attempts to use computers in classrooms failed because computer-based learning systems simply tried to replace printed books with electronic textbooks. PC-based educational software market, which was expected to expand rapidly, was last year one-third of what it was in year 2000. At least partly the burst of the computer-based education bubble results from the realization that the conventional mainstream learning models simply are not very useful. When the traditional models are implemented using computer software, the theoretical limitations of these models become explicit, and difficult to hide by competent human teachers. In a way, we learn how our implicit theories about learning went wrong when we implement our ideas using computers. This also creates the opportunity to rethink what this obvious thing we call learning, actually is.

The proper way to analyze the potential impact of information and communication technologies on learning, therefore, requires that we use theoretical grounded concepts to localize those points in the learning process where technology will create important new opportunities for learning. This work is just beginning. It will lead to new ideas about how to support learning with computers and information technology, and it will produce new insights on how to reorganize education.

One may argue that there can be no discontinuities in learning, as learning, itself, will not change even when educational systems undergo radical change. If we really understand what learning is and how it happens, this implies that our model of learning is accurate in different environments and periods of time. On the other hand, one could also ask whether the emergence of the knowledge society actually means that the social and cognitive processes and the practices of learning are now changing in fundamental ways that will require new models of learning. This, indeed, would be what Bateson called Learning IV. He argued that it could happen, but that it is something that we have rarely seen in the human history.

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