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Learning in the Age of Networked Intelligence

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Introduction

Soon we shall be living in a world where knowledge is readily available whenever and wherever we need it. How far will the traditional aims of education remain relevant in this changing world? Will the institutions of learning adapt, or will they be replaced by new forms of learning and knowledge management? What will learning and education look like in this new world of knowledge?

In this article, I present ten 'theses' on future education and learning, highlighting emerging trends that will shape future educational systems. The focus is on the impact of the innovation economy and knowledge society on learning. To place the discussion in a context of social change, the article starts with a brief review of Niklas Luhmann's analysis of the social function of education. It then zooms in to a more historical description of socio-economic transformations to highlight the characteristics of the ongoing evolution towards the innovation economy and knowledge society. Specifically, the article elaborates the changing dynamics of production models, arguing that in the last few years we have been in a globalisation process that is qualitatively different from the earlier ones. This new model has consequences for skill demands and their regional distribution. An historical outline of production models is useful, as educational institutions are optimised for the requirements of the past production models.

The emerging innovation economy is not only about the greater importance of new products, services and knowledge in making profit. It is also about new approaches in producing innovation and knowledge. Fundamentally, it is about new ways of linking learning and social and economic change. To create these links, we need to revisit some traditional ideas about the nature of innovation. The article therefore outlines a new theoretical view which connects innovation with social change and learning. The new 'downstream' model highlights the active and creative role of user communities in making innovations real.

An historical description is useful when we try to understand where we came from and where we are today. The article, however, moves beyond the diagnosis of the historical trends and proposes a set of possible futures. These are presented as ten 'theses'. It ends with a short concluding section.

Education in the Information Society

Human beings have countless characteristics and experiences that make each of them different. According to the sociologist Niklas Luhmann (2002), the existence of social order and meaningful communication requires that this potentially infinite complexity is reduced and simplified. The *Erziehungssystem* of society — the functionally specialised system that 'brings up' and educates human beings — makes newborn human beings constituents of society. In the context of the social systems theory, its function is to reduce social complexity. A specialised system of education emerges when society's functional differentiation increases. In the modern highly complex world, the simple socialisation and internalisation of traditional roles and practices become insufficient and society starts to rely on a specialised functional system of education that 'manufactures' a large variety of specialised persons who can occupy social roles. The primary social function of education is to produce 'generalised persons' who can reproduce society and keep it going. Its secondary function is social selection. Human beings have different abilities and potential capabilities. The educational system therefore also functions as an evaluation and selection mechanism that puts human beings on alternative career paths.

Luhmann's description of socially specialised educational systems is based on his general theory of social systems (Luhmann, 1995; Qvortrup, 2006). In this context, education emerges as one of the many functionally diversified sub-systems of a modern society. Assuming Luhmann's description accurately characterises the social function of education, we can ask whether future knowledge societies will need educational systems. If Luhmann is right, they are needed as long as newborn human beings have to be developed into socially differentiated 'persons' and society benefits from the selection that occurs in the educational system.[1]

In the modern world, innovation rapidly reconfigures social categories. The post-industrial world is characterised by fluid social roles, unpredictable life paths, and increasing mismatches between traditional professional careers and labour market demands.

The processes of creative destruction now also operate inside educational systems. Luhmann, however, argued that these have one stable core function: to simplify complex societies and make them more predictable. Will there be other ways to achieve this in the future?

Anthony Giddens (1985) has argued that organised states are inherently information societies.[2] The generation of state power presumes reflexively gathering, storing, and controlling information, applied to administrative ends. Somewhat paradoxically, therefore, the expansion of the Information Society can be understood as a response to the growing need for education. One way to make societies more predictable is to collect and process data and make them more information intensive.

In Luhmann's view, social categories are not only needed to manage societies and their complexity. A society could simply not exist without categorisations that simplify this complexity. Theoretically speaking, education and statistics are, therefore, complementary: education creates social categories that simplify social complexity, whereas statistics collect data that can be used to manage that complexity. The paradoxical outcome is that when greater social predictability is gained through increase in information, modern society reflexively uses all the available information to increase its complexity. In the last five decades, the historically unparalleled pace of developments in data processing technologies has guaranteed that complexity can increase faster than predictability.

The Information Society, however, also open new paths for development. From a social-systems point of view, information and communication technologies are technologies for managing social complexity. We can now also use these to create social categories on demand.[3] For example, the social importance of formal educational certificates is now declining, as people's capabilities, interests, and reputations can be directly evaluated with information and communication technologies. The underlying social complexity can therefore remain high. In practice, people play multiple roles in society and can switch amongst these very rapidly using information and communication technologies.[4] They can become more individual and unpredictable, as information processing capacity increases in society. Statistically speaking, the increasing individualism does not matter, as socially relevant data can be collected and processed in real time.

The ongoing socio-economic re-organisation of society will also influence vocational and professional categories which emerge as complements for specific ways to organise labour. When systems of production change, vocational categories change. The economy of the future is increasingly distributed geographically and innovation and novelty are the key sources of economic value. The traditional constraints of economic production and theory are radically changing as we move from the economy of scarcity towards the economy of value.

Professional and vocational categories have been key social categories in shaping educational systems. The emerging knowledge society removes some traditional constraints for managing social complexity, creates new trade-offs, and shifts balances. This emerging new 'world order' will therefore change the context of education. The social system of meanings will increasingly be learned outside formal education, which, in turn, will focus on the development of generic capabilities. Most importantly, future educationalists and policy-makers must be able to answer the question: why does society need education?[5]

Will We Need Education in the Future? A Socio-Economic View

In industrialised countries, educational systems address specific social and economic challenges that emerged in the 19th and 20th centuries. The legal, political and economic institutions that underlie vocational education and training, in particular, have evolved to meet the demands of industrialised mass-production. In many ways, the reality of educational systems reflects the need to optimise production in an historically unique setting, where boundary constraints were set by the limits of transportation capability, resource availability, access to knowledge, and coordination and information processing capacity. Information and communication technologies are now moving these boundaries in both industrialised and developing countries.

Technologies, vocations, skills, and the ways in which work is organised are closely related. Vocations, skills and organisations are different in agrarian, industrialised and knowledge societies. The emerging global knowledge society is unique in its capability to connect countries across geographical distances and economic levels of development. Development, in this context, does not necessarily mean that vocational and educational practices trickle down from the economically most advanced countries to the rest of the world. The best existing vocational education and training systems in the economically developed countries represent the best answers to yesterday's socio-economic challenges. In principle, there is no obvious reason why these systems would be beneficial in the emerging knowledge society. On the contrary, it is quite possible that educational systems that are optimised for yesterday's world can be dysfunctional in today's and tomorrow's world. To locate historically the formative factors that underlie modern educational systems, the ongoing socio-economic transformation can be characterised as the most recent link in a chain of production paradigms. Each of these has its own 'social logic' where specific ideas about 'vocation', 'education', and 'training' make sense. When the paradigms changed, these terms were reinterpreted so as to remain meaningful in the new context.

According to Pérez (1985; 2002), the dominant 'logics' of production have undergone five major changes since the first Industrial Revolution. Each production paradigm has been organised around a 'standard way of doing business' in a way that effectively used a new generic key technology. Since the beginning of the first Industrial Revolution in England in the 1770s, there have been five such 'industrial revolutions' and 'techno-economic paradigms'. The first was based on mechanised work and new infrastructures such as canals and the wide availability of water power. The second was based on steam and railways, standardised components, and a universal postal service. It started in Britain and spread to Continental Europe, the US, and eventually the rest of the world. The third paradigm, according to Pérez, can be called the Age of Steel, Electricity and Heavy Engineering. Starting from 1875, it introduced cheap steel, electrical networks, tunnels, bridges, and worldwide railways. The fourth paradigm, the Age of Oil, Automobile and Mass Production, was the leading organising principle of most of the 20th century. It started in North America and spread first to Europe and then to the rest of the world. This fourth paradigm is still of key importance when describing the rationale for many institutional structures of education. In particular, the implicit goals of technical and vocational education and training are frequently associated with the requirements of a functionally diversified and hierarchical approach to organising work. In this organisational setting, work tasks and related competences can be defined relatively easily. A functionally diversified and hierarchical organisation fixes and stabilises work tasks for which relevant competences can be easily defined. Training and education for such work can, therefore, be specialised. The industrial structure creates its 'mirror image' as a professional and skill structure, and in the special case of the fourth mass-production paradigm, professional categories themselves become statistically dominant. In this historically unique situation, standardised vocational education can mass produce skills that are useful and in demand in the labour market.

Since the invention of semiconductors and general-purpose microprocessors, the economic system has increasingly been organised around efficient use of information and communication technologies. Pérez calls this fifth paradigm the Age of Information and Telecommunications. It is commonly called the Information Society. Its concept hides two quite independent developments in production systems. The first is the greater capability to coordinate labour across time and space. This aspect is often discussed in terms of globalisation. The second can be found in the shifting sources of economic value. This is often discussed in terms of innovation. Both have fundamental implications for educational systems. To understand these, we must describe in some detail the emerging production model and its relation to the new models of globalisation and innovation.

The Third Globalisation as the Sixth Industrial Revolution

We can distinguish three major stages of globalisation. The first was based on physical transportation of goods and people. In its final phase, after the 1940s, it created multinational corporations, as jet aeroplanes enabled managers to travel and develop integrated planning and decision systems. Due to limited communication capabilities, a clear distinction remained between planning and production functions.[6]

In the mid-1960s, international telephony achieved a milestone when it became possible to make 500 simultaneous telephone calls between Europe and North America. Multinational corporations, however, had considerable difficulties in effectively linking their regional operations before the continents were connected with fibre optic cables in 1992 (Tuomi, 2002, p. 60).

The second globalisation occurred when the Information Society expanded beyond national boundaries. The true impact of the new communication technologies was, however, only felt in the early 1990s when corporations became able to exchange documents with rich content. The impact has been the geographic re-location of work and production in the last decade. The less visible impact has been the introduction of new work and management practices that rely heavily on information and communication technologies, as well as new knowledge and competence-based views on organisations (Tuomi, 1999).[7]

The *third globalisation*[8] has a qualitatively new model which relies extensively on broadband communication networks. In the previous phases, the global division of labour required separate stages of product planning, production, and delivery. The new Internet-based business models make this redundant. They are based on dynamic creation of transient global production networks that pop up at the click of a mouse and disappear as soon as production is over. Such real-time global connectivity and coordination would have not been possible in the 1990s. In the next decade, it will be the dominant techno-economic paradigm.

In theory, comparative advantages would lead to a global division of production and associated specialisation of human skills and knowledge. Globalisation, in the context of the Information Society, however, means that comparative cost advantages become absolute again. Whereas the classical theory of international trade followed Ricardo and assumed that capital was sticky and did not move from one country to another, in the modern economy capital flows quite freely across country borders.[9]

The importance of absolute advantages is that employment follows capital. In economic terms, both the utility and individual demand for skills and knowledge change when opportunities for their use change. In those regions where absolute advantages lead to better job opportunities, people flock to education that materialises the emerging economic opportunities. The key source of economic growth, then, becomes the amount of potential human capital that can be rapidly put to productive use. The shifts in capital are further accelerated because economically relevant knowledge and skills are often learned at work. Workers can rapidly lose their productivity if their skills are not used and updated regularly. Hence, traditional professions and vocations have seen rapid shifts in regional demand in recent years. Forecasted needs for vocational skills have typically been based on historical trends. Trends, by definition, provide misleading estimates when structural change dominates. As a result of the very rapid globalisation of production, educational planning has therefore become quite difficult.

The various techno-economic paradigms do not replace each other. Instead, they leave their inedible marks as networks that connect cities, shipping terminals, airports, and communication centres. Accumulated knowledge and technology do not disappear but become reinterpreted and reused.

The present socio-economic transformation is, however, unique in its capability to both create new domains of production and reorganise the earlier ones. The Knowledge Society systematically 'modernises' traditional industries, agricultural production, as well as local markets and the production of crafts, arts, and values. Information and knowledge are 'generic technologies' even more than steam, electricity, steel or petroleum, as they can enhance all production and products.

The ongoing transformation therefore also penetrates boundaries that emerged and were shaped through the forces of the previous techno-economic paradigm. Politically, one of the most important of these boundaries is the one that separated 'industrialised' countries from 'developing' countries. The global knowledge-based economy slices geographical regions in new ways, where national borders have decreasing relevance. Instead of geographical proximity or local availability of resources, the underlying organising principle in the knowledge economy is based on global networks (Castells, 1996). The distinction between 'developing countries' and 'developed countries' is therefore becoming increasingly anachronistic. This change can now readily be seen in countries such as South Korea, India, and China, where regional hubs connect with global production networks. A similar reorganisation can also be seen in the leading industrialised countries, where geographic specialisation is now essentially based on diversification in the context of global systems of production. This means that the challenges of vocational education will be surprisingly similar in countries that vary widely in their current economic level of development. This, indeed, is one of the key differences between the Industrial Age and the Knowledge Age. The Industrial Age produced the distinction between 'developed' and 'developing' countries. It also carried with it a specific global division of labour where vocational categories in both 'developed' and 'developing' countries made sense. The impact of the emerging global innovation economy is already clearly visible in developed countries but it is not limited to these countries. In the next few years, it will also reach the most remote villages, connecting them to the new global socio-economic system.

Education and the New Innovation Model

The other dimension that defines the socio-economic structure of the Information Society is the importance of innovation for economic growth. Innovation has emerged at the top of the agenda because the globalisation process leads to greater cost competition, squeezing the profits in existing industries. Innovation counteracts this by creating new products and temporary monopolies that can lead to extraordinary profits. Financial capital accelerates the push towards innovation, as it concentrates on those areas where extraordinary profits are possible.

The way in which we conceptualise innovation has important consequences for the educational systems of the future. The traditional model assumes that innovation consists of a process where an original insight is followed by product development, marketing and the dissemination of innovative products. This model emphasises original 'acts of creation' and the role of scientific and technical knowledge as the sources of innovation. When innovation is perceived to be a key to economic growth and industrial competitiveness, the need for innovation is then translated into a call for increasing levels of educational achievement and investments in higher education and research. In practice, innovation rarely occurs according to this traditional model. Studies on the evolution of socially and economically important innovations reveal that the key to innovation is the social adoption of new technological opportunities (Tuomi, 2002). 'Original insights' are rarely original, and innovative ideas are often re-inventions. Furthermore, many important innovations are 'system innovations' that add new elements to existing systems or reconfigure existing systems in novel ways. Instead of the focus on the 'heroic inventor' and his original acts of creation, recent research on innovation has therefore started to emphasise the processes that underlie the social adoption of innovative opportunities. In such studies, it has become clear that the term 'adoption' is quite misleading: the processes that determine the fate of innovative opportunities are better described as user-centric innovation, knowledge creation, and learning.

Various authors have highlighted different aspects of this new innovation model, usually in the context of industrial research and development. Nonaka (1991) argued that industrial innovation should be viewed as an organisational knowledge creation process. Brown and Duguid (1991) linked organisational innovation directly with social learning that occurs in professional communities of practice. Kodama (1995) pointed out that product development occurred increasingly in multidisciplinary projects where complementary bodies of knowledge were brought together to create new products and product concepts. Kodama also highlighted the importance of 'mutual learning' and 'demand articulation' in product development. Von Hippel (1976; 1988), in turn, pointed out that users were often important sources of product development ideas and that the traditional 'downstream' phase of product dissemination was often linked to the 'upstream' concept development. My own work (Tuomi, 2002) argued that the 'creative act' that makes innovations real and defines them occurred when user communities changed their social practices. This, in turn, depended on dynamics of change and learning in an ecology of social communities.[10] To contrast this last model with the conventional 'upstream' model, I will call it the 'downstream model' below.

The downstream innovation model highlights the point that innovations are fundamentally social. In the traditional model, inventors were often described as extraordinary people who created new ideas, technologies and gadgets. Innovation, education, and technology policies that follow the traditional model tend to emphasise technical specialisation and industrial application of knowledge. In the downstream model, the emphasis is on social learning and knowledge creation in communities of potential users.

The traditional innovation model that emphasised the 'upstream insight' is inadequate in explaining the development of many socially important technologies and ideas. Insights and technologies become real when they are integrated in specific social practices. The interpretation of an idea or technology becomes fixed only when it starts to have practical implications for a specific community of users. A specific technical artefact can have multiple meanings if several communities use the same artefact in their practices. In this sense, a specific implementation of technological functionality is like a word that can look the same but mean different things in different languages.

The practical consequences of different innovation models are different. The traditional 'heroic' model leads to calls for 'creativity', understood in an individualistic sense. The user-centric 'downstream' model, in turn, leads to a more social view, where innovation is perceived as a change and revolution in social practice. In the latter view, it becomes natural to ask why some possible revolutions fail and how some revolutions and revolutionaries survive. Furthermore, from a broader innovation policy perspective, one may ask what kinds of institutional arrangements make continuous revolution possible in some societies. In other words, one can ask how societies and economies can become innovative.

The demand for 'innovativeness' has generated tensions in educational systems because it shifts the balance between two incompatible aims of education. First, education has a socially important function in civilizing people and socialising them in existing traditions and cultures. This is the function emphasised by Luhmann and Confucian educational systems. It is often carried out with pedagogies that use rote learning and 'transfer' of knowledge from a teacher to the students. Second, in particular in the industrialised countries, education also implements ideas about the development of individual human potential. The latter aim leads to pedagogies that emphasise individuality, creativity, and problem-solving capabilities. In its less individualistic versions, it leads to critical pedagogies that see education as a means for social progress.[11]

When innovation becomes increasingly important for the economy, the balance shifts from cultural transfer to creativity. Whereas in the transfer mode existing stocks of knowledge and meaning provide the foundation for learning, in innovative learning the fundamental aim is to generate knowledge that is new to society. In the latter case, students are expected to be able to produce knowledge and meaning that are also new to the teachers. Innovative learning therefore focuses on producing capabilities for thinking, problem solving and knowledge creation. How such innovative learning should be implemented depends on the underlying concept of innovation. If innovation is understood as problem-solving in practical contexts, one could start from the individual experiential learning models (Dewey, 1991) or Nonaka's knowledge conversion model (Nonaka, 1994). If it is understood to emerge from the capability to use general scientific concepts in varying concrete situations, a natural approach could be the Davydovian method that emphasises the formation of theoretical concepts by ascending from the abstract to the concrete (Davydov, 1982). If innovation is understood as change in social practices, one might implement education using activity theory, where learning in educational institutions can be embedded in more extended social learning processes (Engeström, 1996).

The downstream innovation model, however, opens up new possibilities. If a key bottleneck in innovation can be found in downstream social learning processes, the upstream innovation processes can also focus on facilitating downstream learning and knowledge creation. In other words, if the problem is not in generating 'original insights' by a creator but in creative adoption and adaptation in the downstream user communities, 'innovative products' can be designed so that potential users can easily innovate. For example, in the downstream model, innovative products can be introduced as generic 'platforms' that enable users to figure out how they can be applied in the user community. The World Wide Web is perhaps the most prominent example (Tuomi, 2002). Such innovation platforms can also be designed so that they do not only allow user innovation, but facilitate and promote it. In the future, an increasing number of products will be able to be designed with pedagogic support built in. As a result, the capability to design for knowledge-creation, learning, and innovation will become economically important. This requires, for example, that technology designers become able to use advanced pedagogic models and concepts in their work practice.

The Future of Learning and Education: Ten Theses

In this section, I will present ten theses on the future of education as practical outcomes of the previous discussion.[12] The discussion above painted a broad picture and provided the overall justification for the theses. Here, the focus is on concrete claims which can also be read as scientific predictions that follow from the theoretical considerations presented above. Although, strictly speaking, social developments cannot be predicted, as societies are reflexive, some developmental trajectories are, indeed, probable in many possible futures.

Thesis 1: Education Becomes Global

Both the demand and delivery of educational services are increasingly distributed across regions and are independent of location. Global competitiveness implies that educational institutions will compete globally for brand recognition and students. Today, universities extend their geographic reach using electronic learning platforms and various forms of distance learning. As broadband networks become widely available across the globe, potential super brands also emerge in the educational sector. At the same time, the rapidly advancing open content and open educational resource movement will increasingly address the needs for mass education.[13] Open educational resources will also be widely available for informal learning and specialised education in local languages, as the OER model enables effective development and distribution of user-produced content.

Thesis 2: New Disabilities Become Challenges for Pedagogy

The Knowledge Society is a cognitively demanding society. Disabilities that were of minor importance in the earlier production paradigms, such as dyslexia and attention-deficit hyperactivity disorder (ADHD), will have a profound impact on people's life paths. Technologies and pedagogies will be adjusted to address these potential new sources of 'digital divides' in a society where learning and cognitive capabilities are critically important. Similarly, as lifelong learning extends to elderly demographic groups, technologies and pedagogies that compensate the effects of ageing will be in great demand.

Thesis 3: Blogs Become More Important than Formal Certificates

Today, people compile extensive life histories using web logs and homepages. In some expertise areas such as computer programming, employment opportunities often depend on a track record that can be reconstructed by search engines and personal blogs. The digital identities of persons now consist of their own representations of achievements and experiences, as well as reputations that accumulate through the comments of others. The importance of blogs and homepages is now rapidly expanding beyond computer specialist communities, and user maintained ePortfolios are becoming common. Formal educational certificates may be components in such digital representations of capabilities, but their relative importance will diminish.

Individual capabilities also often have their origin in the individual's capability to mobilise social resources. In the Knowledge Society it is often more important to know the right experts than to be an expert. Electronic track records provide an historical record of an individual's social networks and 'social capital', which are important factors when people compete in the labour market. Traditionally, a high value has been put on 'Ivy league' institutions, as their certificates implied good social connections. In the future, the existence of these connections will be directly observed through electronic track records. Formal certificates from respected educational institutions can be replaced by proof of actual merit and accumulated achievements in practical contexts. Personal 'brand management' expands to cover digital identities over time and space.[14]

Thesis 4: Demographic Change Leads to Slowdown in the Growth of Human Capital in Europe

Particularly in Europe, the increase in average educational attainment has resulted from the fact that the large post-war age groups received much more education than their parents. This has generated fast growth in educational averages. Simultaneously, the increasing participation of women in higher education has amplified the effect. In the near future, these demographic flows will slow down and become reversed in many European countries. This will lead to a rethinking of macroeconomic growth policies that emphasise the role of human capital. The attractiveness of Europe as a production location also declines, as product and labour market growth are important for production efficiency and innovation.

Thesis 5: Home Becomes the Classroom

The availability of broadband networks will mean that classrooms become extended in time and space. One driver is the social and cultural diversity that globalisation brings with it. Societies are becoming increasingly diversified cultural mosaics. For some parents, this means more value- and culture-oriented education, whereas for others it may mean education that aims at social mobility and competitiveness in the labour market. The cost of producing customised and mass-customised education is declining radically, as it can be produced for a global market, including niche and micro markets that could not support such services locally.

Customised education works against the civilising and standardising function of education emphasised by Luhmann. It is therefore also possible that policy-makers will perceive standardised education as an objective in itself. Many parents will also find themselves unable to define what exactly they want their children to learn. Commercial educational service producers, national policy-makers, and, for example, religious leaders will therefore offer competing educational 'service packages'. Parents will often subscribe their children to educational services by following the choices of their chosen peer groups. The selection greatly depends on how parents understand the role of education for individual development and society.

Another driver is the transformation of work that results from the emerging knowledge-intensive production model. As parents have increasingly fuzzy boundaries between work and private life, it is increasingly difficult to organise education so that it matches families' time and space requirements. Today, the time-space organisation of schools fulfils two important social functions. One is to build cognitive and social competences and transfer knowledge and values. The other is to put children in a safe environment so that their parents can work. In the future, these two functions will be increasingly separated. The efficiency of tailored and computer-supported education will increase, enabling effective learning outside classrooms. A broad network of social support can now be integrated with learning experiences, e.g. by involving grandparents in educational processes.

The 'day care' function of schools, on the other hand, will require increasingly flexible arrangements. Parents will pick educational curricula for their children from the global market for educational services, based on the values and aims they prefer, and they will use the greater flexibility for reorganising learning in time and space. As formal locally controlled educational certificates will decline in importance, parents will perceive a major increase in the richness of educational variety, with relatively little social or economic costs.

Thesis 6: Immersive Social Games Replace the Textbook

Play has a critical function in cognitive development. It creates an imaginary world where new concepts and skills can emerge. For young children, it provides a field of experimentation and experience where activity can become meaningful and where they can start acting in a cognitive way.

Play is creative and therefore not always easy to control. Pedagogies that aim at transfer of knowledge have traditionally emphasised disciplined learning. Often discipline itself has been understood as an important outcome of education. Play, on the contrary, has been viewed as something for which children have a natural tendency, and which should occur mainly outside school hours. This strict separation of 'work' and 'play' results partly from the idea that learning occurs by knowledge transfer. Partly it follows from the concrete constraints in educational settings. An important constraint in traditional school learning has been the requirement that the same content has to be delivered to many students at the same time. This means that the learning experience must be controlled by a teacher who delivers the content and who keeps the learning of a group of students synchronised. This model has problems in using creative play in learning. Although children achieve the highest levels of self-control in play, traditional pedagogies organise learning with a centralised source of external control.

Vygotsky (1978) argued that the expansion of cognitive capabilities occurs in play.[15] To the extent that this is true, school learning has relied on cognitive development that occurred outside the educational system. In future, institutionalised development of cognitive capabilities will become more important than institutionalised transfer of existing knowledge, and the dynamics of play will therefore be directly integrated in educational practices.

Computer software will have an important role in this, as it is essentially a medium for creating rule-based realities. The declining costs of computing means that highly sophisticated and 'realistic' simulators can now be implemented using cheap personal computers. In the future, games will not only be useful in simulating the real world and providing platforms for skill and knowledge creation.

They will also provide social microworlds that become platforms for creative and immersive experimentation.

Information and communication technologies can be used to make 'real the unrealisable', to use Vygotsky's expression, and to provide expanded zones of development where new knowledge and advanced thought processes can develop. Whereas the textbook was an important artefact that synchronised a group of learners in a mass-production learning environment, play and games will be the media for learning that develop cognitive capabilities. Social games will emphasise peer-to-peer learning, at the same time developing the basic skills that are required in real world tasks in the Knowledge Society, where the skill in mobilising social resources and socially distributed knowledge is often more valuable than their possession and ownership.

Thesis 7: Audio Makes Education Portable

For almost a decade, digital memory has been a cheaper form of storage than paper. As the cost of digital memories has roughly halved every year in the last few years, it is now economically and physically possible to carry huge amounts of data in one's pocket.

Technology-oriented visionaries have often concluded that the declining costs of storage and improved processing power will make portable video an important medium for education in the future. From a technical point of view, it is natural to think that rich media, with images, animation, and video, will dominate.

In many applications, however, audio outperforms video. Video requires concentration, whereas audio can accompany many everyday activities without interfering with them. Audio can also be rapidly uploaded in a compressed format. Educational programming will be one of the important applications of portable and personalised audio. One natural application will be language learning. The new economics of digital storage, however, also make other applications possible on a radically new scale. For example, it is now possible to have full textbook libraries in audio format in a space that is comparable to a traditional library card.

Thesis 8: Products Become Pedagogical

The innovation economy is based on the rapid introduction and adoption of new products and services. As the amount of novelty increases, the end users have to spend an increasing amount of time and effort to learn how the new products and services work. In the last two decades, this has led to repeated calls for 'easy-to-use' products and 'user-centric design'.

The idea that a functional product could be 'easy-to-use' implicitly assumes that the functionality and the 'proper use' of the product can be determined. This contradicts the basic insight of the new downstream innovation model, where innovative products succeed if they have 'interpretative flexibility'. In the old mass-production economy, this did not matter much, as the dominant style of use could, indeed, be defined as 'standard' or 'average'.

The logic of mass production therefore started from the assumption that there are typical proper uses of standardised products. In the emerging innovation-based economy, the evolutionary dynamics of product and service innovations are different from the mass-production model. It will be easy and cost-effective to build in flexibility into product designs, and this flexibility will enable new innovation paths that are sources of profitability and competitiveness. At the same time, flexibility must be implemented in a way that makes easy adoption and user-centric innovation possible.

These developments will lead to product and service designs that incorporate support for user innovation and learning. In the future, product designers will increasingly design functional and meaningful product-user combinations where the design is successful when the combination 'works'. The combination, in turn, works when the product's potential technical capabilities are complemented with user competence. Effective design of technical functionality, therefore, requires parallel design of paths that make the user a competent user. One way is to implement 'pedagogic veils' that can be 'thrown over' complex product designs, so that a novel product can increasingly carry information and knowledge that support learning processes that create competent users (Tuomi, 2005).

The new innovation model will therefore also create demand for sophisticated pedagogical models that can be used in product design. Active software help-systems have been studied extensively in the last three decades, and commercial software is now typically packaged with electronic manuals, tutorials and documentation. In the future, products and services will be increasingly integrated and enhanced with software. Products will know how their users can become competent users. Instead of sending people to classes and training courses, product designers will embed pedagogical functionality in their products. This will often make separate product- and application-specific training redundant. The downstream innovation model also highlights the point that user competence is always related to the underlying social practice. Technology adoption requires social learning. Future products will therefore embed pedagogic models that guide users through 'zones of proximal development' that make them competent members of the user community. In addition, they act as platforms for social innovation and experimentation, making possible social change that is required to make innovations real.

Thesis 9: Informal Social Learning Becomes the Key to Competence Development

Lave and Wenger (1991) argued that professional skills were often learned in a social process, where people participated in a specific community of practice. They proposed that learning starts when novices gain the right for 'legitimate peripheral participation' in the community, which gradually allows them to become competent 'old-timers' and leading 'gurus'. In their work, Lave and Wenger popularised the idea that learning was fundamentally a social process and that knowledge resided in 'communities of practice'.[16]

Research has shown that high-level competences can be gained surprisingly fast when people participate in Internet developer communities (Tuomi, 2001; 2002). For example, open source software communities have allowed relatively inexperienced software programmers to rapidly become globally leading gurus in sophisticated software architectures. Learning in these communities has often been based on informal observation and interaction with peers. Moreover, learning and competence development in Internet developer communities typically occur across distance.

Internet aficionados and developers were the early entrants to this new mode of competence development. In recent years, the model has, however, spread widely. Communities that focus on specific interests and practices are now a major source of knowledge and learning in many different domains.

Informal social learning has always been an important source of skills and knowledge. New information and communication technologies, however, make it much more effective and visible. Informal learning in communities of interest and practice is typically problem- and practice-oriented. It is driven by learners' motives and effectively uses their contextual and situational knowledge. New knowledge, thus, becomes naturally linked to what is already known, resulting in rapid accumulation of knowledge and skills. As the Internet often makes the learning process visible, the benefits of social learning accumulate fast.

The 'virtual' community also provides support in an extraordinarily effective way. As more experienced peers typically are people who have recently been in the learner's position, they can easily adjust their support so that it matches the learner's requirements. In Vygotsky's terms, the peers are optimal guides through the zone of proximal development. Furthermore, as the peers typically best support those learners who show a genuine intent of learning, the learners have to put substantial effort in the learning process if they want to advance in the community. In such communities, active learners can flexibly mobilise substantial amounts of social capital to speed up their competence development. As the community recruits more novices and as they become old-timers and gurus, the total accumulated learning capacity of the community increases. Informal communities of learning can therefore produce a learning dynamic that, in economic terms, has positive returns. The community may become a 'common pool' learning resource that, in contrast to traditional economic resources, increases its value the more it is used.[17]

Many economically important competences are relatively short-lived in the innovation-based economy. Effective learning, therefore, requires flexible competence development models. Self-organised informal learning can, in this regard, easily fulfil the demand. Formal education, in contrast, tends to have much slower response time.[18]

Thesis 10: Educational Programmes Become Integrated with Real Social Change

A constant challenge for educational theory has been the missing link between school learning and cognition outside the school. Lauren Resnick highlighted this point in her 1987 Presidential Address to the American Educational Research Association:

> There is growing evidence, then, that not only may schooling not contribute in a direct and obvious way to performance outside school, but also that knowledge acquired outside school is not always used to support in-school learning. Schooling is coming to look increasingly isolated from the rest of what we do. (Resnick, 1987: 15)

Engeström (1996) reviewed the subsequent debate and proposed a model where learning activity was integrated with transformation of social practices outside the school. He argued that eventually the school institution had to be turned into a collective instrument for teams of students, teachers, and people living in the community. The objective of learning is not to learn for the school but to learn for life, and learning in real life means change in the practices of the community.[19] Engeström's 'expansive learning' model is one of innovative learning and is compatible with the downstream innovation model. It does not stop at individual development or change. Instead, it expands beyond current social reality, potentially transforming it. This model, therefore, builds an interesting link between discussions on innovation economy, knowledge society and the processes of learning.

In the innovation economy, an important generic capability is the capability to change social and economic realities. In the future, people will therefore need to learn how to change the world and how to mobilise social resources. In the innovation economy, the demand for capabilities to initiate and manage social change increases, and new information and communication technologies make new forms of social change possible. As people increasingly learn skills and knowledge outside formal education, it also becomes increasingly useful to integrate in learning the knowledge that people have learned outside formal education. In the future, social, economic and technical change will thus create pressures that will reverse the trend that was highlighted by Resnick.

Conclusion

A challenge to Luhmann's theory is that its abstractions are so strong that they purify the theory from all material, historical, and practical impurities, at the same time making it difficult to apply the theory in real contexts. In principle, it can suggest an answer to the question why educational systems exist as differentiated systems in a modern society; it cannot, however, say much about what people do in these systems.

In a somewhat similar way, economic theories that highlight changes in production paradigms may point to innovation as the new source of economic value. They can also explain how the needs for vocational education change as a result of new global production logics. Yet, to fully understand the nature of this change and its implications, we need to understand the processes that will underlie innovation and value creation in the future. Here, the new innovation models that focus on social learning and knowledge creation provide useful new insights.

When emerging technical opportunities are taken into use, social practices and society itself change. Since Schumpeter (1975), historians of economy and technology have argued that economic and social development are not driven by new technologies as much as they are constrained by the capability of social institutions to change. In the new innovation model, the benefits of new technological opportunities become real only when the society adapts its practices so that the new technology can be used in beneficial ways. This means that the wealth-creating potential of a new key technology is only achieved when social institutions change. New production paradigms do not emerge simply because new technologies become available. Instead, the dynamics of development are strongly constrained by the speed at which social institutions change. In the global innovation economy, the speed of change can become an absolute competitive advantage in itself.

Social institutions include elements such as legal, political, economic, and educational systems, as well as practices for organising work and production. The availability of steam engines, railways, electric power lines, or telephone networks does not, in itself, dictate a specific world order. Social practices and technical systems co-evolve so that new technical opportunities are gradually taken into use in society.

The potential of new key technologies are widely perceived already when key technologies are new. Yet, although the technology and its potential are there in a latent form, the social and institutional conditions are not. The requirements of the earlier paradigm are deeply ingrained in social institutions, including laws that regulate work, managerial practices, and educational systems that produce and qualify skilled workers.

This is the situation in which many developed countries find themselves today. An indication of the emergence of the Knowledge Society and its associated new paradigms of production is the fact that statistically visible social categories of the Industrial Age start to have little descriptive value. Competitive business organisations are now experimenting with radically new forms of organising and managing production. They are also trying to find new sources of economic value. The innovation models that underlie the emerging innovation-based economy are themselves changing, and an increasing amount of innovative activity is now focused on configuring existing knowledge and technologies in new economically useful ways.

The evolution of educational systems and practices, of course, depends on many factors that have not been discussed above. Possible futures, however, are not random. The potential paths for development are constrained by social and economic demand and technical opportunities. We do not necessarily have to imagine a non-existent future to outline probable developments. Instead, we can simply take the current situation and try to see how it unfolds when no unexpected or unpredictable events intervene. As was pointed out above, in the future, learning will be increasingly social and about changing the world. If we learn that some of the discussed developments are not what we want, we can also change the future.

NOTES

1. Luhmann's view of education is highly abstract and 'systemic'. It may appear to contrast with humanistic views that emphasise individual development. Implicitly, a related view is adopted by educational planners who try to match future job market requirements with educational curricula. The level of contrast also depends on how concepts such as individuality and development are understood. For example, the Confucian Daxue emphasised self-development that had its source in right knowledge, verified opinions, and the cultivation of persons. The ultimate goal of all education is illumination and shining virtue. According to Confucian thinkers, this, however, requires an orderly state. Harmony requires cultivated persons, who become cultivated when their minds are rectified by verified and researched opinions. Education, thus, leads to an orderly state, where cultivated people can take their proper positions in society.
2. For a discussion, see Webster (1995, Ch. 4).
3. Instead of asking whether a candidate for a job has a formal educational status, a potential employer can now review his track record, blog postings, and possibly e-portfolios.

4. A large variety of technologies is used today for dynamic analyses of information. These include software systems for data mining, online analytical processing, statistical clustering, rule-based decision support systems, and social network analysis, amongst others.
5. This will lead to the classical question whether it is possible to teach values (see Tuomi, 2005, pp. 50–55). In the global multicultural world, this question is both important and non-trivial.
6. The implicit theory of organising is reflected, for example, in the idea that corporations have 'headquarters'. The assumption of limited communication capabilities of firms also underlies the information processing view of multinational organisations (e.g. Egelhoff, 1988; Tushman & Nadler, 1978).
7. Since the mid-1990s, the knowledge-based view on firms has been increasingly dominant, leading to extensive research on organisational learning, knowledge management, and organisational sensemaking. See, e.g. Brown & Duguid (1991), Hedlund (1994), Grant (1996), Nonaka (1994), Quinn (1992), and Weick (1995).
8. This nomenclature, of course, is somewhat arbitrary. One could, for example, argue that the jet aeroplane created a qualitatively different second phase of globalisation and the multinational organisational form. For the present purposes, I simply distinguish the 'classical globalisation', the 'informational globalisation', the third globalisation, based on a 'real-time virtual service configuration model'. Zysman (2006) calls the underlying transformation in service production 'the Algorithmic Revolution'.
9. The classical theory of international trade was based on David Ricardo's idea of comparative advantage, where each region can benefit by specialising in those types of production where it has relative advantages. According to Ricardo, although it is cheaper to produce both wine and cloth in Portugal than in England, international free trade makes it still beneficial for Portugal to focus on producing wine and selling it to England to buy cloth manufactured in England. The relative advantage of producing wine in Portugal, compared with England, allows Portugal to use its resources to produce large enough amounts of wine so that it can buy more cloth from England than it would be able to make on its own. Both countries, therefore, end up better off by trading goods where they have relative advantages.
10. This view is different from, for example, Chesbrough's model, which has a corporate-centric view on innovation and product development. Chesbrough (2003) popularised the term 'open innovation' to argue that companies need to import and export knowledge through their organisational boundaries. As the empirical focus in my studies was on the historical evolution of Internet-related innovations, such as computer networks, the World Wide Web, and the Linux open source operating system, my theoretical models emphasised social dynamics and sensemaking rather than corporate strategies.
11. These conflicting aims of education have been discussed in detail by Jarvis (1992). Well-known critical pedagogies include, for example, Freire (1972).
12. Earlier versions of these theses were presented at the Joint DG JRC-DG EAC Workshop on "The Future of ICT and Learning in the Knowledge Society," 20–21 October 2005, and in "Innovations in Learning: The Present Future of Learning in the Knowledge Society," at the EU eLearning Conference, 4 July 2006.

13. For a definition of open educational resources, see Tuomi, 2006.
14. Today, blogs are frequently used for such 'brand management'. They are also combined with social networking and profile management sites. At present, the most popular site is MySpace (www.myspace.com), which has over 150 million registered users. According to Alexa (www.alexa.com) traffic data, about 5% of Internet users used MySpace daily in February 2007. This translated roughly to 50 million users a day.
15. Vygotsky emphasised the importance of play for children. In the Knowledge Society, learning, however, does not end in adolescence. In play, things and actions stand for things and actions that they are not, thus allowing one to 'play with' potential realities and to detach oneself from the actual constraints or reality. It is in such 'zones of proximal reality' that learning and innovation occur.
16. Historically, the importance of social processes in learning has been one of the key starting points in cultural-historical and socio-cultural theories of learning (e.g. Vygotsky, 1986; Scribner, 1997; Rogoff, 1990). The first detailed study on the emergence of scientific communities and their knowledge is by Fleck (1979), who, in the 1930s, described the history of syphilis and the evolution of its treatments and diagnostic practices through the centuries. The importance of communities of practice has also been highlighted in technology studies (e.g. Constant, 1984), in cultural anthropology (e.g. Douglas, 1996), in linguistics (e.g. Bakhtin, 1987), and, more recently, in science studies (e.g. Knorr Cetina, 1999). For a review and discussion, see Tuomi (2002 Ch. 6).
17. I have previously called such resource pools 'fountains of goods' (Tuomi, 2005, p.444). Such pools are difficult to describe in economic terms, as, historically, the fundamental economic assumption has been that resources are scarce and can be depleted through use. In conventional economics, common-pool resources lead to the famous 'tragedy of commons', where shared resources become destroyed.
18. It would have been quite impossible for educational planners to respond to skill demand for Internet video production, for example, as this was an invisible niche application just two years ago. Today, there are roughly 60 million people producing and distributing Internet video clips using YouTube (www.youtube.com). Video production and distribution technologies are mainly learned through peer-learning and practical experimentation.
19. Strictly speaking, Engeström's theory of expansive learning refers to activity systems (cf. Engeström, 1987). The activity-theoretical concept of activity is related to social practices, but the concepts can also be interpreted in theoretically different ways.

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