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Semantic e-learning: synthesising fantasies

Miltiadis Lytras and Ambjörn Naeve

Miltiadis Lytras is the leader of the Association for Information Systems Special Interest Group on Semantic Web and Information Systems and the editor in chief of the International Journal of Knowledge and Learning. Email: mdl@aueb.gr. Ambjörn Naeve is the head of the Knowledge Management Research group at the Royal Institute of Technology in Stockholm, Sweden.

Abstract

When the subject of scientific analysis is learning, the research needs to be anchored in various nonmonolithic pillars. Several disciplines require a common ground of convergence. An objective observer of the domain can easily conclude that semantic e-learning brings together the three different worlds of learners, pedagogues and technologists.

In this short concluding paper of the special issue, we criticise the monolithic approaches to technology-enhanced learning. We argue that semantic e-learning presents a critical research challenge to move towards extended openness, meaning exploitation and unforeseen learning opportunities for the global community.

The concluding remark is a call for a new learning generation primer. Synthesizing fantasies is in fact an invitation to semantically define our commitment to collaborate and to agree on the technology-enabled services that bring learning to the forefront. The promotion of the knowledge-and-learning-society requires an integration of the demand and supply side of knowledge and learning.

The semantics of the word 'semantics' in 'semantic (e-) learning'

The concept of 'semantics' is not novel but very much present in the classic literature of philosophy, computer science, linguistics, information systems and artificial intelligence. Sheth, Ramakrishnan and Thomas (2005) provide an important summary and analysis of the meaning of the word 'semantics' within the context of scientific disciplines:

Semantics has been a part of several scientific disciplines, both in the realm of computer science and outside of it. Research areas such as Information Retrieval (IR), Information Extraction (IE), Computational Linguistics (CL), Knowledge Representation (KR) Artificial Intelligence (AI) and Data(base) Management (DB) have all addressed issues pertaining to semantics in their own

ways. Most of these areas have very different views of what 'meaning' is, and these views all build on some metatheoretical and epistemological assumptions. These different views imply very different views of cognition, of concepts and of meaning.

IR, IE and CL techniques primarily draw upon analysis of unstructured texts in addition to document repositories that have a loosely defined and less formal structure. In these sorts of data sources we are faced with *Implicit Semantics*.

In the fields of KR, AI and DB, however, the data representation takes a more formal and/or rigid form. Well-defined syntactic structures are used to represent information or knowledge, where these structures have definite semantic interpretations associated with them. There are also definite rules of syntax that govern the ways in which syntactic structures can be combined to represent the meaning of complex syntactic structures. In other words, techniques used in these fields rely on *Formal Semantics*.

Usually, efforts related to Formal Semantics have involved limiting expressiveness to allow for acceptable computational characteristics. Since most KR mechanisms and the Relational Data Model are based on set theory, the ability to represent and utilize knowledge that is imprecise, uncertain, partially true and approximate is lacking, at least in the base/standard models. However, there have been several efforts to extend the base models (eg, Barbara *et al* 1992). Representing and utilising these types of more powerful knowledge is, in our opinion, critical to the success of the Semantic Web. Soft computing has explored these types of powerful semantics. We deem these *Powerful (soft) Semantics* as distinguished, albeit not distinct, from Formal and Implicit semantics.

In our view, this is a powerful (semantic) model for the word 'semantics'. Within the knowledge and learning domains, these three types of semantics are especially important when the knowledge representation relates to behavioural and psychological characteristics. The key challenges to exploit learning content and to bring together learning networks require an extensive analysis, as well as modelling and contextualisation of the learning processes involved. It now seems that the relevant discussion in scientific terms has reached the required maturity to 'look behind the wall' of monolithic technological considerations and to tackle the softer and more implicit questions involved.

A provocative reflection on the evolution of the Semantic Web is that the Semantic Web vision is much too slow in becoming a reality. Hiding behind this simplistic position statement is a knowledge gap on the evolution of the Semantic Web. Our active involvement with the Association for Information Systems Special Interest Group on Semantic Web and Information Systems (AIS SIGSEMIS) and the sponsorship of the International Journal on Semantic Web and Information Systems constitute a community contribution. In the next section, we summarise the state-of-the-art of the Semantic Web and identify the converging fields that constitute the semantic learning domain.

Semantic Web at a glance

Sure and Studer (2005) have presented an excellent overview of the current evolution of the Semantic Web. The vision of Berners-Lee—as presented in the classic paper of the Scientific American (Berners-Lee, Hendler & Lassila, 2001)—presents many challenges and requires a multifold approach, both technically and managerially (Figure 1).

On top of the core standards for extensible markup language and resource description framework, in 2004 the World Wide Web Consortium Web Ontology (WebOnt) working group (http://www.w3.org/2001/sw/WebOnt) has released the Web ontology language standard (http://www.w3.org/TR/owl-ref). Moreover, Corcho and Gomez-Perez (2005) elaborate on the key theme of ontology translation systems, while Cristani and Cuel (2005) discuss ontology creation methodologies. Ontologies for everything seem to be the new buzzword of our decade. However, this ontology mania requires a community consensus and agreement. In a recent interview with Tom Gruber for *AIS SIGSEMIS Bulletin*—(Gruber, 2004)—he emphasises that 'Every ontology is a treaty—a social agreement—among people with some common motive in sharing.' This social agreement between the people on the learning domain is maybe the most challenging aspect of the current evolution of the Semantic Web for learning. In our view, this has to be achieved in a bottom-up way, eg, by using the conceptual calibration technique described in Naeve (2005).

Moreover, much work remains to be done for the logic, proof and trust layers. In this direction, Bry *et al* (2005) discuss in detail the critical need to reconsider the design of querying on the Web. The traditional approaches in locating and exploiting web resources and content for learning purposes require reconsiderations. We can provide

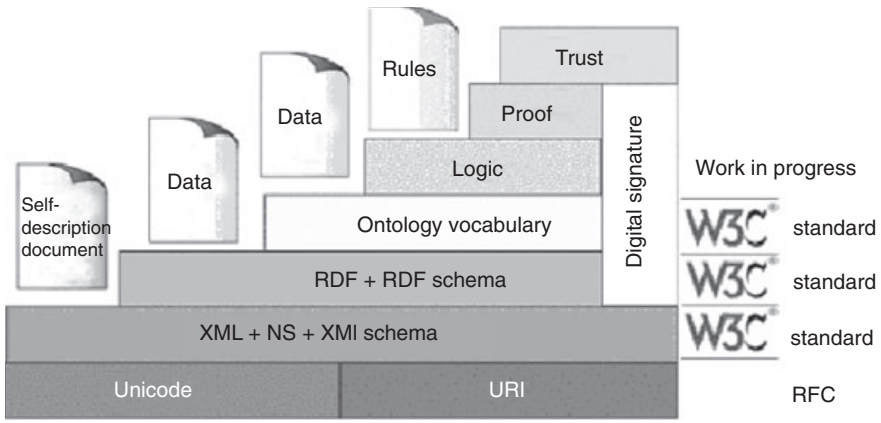

Figure 1: Semantic Web at a glance
Source: Sure and Studer (2005).
RDF, resource description framework; XML, extensible markup language; W3C, World Wide Web Consortium; URI, Uniform Resource Identifier; RFC, Request for Comments; NS, Namespace Specification

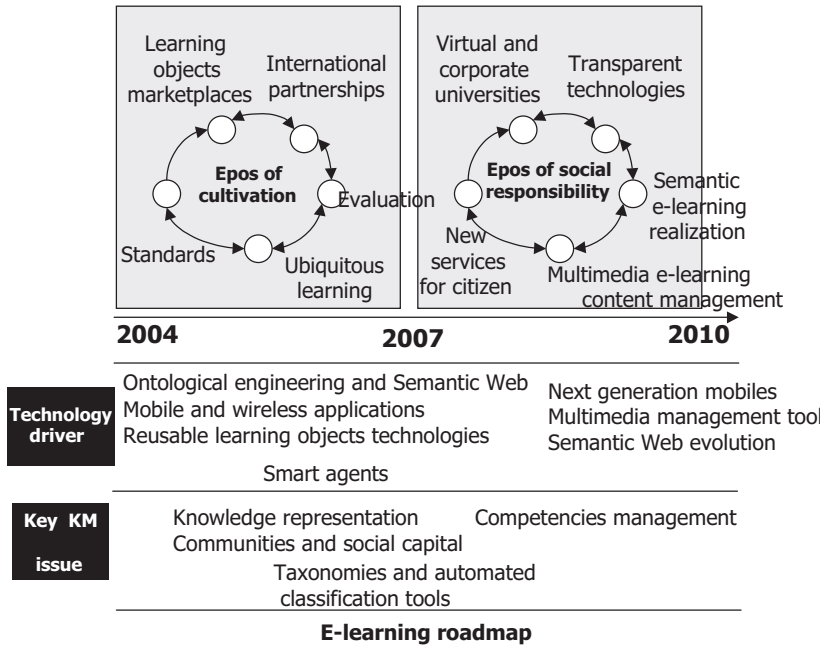

Figure 2: e-Learning roadmap: 2004–10
Source: Lytras, Naeve & Pouloudi (2005b).
KM, knowledge management.

several scenarios where learning content diffusion require multiple views of the same content as well as multichannel delivery. The knowledge manifold architecture proposed by Naeve (2001a,b) formulated as a 'conceptual web' in Naeve, Nilsson and Palmér (2001) and implemented in the Conzilla tool (Palmér and Naeve, 2005) provides a step in this direction. From this perspective, it seems that we are moving towards a context-based paradigm, away from the 'interoperability nightmares' of our days. Dolog, Henze, Nejdl & Sintek (2004), Gasevic and Hatala (2005), Hadrich and Priebe (2005), as well as Aroyo *et al* (2006) promote the scientific debate on context-centric semantic learning.

In a recent special issue of the International Journal of Distance Educational Technologies (Lytras, Naeve & Pouloudi, 2005b), we have tried to summarise our key concerns for the evolution of the e-learning discipline from a knowledge management (KM) and Semantic Web perspective.

Figure 2 presents a roadmap for e-learning, where a number of critical milestones provide a significant path for the evolution of the discipline. Towards this direction, the Semantic Web is a critical enabler. The ongoing PROLEARN roadmapping initiative (Kamtsiou, Stergioulas & Koskinen, 2005) further elaborates on these issues.

Every layer of the 'semantic cake' is full of challenging and open issues. The various competence and research centre on Semantic Web work on several aspects of the Semantic Web agenda. We will not discuss this in detail in this section, but our AIS SIGSEMIS (http://www.sigsemis.org) is a good reference point for knowledge related to the evolution of the Semantic Web. We also encourage you to download (for free) the recently published *Semantic Web Fact Book* from our portal, covering much of the fascinating Semantic Web research that is going on today.

Technologists and pedagogues, but where are the users—and where is the semantics?
Having introduced our 'semantic' point of view on semantic e-learning—as well as the key research streams of the Semantic Web community, we carry on our provocative discussion by elaborating on a key question: How can we bring together pedagogues, technologists and learners in order to exploit the semantically enriched learning content in the best possible way?

Lytras, Pouloudi and Poulymenakou (2002b) analyses the unified process of learning content development. In general—as shown in Figure 3—three key activities take place within this context. First, a general KM life cycle results in a collection of knowledge objects. Then, a learning exploitation (enrichment) process adds 'semantic elements' to these knowledge objects—turning them into learning objects. Finally, there is a need

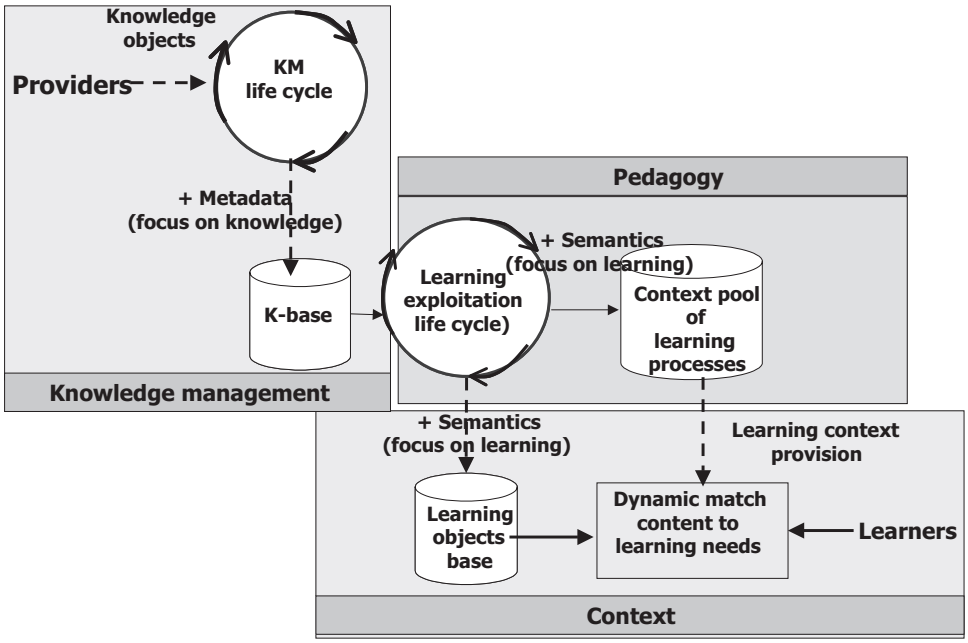

Figure 3: Content + context + pedagogy + community
Adopted from Lytras, Pouloudi and Poulymenakou (2002b).
KM, knowledge management; K-base, knowledge base.

for a dynamic matching process, which connects these learning objects to personalised learning needs. This question will be researched within a recently approved EU project called LUISA, which will use Semantic Web services to try to effectively achieve this type of matching.

A review of the relevant literature concerning semantic e-learning gives rise to many interesting conclusions. Maybe the most interesting one is the inability of learning objects standards and recent learning design approaches to effectively manage the requirements for 'active pedagogy in learning contexts'. A huge industry and billions of dollars have been invested, but still the question is not answered: Does e-learning promote effective learning? Can you prove it?

In trying to answer this question, a lot of effort has been invested in the modelling of the learning process with a parallel intensive analysis of the content requirements. However, this 'context versus content rivalry' seems to miss a key critical factor for the effectiveness of technology-enhanced learning. Learning is a unique experience for learners. So, if we make general hypotheses about the learners' readiness to learn, then we in fact decontextualise the problem from its key ingredient: the individual learning needs. Personalised and adaptive learning that takes into account such individual learning needs is a very difficult but important issue that is being addressed, eg, within the PROLEARN network of excellence (www.prolearn-project.org).

The content–context–pedagogy–community approach and the proposition for the semantics of learning do not constitute a panacea. However, they provide an interesting set of principles that must be considered when we go beyond local implementations. For example, the obvious question of where we can find the semantics or who can contribute the semantics for the learning content needs extensive analysis. If we analyse the requirements on semantics—as shown in Figure 4—then, in each of the three layers of the semantic enrichment, we will face a complex set of requirements, where the semantics are not taken for granted.

Moreover, the semantics for learning are the same as the semantics for content in general. If we build our community commitment on the previous simple principle, then the puzzle of semantic e-learning would require a return to the basics of learning: learners are the ultimate evaluators of the semantics that (semi-) automated leading-edge approaches have created for them. And furthermore, experience publication networks—as described in Naeve (2005) and Naeve, Nilsson, Palmér and Paulsson (2005) and further discussed subsequently—can cultivate the quality of learning on top of pools of dispersed learning content.

Maybe this is the key issue for the promotion of semantic (e-) learning: to build collaborations that exploit local contributions within a global vision. Here, open-source approaches provide new opportunities for bridging value-added initiatives of various aspects of semantic learning. Without such integration and joint efforts, the potential of semantic e-learning will not be effectively realised.

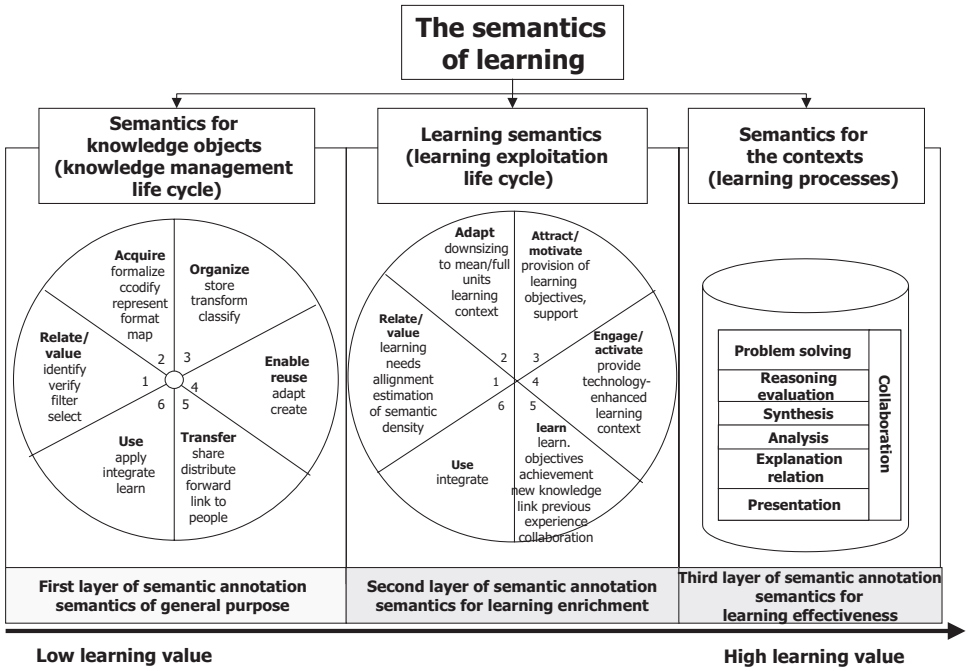

Figure 4: The semantics of learning
Adopted from Lytras, Pouloudi and Poulymenakou (2002a).

The open research agenda of semantic (e-) learning

Over the last few years, Semantic Web approaches to e-learning have emerged as a new value proposition (Sampson, Lytras, Wagner & Diaz, 2004). A rapidly growing research community is conducting research, experimenting and exploiting the developments of the Semantic Web. Although this research is producing important results, several open questions remain from a semantics perspective of the learning domain:

- Which are the implicit, formal and powerful semantics of the learning domain?
- How do we apply automatic and semi-automatic methods to enrich content with the required semantics in order to expand the learning potential of dispersed content?
- How can we embed pedagogical strategies into formalisations through semantics?
- How can the metadata imperative of learning objects and learning designs be transformed into semantic-enabled multicontext approaches?
- Which are the tools that bring new insights and delivery methods for learning content from a Semantic Web perspective? In other words, how can the tricky words and lofty visions of 'adaptability', 'interoperability' and 'personalisation' be realised through applied technologies?
- How do we convince learners, teachers and other nontechnocratic communities of the usefulness of the new generation of learning tools?
- What is the life cycle of learning content, and how do we integrate its supply and demand perspectives?

- How can intelligent agents and knowledge/learning portals exploit the Semantic Web capabilities towards a better match of learning needs and learning resources?
- How can we apply rules and logic at an upper layer of learning content in order to diversify the underlying logic of content exploitation?
- And the most important question of all: How do we apply leading-edge learning research in our daily learning life?

The emerging semantic learning research agenda requires a number of ontological agreements for the learning domain. This step is critical in order to exploit the synergies of the various scientific communities involved. In our humble opinion, there is a significant knowledge gap in understanding how technology-orientated researchers can expand the value contribution of pedagogues. The bridging of these two worlds requires open standards and community-aware campaigns for the specification of requirements.

Another critical objective for the semantic learning research community is to provide transparent tools and services for the citizens/learners at every level of formal and informal education for diverse kinds of scenarios (Sicilia & Lytras, 2005). This transparency is critical in order to overcome the knowledge deficit of the mediators, ie, the teachers, in using emerging technologies. Several times we take for granted that the high-level research propositions that are transformed to advanced frameworks and tools are also usable by the average learner. But this is definitely wrong. So the relevant debate on how to promote technology-enhanced learning in the context of everyday use—and not only in experiments or lab assignments—requires down-to-earth practices. If we evaluate the 'learning objects era' of the current decade from a teacher's perspective, then the outcomes are rather disappointing. We have developed theories, standards and guidelines, but unfortunately, we have not brought learning objects in touch with the everyday learning community. If you ask or explain what a learning object is about to teachers in primary schools or in secondary education, then the average reaction is unexpected.

So this is what Semantic e-learning is all about: to provide a transparent upper layer for the educational domain, which focuses on the learner, aiming to use learning needs and personal characteristics as input to the manipulating mechanisms of content distribution. Naeve (2005) provides a memorandum on the need to further promote the vision of a human Semantic Web. The strict emphasis on justifying and promoting the Semantic Web as a machine-understandable data primer requires reconsideration because if we rely on this perspective alone, we would loose the high-level conceptual aspects that are characteristic of human-to-human interaction the social agreement part of establishing an ontology, which is emphasized by Tom Gruber (2004).

Apparently, such ontological agreements cannot be easily achieved on the spot, but they require a systematic interchange of ideas and demonstrations of how technology activates pedagogy. Moreover, it is our opinion that this cannot be achieved in a top-down

manner that forces us to reach a consensus, but instead requires a bottom-up approach, such as the conceptual calibration process described in Naeve (2005), where we build ontological bridges between different perspectives by (1) agreeing on what we agree on, (2) agreeing on what we do not agree on and (3) documenting points 1 and 2 in a way that we agree on.

Moreover, we must see how the roles of teachers or academics are affected by the new requirements of semantic learning. Obviously, new emerging roles need to be addressed in a way that encourages open learning.

The pitfalls of semantic e-learning—what Semantic Web cannot do for learning

Today, the Internet is universally hailed for its fantastic possibilities to enhance learning. But there might be another side of this coin. We discuss here an extremely interesting presentation—called *ICT: The Way to Paradise or Hell?*—given at the Online Educa conference in Berlin in December 2005 by Roni Aviram and Nimrod Matan (2005) from the Centre for Futurism in Education at the Ben-Gurion University in Israel. According to these educational researchers, there is a need for formation of long-term strategies and policies towards the development of e-learning based on deep and wide analysis of the long-term impact of the Internet on users. If, as McLuhan (1964) claimed, 'the medium is the message', then we must take into account that the Internet is

- *defining*: It changes our nature, personality, cognition, sociability and even our most basic 'physiological' tendencies.
- *all-engulfing*: It relates to all areas of our lives and pertains to most of our waking time, either directly, when we spend time in front of the Internet, or indirectly, by changing or 'internalising' all aspects of our physical environment.
- *environment*: It creates (both directly and indirectly) the environment that we live and act in, and hence all our practices, and in this way, our very selves.

Moreover, according to Aviram and Matan (2005):

The Internet supports learning by supplying learners with

- easy accessibility of updated materials, other learners, experts, teachers;
- easy authoring of material;
- easy presentation and distribution of material;
- individuation and customisation of learning processes;
- the facilitation of changes in texts;
- the facilitation of graphic presentations, including 3D;
- the acceleration of feedback;
- the dramatic facilitation of saving, retraction, analysis, and annotation of first-level learning processes, and hence of reflection, or of second-level learning processes;
- the erosion of differences between process and product: the enhancement of a process-orientated approach.

On the other hand, the Internet threatens learning by

- threatening linearity, and hence logical thinking and rationality (= the desire and ability to learn);
- threatening literacy (in the traditional sense), and hence the ability for abstraction and rationality;
- threatening depth, and hence curiosity, wonder and rationality.

In our view, these potentially negative aspects of the Internet have been far too little discussed. As with all technological innovations, we tend to take them for granted and focus exclusively on their positive aspects. A prime example of this attitude is television, where a critical debate about its physiological effects on the viewers has been almost completely lacking. A notable exception is given by Mander (1978).

So, what can the Semantic Web not do for learning? In addition to the 'threatening propositions' of Aviram and Matan (2005) previously listed on the effects of the Internet in general, we claim that the Semantic Web cannot

- discourage knowledge emulation, which is a disease that seems to be spreading rapidly. In the emerging 'knowledge-emulation society', the important thing is not what you know, but what you can convince other people that you know.
- increase the motivation for deep and reflective learning. In the information-overloaded, efficiency-obsessed, cut-and-paste environment of today, it is becoming increasingly difficult to find the time (as well as the peace of mind) for the reflection and deep thinking that is crucial for the 'magic transmutation' of knowledge into understanding.
- substitute for our local networks and personal relations that are increasingly neglected as we spend more and more time within our web-based global networks. Today, it seems that we are 'connecting globally' and 'disconnecting locally'.

Synthesising fantasies/conclusions

On the first generation of the Internet (which still dominates today), the information is distributed, and anyone can link anything to anything. In fact, this is precisely what has made the Internet such a great success. However, the information about the information (the metadata) is still mostly centralised and resides in databases that are hidden behind portals.

The most important aspect of the Semantic Web is that it allows the information about the information to become as distributed as the information itself. This is possible because, on the Semantic Web, every piece of information has a unique identity, and therefore a machine can decide whether or not we are talking about the same thing—even though the machine will never understand what we are talking about. Hence, as described in Naeve (2005), the semantics of the expression 'Semantic Web' is rather misleading because it is not a 'meaningful Web' (for machines) but rather, an identity-resolvable web.

This fact has several fundamental consequences, some of which the Semantic Web allows a shift from 'knowledge push' to 'knowledge pull'. Within the field of learning, this enables a shift away from the traditional teacher-centric and curriculum-orientated course perspective towards a more learner-centric and interest-orientated approach.

As described in Naeve *et al* (2005) and in Nilsson, Palmér and Naeve (2002), metadata are not always objective but must also allow subjective expressions. Moreover, metadata are not produced once and for all, but are the results of an ongoing annotation process. Hence, on the Semantic Web, the distributed quality of metadata makes it possible for learners and teachers to express their experiences with different learning resources (learning objects) so that the user experiences with a certain learning object can be retrieved from the identity of the learning object itself. Such an 'experience publication network' represents extremely valuable user feedback because these experiences can be aggregated and systematised in a way that highlights quality. Such an experience publication network has been implemented in the *Confolio* (www.confolio.org), which is an electronic portfolio system developed under the coordination of the Knowledge Management Research group (http://kmr.nada.kth.se). Of course, this is useful in many other areas than just learning. In fact, it constitutes the essence of a new generation of customer relationship management systems. See Naeve (2005) and Naeve *et al* (2005) for a further discussion of this topic. In fact, from an evolutionary perspective, such feedback creates a selection pressure for quality, which lays the foundation for a global, collective production process of learning resources of successively increasing quality. In our opinion, creating such an ecosystem of quality is the most valuable contribution that the Semantic Web can provide for learning because it can provide enriched approaches to organisational learning and can effectively enhance the quality of the global, lifelong learning process.

References

Aroyo, L., Dolog, P., Houben, J., Kravcik, M., Naeve, A., Nilsson, M. *et al* (2006). Interoperability of adaptive learning components. In D. Olmedilla, B. Simon & N. Saito (Eds), *Interoperability of educational systems*, Special Issue of the *Educational Technology and Society Journal*, to be published in April 2006.

Aviram, R. & Matan, N. (2005). ICT: the way to paradise or hell? Presentation at the Online Educa conference in Berlin, December 2, 2005.

Barbará, D., Garcia-Molina, H. & Porter, D. (1992). The Management of Probabilistic Data, in IEEE Transactions on Knowledge and Data Engineering, *4*, 5(October 1992), 487–502.

Berners-Lee, T., Hendler, J. & Lassila, O. (2001). The Semantic Web, Scientific American, May 2001.

Bry, F., Koch, C., Furche, T., Schaffert, S., Badea, L. & Berger, S. (2005). Querying the Web reconsidered: design principles for versatile web query languages. *International Journal of Semantic Web and Information Systems*, *1*, 2, 1–21.

Corcho, O. & Gomez-Perez, A. (2005). A layered model for building ontology translation systems. *International Journal of Semantic Web and Information Systems*, *1*, 2, 22–48.

Cristani, M. & Cuel, R. (2005). A survey on ontology creation methodologies. *International Journal of Semantic Web and Information Systems*, *1*, 2, 49–69.

Dolog, P., Henze, N., Nejdl, W. & Sintek, M. (2004). The personal reader: personalizing and enriching learning resources using Semantic Web technologies. Technical report, Hannover, Germany: University of Hannover.

Gasevic, D. & Hatala, M. (2005). Searching context relevant learning resource using ontology mappings. In Proceedings of *SW-EL Workshop at the Third International Conference on Knowledge Capture (K-CAP05)*, Banff, Canada, pp. 45–52.

Gruber T. (2004). Every ontology is a treaty—a social agreement—amongst people with some common motive in sharing: an interview with Tom Gruber. *AIS SIGSEMIS Bulletin*, *1*, 3, 4–8. October.

Hadrich T & Priebe T, (2005). A context-based approach for supporting knowledge work with semantic portals. *International Journal of Semantic Web and Information Systems*, *1*, 3, 64–88.

Kamtsiou, V., Stergioulas, L. K. & Koskinen, T. (2005). *A roadmapping framework for technology-enhanced professional training. The proceedings of the 8th IFIP world conference on computers in education (WCCE 2005)*, Cape Town, South Africa, July 4–7, 2005 (pp. 157–166).

Lytras, M., Naeve, A. & Pouloudi, A. (2005). Knowledge management as a reference theory for e-learning: a conceptual and technological perspective. *International Journal of Distance Education Technologies*, *3*, 2, 66–73.

Lytras, M., Naeve, A. & Pouloudi, A. (2005b). A knowledge management roadmap for e-learning: the way ahead. *International Journal of Distance Education Technologies*, *3*, 2, 1–11.

Lytras, M., Pouloudi, N. & Poulymenakou, A. (2002a). Dynamic e-learning settings through advanced semantics. The value justification of a knowledge management oriented metadata schema. *International Journal on e-Learning*, *1*, 4, 49–61.

Lytras, M., Pouloudi, N. & Poulymenakou, A. (2002b). Knowledge management convergence: expanding learning frontiers. *Journal of Knowledge Management*, *6*, 1, 40–51.

Mander, J. (1978). Four arguments for the elimination of television, quill. New York, ISBN 0–688–03274–5.

McLuhan, M. (1964). Understanding Media: The Extensions of Man. Cambridge, MA: The MIT Press.

Naeve, A. (2001a). *The knowledge manifold—an educational architecture that supports inquiry-based customizable forms of e-learning. Proceedings of the Second European Web-based Learning Environments Conference*, Lund, Sweden, October 24–26, 2001 (pp. 200–212). http://kmr.nada.kth.se/papers/KnowledgeManifolds/KnowledgeManifold.pdf

Naeve, A. (2001b). *The concept browser—a new form of knowledge management tool. Proceedings of the Second European Web-Based Learning Environment Conference*, Lund, Sweden, Oct. 24–26, 2001 (pp. 151–161). http://kmr.nada.kth.se/papers/ConceptualBrowsing/ConceptBrowser.pdf.

Naeve, A. (2005). The human Semantic Web: shifting from knowledge push to knowledge pull. *International Journal of Semantic Web and Information Systems*, *1*, 3, 1–30. http://kmr.nada.kth.se/papers/SemanticWeb/HSW.pdf

Naeve, A., Nilsson, M. & Palmér, M. (2001). The conceptual Web—our research vision. *The proceedings of the First Semantic Web Working Symposium*, Stanford, Ju1y 2001. www.semanticweb.org/SWWS/programme/position/soi-nilsson.pdf

Naeve, A., Nilsson, M., Palmér, M. & Paulsson, F. (2005). Contributions to a public e-learning platform—infrastructure, architecture, frameworks and tools. *International Journal of Learning Technology*, *1*, 3, 352–381. http://kmr.nada.kth.se/papers/SemanticWeb/Contrib-to-PeLP.pdf

Nilsson, M., Palmér, M. & Naeve, A. (2002). *Semantic Web metadata for e-learning—some architectural guidelines. Proceedings of the 11th World Wide Web Conference, Hawaii, May 7–11, 2002*. http://kmr.nada.kth.se/papers/SemanticWeb/p744-nilsson.pdf

Palmér, M. & Naeve, A. (2005). *Conzilla—a conceptual interface to the Semantic Web*. Invited paper at the 13th International Conference on Conceptual Structures, Kassel, July 18–22, 2005. In Proceedings: F. Dau, M.-L. Mugnier & G. Stumme (Eds), *Conceptual structures: common semantics for sharing knowledge*. Springer Lecture Notes in Computer Science, ISBN 3–540–27783–8. http://kmr.nada.kth.se/papers/SemanticWeb/Conzilla.pdf

Sampson, D., Lytras, M., Wagner, G. & Diaz, P. (2004). Ontologies and the Semantic Web for e-learning. *IEEE LTTF Educational Technology and Society Journal*, *7*, 4, 26–28 (Guest Editorial).

Sheth, A., Ramakrishnan, C. & Thomas, C. (2005). Semantics for the Semantic Web: the implicit, the formal and the powerful. *International Journal on Semantic Web and Information Systems, 1*, 1, 1–18.
Sicilia, M. A. & Lytras, M. (2005). Scenario-oriented reusable learning object characterizations. *International Journal of Knowledge and Learning, 1*, 4, 332–341.
Sure, Y. & Studer, R. (2005). Semantic Web technologies for digital libraries. *Library Management Journal, Special Issue on Semantic Web, 26*, 4/5, 190–195.

Some relevant websites

SIGSEMIS: www.sigsemis.org
PROLEARN: www.prolearn-project.org
KALEIDOSCOPE: www.noe-kaleidoscope.org/pub
SAKAI: http://sakaiproject.org
KMR-group: http://kmr.nada.kth.se
Edutella: http://edutella.jxta.org
Conzilla: www.conzilla.org
Confolio: www.confolio.org
WSMO: www.wsmo.org
IMS-LD: http://www.imsglobal.org/learningdesign/index.cfm
e-Europe: http://europa.eu.int/information_society/eeurope/2005/text_en.htm