

Knowledge Practices, Epistemic Technologies, and Pragmatic Web

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Abstract: The purpose of the present article is to examine the implications of the pragmatic web for the research and development of educational technology. It is argued that, beyond knowledge acquisition and social participation, technology-mediated learning environments based on a semantic and pragmatic web have the potential for facilitating creation and advancement of knowledge. In order to capitalize on the increased information and social connectivity of the novel ICTs, it is essential to develop adaptive informatics that co-evolves with knowledge-laden social practices. The present arguments are grounded on a vision of “Metaweb” which is elaborated further from the perspective of social practice. Implications of the position presented concerning the research and development of technology-mediated learning environments are discussed.

Keywords: epistemic technology, knowledge practices, learning, dialogical inquiry, social media

Categories: L.1.4, L.2.3, L.3.0, L.3.6., L.6.2

1 Introduction

The purpose of the present article is to examine the implications of the pragmatic web for computer-supported collaborative learning (CSCL). The present theoretically oriented elaborations emerged in the context of the Knowledge-Practices Laboratory (www.kp-lab.org); 22 organizations from 15 European countries take part in this integrated EC project focused on developing semantic-web- based technologies for supporting knowledge-creating learning in higher education and workplaces. While the semantic web has been the general foundation of the project, KP-Lab undertaking also have practice-based emphases extending mere semantic considerations and highlight the importance of examining the boundaries of the semantic and pragmatic webs.

In the background of the project are three metaphors of learning, i.e., the knowledge acquisition metaphor, the participation metaphor, and the knowledge-creation metaphor [compare Sfard, 98; Lave, 91, Figure 1]. The acquisition perspective examines knowledge as a characteristic of an individual mind and

considers an individual as the basic unit of knowing and learning. This cognitive view of learning relies on an assumption that the mind is a container of knowledge and learning is a process that fills the container, implanting knowledge there [Bereiter, 02]. An alternative approach is the participation metaphor of learning, according to which learning is an interactive process of participating in cultural practices and shared learning activities that structure and shape cognitive activity in many ways. Accordingly, learning is seen as a process of growing up and socializing to a community and acquiring the skills to communicate and act according to its socially negotiated norms. The situated nature of human knowledge and cognition is emphasized and examined social appropriation of community knowledge and adaptation to existing cultural practices.

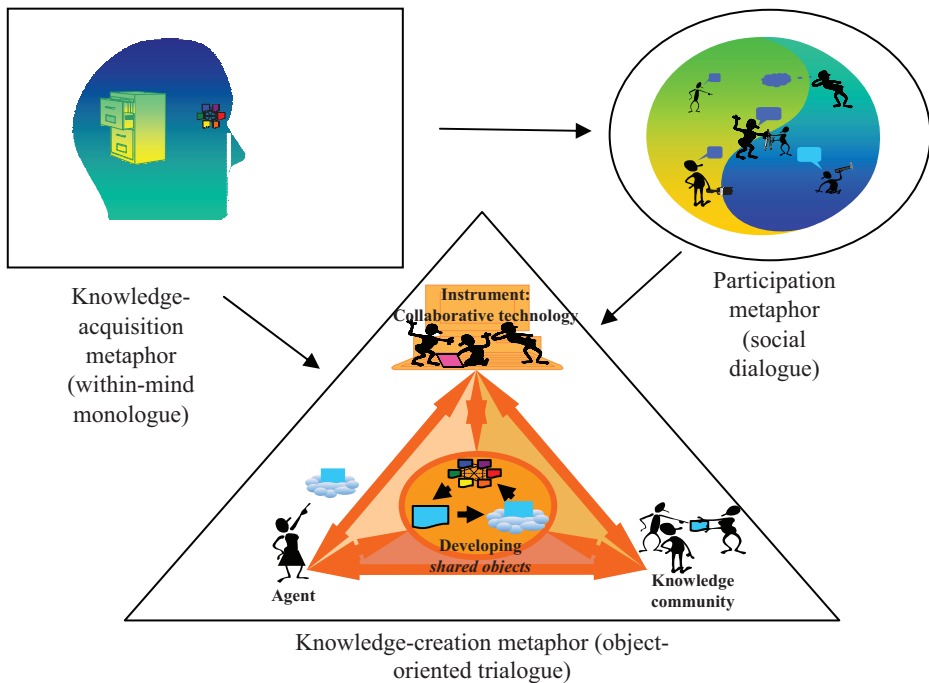


Figure 1: Three metaphors of learning

The division of two basic metaphors of learning is very fundamental. Neither of the above metaphors appears, however, to be sufficient when addressing processes of deliberately creating and advancing knowledge characteristic of an advanced knowledge society. The acquisition approach and the participation approach can both be developed so that they take innovative aspects into account, but this is not where these approaches appear to be at their best [Paavola, 04].

In order to overcome the dichotomy between the acquisition and participation metaphors, the present authors have proposed a third, knowledge-creation metaphor of learning [Paavola, 05; Hakkarainen, 04] drawing upon Yrjö Engeström's [87] expansive learning theory based on the cultural-historical activity theory, and Carl

Bereiter's [02] knowledge-building theory. Within this framework, learning is understood as a process of innovative inquiry aimed at the progressive advancement of knowledge and deliberate transformation of social practices [Paavola, 04]. If the acquisition metaphor represents a "monological" (within-mind) and the participation metaphor a "dialogical" (interactive) view of learning, the knowledge-creation metaphor is "trialogical" because of its emphasis on transformative learning mediated by cultural artefacts and communities of people. Transformative learning radically broadens the shared objects by means of explicitly objectified and articulated novel tools, models, and concepts. It is characteristic of this kind of knowledge advancement that it takes place within epistemic communities rather than only within individuals (although individuals with heterogeneously distributed competencies have an important role, supported by cultural knowledge resources). Developing an object-centered view of human activity, characteristic of the trialogical approach, is a significant trend from philosophy [Davidson, 01; Clark, 03; Skagestad, 93; Sterelny, 04] to post-human social studies of science [Latour, 05; Knorr-Cetina, 99] and from organizational research [Engeström & Blackler, 2005; Law & Singleton, 2006] to psychology [Donald, 91; Gruber, 81; Hakkarainen, Lonka & Paavola, 04].

The metaphors of learning are associated with corresponding forms of ICTs, the knowledge-creation approach capitalizing on collaborative technologies that support sustained efforts of knowledge advancement (Figure 2). The challenge of the KP-Lab project is to integrate efforts of technological partners oriented to designing the semantic web, pedagogical partners aiming to facilitating transformative learning, and users collaborating through novel ICT tools in higher education and work environments. Collaborative conceptual tools are needed for processes of multi-voiced negotiations on meanings. The present paper focuses on examining some concepts and theories that have functioned as KP-Lab's reflective tools for co-designing collaborative learning technologies at the intersection of the semantic and pragmatic web. One tool of theoretical communication used by the KP-Lab project is Nova Spivack's vision of Metaweb.

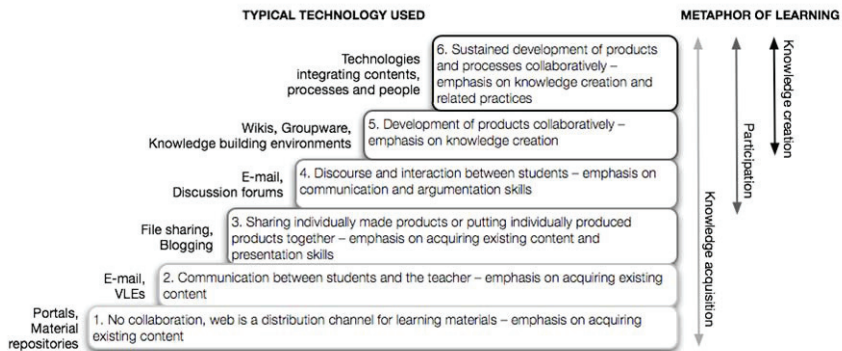


Figure 2: Epistemic technologies and metaphors of learning [Lakkala, in press]

2 From Metaweb representations to social practices

Nova Spivack has created a vision concerning Metaweb that arise from increased social (social software) and information connectivity (semantic web)¹. Rather than merely capitalizing on accumulating information resources or social interaction, the central characteristic of Metaweb is to provide tools and practices that amplify social-collaboratively intelligent human pursuits. According to Spivack the Metaweb vision begins from representations of individual and group knowledge to connecting them together into knowledge representation of the whole Web². Although Spivack's vision has gained much attention, there are certain shortcomings in the Metaweb that are familiar to semantic web technologies and visions in general. Ontology-based semantic information technologies are criticized to be hierarchical and authoritative [Pike, 07]. This is especially relevant when target is on systems that support knowledge work and knowledge creating tasks such as scientific exploration. Too strict and authoritative frameworks of knowledge (representations) cannot merge with demands of innovative knowledge work that is in need of constant re-evaluation and transformation of its concepts and practices. The issues of context and change are also noticed as relevant in future developments of semantic and pragmatic web technologies. Proposed developments in semantic services include pragmatic contextualization [Grobelnik et al, 08] and situated representations [Pike, 07]. It is suggested that ontologies should capture more specified domains of knowledge and integration of different domains should include integration of contextual information between contexts [Alani et al, 08].

Although sensitively developed Metaweb technologies can avoid some of the challenges and criticisms mentioned above, there are also other challenges taken up for the kinds of Semantic Social Software and Semantic Web technologies similar to the Metaweb [Schaffert, 08]. While the vision of Metaweb is very attractive, it appears essential to go beyond semantic-web based assumptions that privilege discursive (information exchange and social communication -related) processes and isolate information networks from social practices. In order to provide the collective intelligence with meaningful content, it should be embedded in the context of *social practices around shared objects and processes of technology use* rather than assumed to represent transcendental bodies of thought and ethereal interactions. From *syntax* (logical forms and symbolic structures) and *semantics* (meaning of symbols), the idea of the pragmatic web is to move toward *pragmatics* through addressing the contexts and practices of creating, using, and developing epistemic artifacts [de Moor, 02; Singh, 02]. This implies that users, their communities and network, as well as their evolving epistemic practices become essential in creating, interpreting, sharing, applying, and extending knowledge.

The notion of the pragmatic web guides one to consider Metaweb three-dimensionally in terms of social practices providing a topography or third dimension of the web's terrain. *Social practices* are assemblages of human activity that involve goal-directed sequences of actions using certain technology and rely on a socio-historically developed system of knowledge [Schatzki, 02; Scribner, 81]. By

¹ See http://novaspivack.typepad.com/nova_spivacks_weblog/2004/04%20new_version_of_.html.

² http://novaspivack.typepad.com/Minding_the_Planet_Article.pdf

knowledge practice [Hakkarainen, 09] the present investigators refer to personal and social practices related to working with knowledge; this should be interpreted broadly to involve pre-reflective implicit and tacit knowledge of expert work as well as shared routines and explicit procedures. Current theories of social practices highlight both the inseparability of knowing and doing and the creative and improvisational aspect of practice: "It is in practice, in fact, that knowledge comes to life, stays alive, and fades away. It is in practice that institutionalized, historically determined, and codified expertise acquires sense and becomes both a resource and a constraint for action" [Nicolini, Gherardi, & Yanow, 2004, p. 26]. Here the term "knowledge" is used in the broadest sense, to include explicit official discourses, implicit habits of expert working; and further yet to that which underlies the competencies of experts, for example, so called "procedural knowledge." Knowledge practices, while sometimes just supporting routine learning, at their creative edge take place in dynamic and fluid settings designed to further innovation and knowledge. Targeting emphasis on social practices, and especially on knowledge practices, pragmatic web can move beyond offering just affordances and environments for social connectivity and emerging social practices.

As we see it, a central characteristic of Metaweb is provide tools and practices, dynamic and fluid in nature, that enable epistemic communities and networks to engage in coordinated, deliberate, and sustained efforts of knowledge advancement. The knowledge-advancement process focuses on developing shared epistemic objects; these epistemic "things" (artifacts) are incomplete, knowledge-laden, yet materially embodied, objects that have a capacity, in principle endlessly, to open up novel lines of inquiry [Knorr-Cetina, 01]. Investigators of the pragmatic web highlight the importance of co-evolution between collective knowledge networks, epistemic technologies, and social practices [Buckingham Shum, 06; DeMoor, 02]. It appears to us that knowledge-centered practices rely on material agency, based on reciprocal tuning of social, technical, and material aspects of activity [Pickering, 95]; knowledge advancement would not be possible without such merging of technologies and practices.

An essential factor in pragmatics is context. When the semantic level is dealt with in a context-free manner, investigators tend to focus on prototypical meanings. Resulting models consist of a set of entities and relations connecting those entities. In their actual use at the pragmatic level, meanings are imprecise and changing, biased at any moment by the particular social and external context. The contextual process of meaning attribution is simultaneously both socio-cultural and cognitively subjective [Honkela et al., 2008]. While the semantic web has been preoccupied with standardization of knowledge and systems of knowledge based on ontologies determined mainly by experts beforehand, the envisioned pragmatic web is oriented toward adapting to the special needs of customers and user communities. Rather than simply assimilating to already existing knowledge ontologies, the vision is to engage user communities in active negotiation and interpretation of meaning and to the development of knowledge structures grounded on their evolving practices and epistemic pursuits [de Moor, 02]. Toward that end, pursuit of centralized solutions is giving way to the co-development of services based on customer-provider negotiations and mass customization and co-configuration of products through reliance on long-term customer relations. As we see it, a central aspect of the

emerging pragmatic web should be to put change, transformation, and creation of knowledge and associated practices into the centre. This implies, for instance, pursuit of directed, ontology evolution so as to assist and guide knowledge-creation efforts.

A potentially highly useful extension of Metaweb is the use of adaptive informatics to build on the communally created, often not mutually compatible resources. If the semantic web involves efforts of top-down knowledge structure and system design, adaptive informatics corresponds to self-organizing processes of technologies that dynamically adapt to evolving requirements of social practices. By utilizing methods and techniques such as the self-organizing map (SOM), automated learning algorithms for discovering and analyzing complex patterns have been developed to support unsupervised and continuous machine learning from large amounts of new data [Kohonen, 01; Honkela, 05]. The SOM is dynamic, associative and consists of elements that can be called adaptive prototypes. The adaptation process in the SOM is based on the principle that what already exists in the system also influences the learning result [Kohonen, 01]. This coincides with the principles of constructive learning, unlike most other computerized models of memory and learning [Honkela, 00]. The SOM approach has been applied for pursuing data-driven analyses of textual contents. By relying on other kinds of adaptive technologies, it is also possible to simulate social practices [Lindqvist, 07] as well as support co-configuration of relationships between producers and users (see <http://www.cis.hut.fi/research/cog/pracsim/>).

3 Knowledge practices in between Semantic and Pragmatic Web

In the context of the pragmatic web, creating, using, and developing knowledge rather than mere transmission of information or social exchange becomes the central concern. Thus far, discourses concerning the pragmatic web have, however, mainly addressed contextual aspects of using information by diverse communities of practice. Also highlighted have been various processes of negotiation of meaning which take place in the context of knowledge usage. Yet, the pragmatic web may elicit knowledge creation by 1) providing a technological infrastructure for augmenting the functioning of more or less distributed epistemic communities, 2) facilitating automated analysis and interpretation of large bodies of data generated by the users, and 3) adapting to and coevolving with human knowledge practices.

A foundational assumption of KP-Lab project has been that epistemic technologies become instruments of knowledge-creating learning only through transformed social practices [Hakkarainen, 06]. In order to facilitate expert-like practices of working creatively with knowledge in higher-education contexts, KP-Lab emphasizes courses where students solve complex problems for real customers coming from professional communities. Rather than eliciting inquiry learning within courses taking place at the prevailing institutional practices and pre-determined curricular boundaries, the project focuses on set-ups, arrangements, and patterns of interaction which elicit cross-fertilization of knowledge practices between educational and professional communities in close collaboration with professional communities. By breaking boundaries between communities, the participants may become reflectively aware of their own social practices.

The technologies and instruments supporting the kind of learning and knowledge creation described above require support to transform and reassess ways of representing and creating knowledge, i.e., support for cultivation of knowledge practices. While belief revision is easy, it is extremely hard for human being to transform their practices based on implicit and tacit knowledge and experience-based habitus. In order to overcome this limitation, the KP-Lab project aims at providing the participants tools for making visible, reflecting on, and deliberately transforming their knowledge practices. Examples of such tool-mediated transformation and cultivation processes of knowledge practices that have been explored and investigated in recent projects include *change-laboratory* methodology [Engeström, 96]. Change laboratory is an intervention method that involves sustained efforts in analyzing and transforming social practices. It comprises a series of workgroup meetings to reflect on current practices and envision future activities. Essential aspects of change laboratories are a) using videotaped practices as a “mirror” for assessing current activity, b) generating ideas and tools (e.g., charts) that help to assess past, present, and future activity, and c) modeling activity system embedded on present practices. Accordingly, the participants are guided to collect videotaped “mirror” material concerning practices of interest (either their own or those of a target community). Knowledge-Practices Environment (KPE) being developed involves Activity System Designer (ASD) tool that allows the participants to reflect, discuss, and annotate such video material, use activity-system triangles for modeling their activity, and envision and implement practical changes. Providing of participants tools and instruments that make them reflectively aware of various aspects of their activity and elicit transformations is a potentially significant aspect of pragmatic web. The proposed direction of development from Semantic web technologies and Metaweb to Pragmatic web is towards tools and systems that enable creation, maintenance, re-evaluation, and transformation of knowledge practices.

The KP-Lab project appears then to be in between semantic and pragmatic webs. Because the notion of pragmatic web had not yet gained momentum while the project was initiated, KP-Lab was framed around ideas and technologies emerging from the semantic web. Yet the very idea of “knowledge practice” interconnects KP-Lab with ideas and concerns of pragmatic web. While pursuing the project, it has been necessary to constantly renegotiate relations between semantic and pragmatic webs, for instance, in terms of highlighting users’ role of defining and transforming ontologies and formal models and using semantic services services (and not, for example, ontologies made by experts of the field). Due to KP-Lab’s position at the boundary between semantic and pragmatic web, it has sometimes been hard to introduce ideas concerning the project; it is much easier to talk about information than address practice-related issues. Overall, it appears essential to continue pursuing research and development of technology-mediated learning environments that focus on eliciting collaborative knowledge creation in parallel of addressing transformation of practice, essential from the perspective of the pragmatic web.

As Perez [2002] argued, however, technological and social innovations are interdependent. It appears that the technology as such does not determine the nature of its implementation but coevolves with gradually transforming institutional practices [Tuomi, 2002]. Our investigations, for more than a decade, indicate that meaningful technology-enhanced learning presupposes expansive learning

[Engeström, 87] processes in which novel technology-mediated practices of learning and instruction are iteratively developed. New technology-enhanced learning environments do not then automatically become instruments in teachers' and students' joint activities; transformation of their social practices is also called for. Such a developmental process involves adaptation and customization of the tool in parallel of cultivating social practices needed for its productive utilization. Before developing social practices in which the use of an instrument is embedded, all of its affordances cannot be productively utilized.

Only when ICT-based tools in general and collaborative technologies in particular have been fully merged or fused with social practices of participants, are their intellectual resources genuinely augmented and learning achievements correspondingly facilitated [Hakkarainen, 04]. Rather than addressing collaborative knowledge advancement efforts as its own sphere of activity, the present researchers understand it to be tightly coupled with evolving knowledge practices of the participants.

The KP-Lab concern is developing epistemic technologies that elicit deliberate collaborative knowledge creation. The project aims at conceptualizing a "triological" framework concerning pedagogical practices and models regarding computer-enhanced collaborative work around shared objects. The framework being developed is intended to be a 'boundary object' [Star, 89], to which various approaches can be compared regarding design of technologies for fostering shared efforts to create knowledge and transform practices. By developing and testing the knowledge-creating approach through a series of empirical studies, the KP-Lab project focuses on creating pedagogical models and guidelines for facilitating collaborative knowledge creation in polytechnics, universities, and professional communities. Neither students, teachers nor professionals should be considered as mere consumers of knowledge, but also as prospective creators of new knowledge and transformers of knowledge practices.

4 Conclusions

One of the initial ideas behind the emergence and development of the semantic web has been the ability to represent and process meaningful content, not just strings of characters. It is now widely recognized that such aspirations have certain practical limitations, such as the contextual dependence of meaning and other semantic features of entities used in representations. One proposal for overcoming this issue is negotiation about ontologies and user-driven generation and definition of concepts and meaning. In the Metaweb vision and in discussions of social semantic software, the kind of user-centered perspective comes to highlight social participation and creation of shared meaning. As noted above, these issues have arisen in discussions in the initial writings on the Pragmatic web [Singh, 02]. When users participate in defining and generating concepts, they can create user-centered and contextually sensitive semantics in epistemic technologies they use.

The implications of the pragmatic web for computer-supported collaborative learning proposed here are intended to reach beyond ontology negotiation and affordances for social collaboration. Focusing on practices, and especially on knowledge practices, pragmatic web technologies have possibilities that do not just

provide affordances for social cooperation, but create technologies that support creation and maintenance of practices of collaboration. The advancement of pragmatic web for CSCL should offer not only means for negotiating of meaning, but a way to facilitate sustained collaborative efforts to advance shared artefacts and elicit other social practices relevant for creating and advancing knowledge.

The background of KP-Lab and discussions of this paper, extending to more general aspects of pragmatic web, knowledge practices and CSCL, relies on the three metaphors of learning, i.e., three paradigmatic ways that knowledge is generated and learned. All of these three ways of learning are relevant and usually serve different roles and functions in learning processes, as it has been previously argued. The first metaphor, acquisition metaphor, is representative of ‘monological’ way of learning. From the perspective of CSCL and the discussions above, these kinds of learning processes certainly benefit from well-structured and meaningful representations of knowledge. Well-defined and general ontologies of semantic web technologies can provide means for learners to acquire knowledge, perhaps as means for further collaborative processes. Here the traditional semantic web idea is seen to be more in terms with the first metaphor of learning, and the emergence of social semantic software can be seen to promote learning processes belonging to the second, dialogical, participation metaphor. In social semantic software, such as semantic wiki’s, users can participate in social practices of learning. For example in semantic wiki’s users can participate in social processes of creating wiki’s by applying knowledge models provided by the system.

The third metaphor of learning promotes collaboration practices that differ in certain respects from modes of participation in social semantic software. The main idea in the ‘trialogical’ knowledge creation metaphor is that knowledge creation is an object-centered process that calls for sustained and iterative collaborative efforts. While individual agents may have a crucial role in such a process, their actions take place upon the fertile ground of collective activity. Similar processes may also be present at the case of social semantic software. Working collaboratively for creating semantic wiki’s is naturally an object-centered collaborative process in respect of wiki being the object of learning. The practice-based perspective adopted here promotes the enhancement of the ways these collaborative processes are implemented: In our view it is crucial how long-standing collaborative knowledge advancement efforts and associated processes of individual learning and transformation of social practices are supported.

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References

- [Alani, 08] Alani, H., Hall, W., O'Hara, K., Shadbolt, N., Chandler, P. and Szomszor, M.: Building a Pragmatic Semantic Web. *IEEE Intelligent Systems*, 23(3), 61-68.
- [Bereiter, 02] Bereiter, C.: *Education and Mind in the Knowledge Age*. Hillsdale, NJ: Erlbaum.
- [Buchingham Shum, 06] Buchingham Shum, S.: Sensemaking on the pragmatic web: A hypermedia discourse perspective. *Proc. PragWeb'06: 1st international conference on the Pragmatic Web*, Stuttgart, 21-23 Sept. Springer-Verlag: Berlin.
- [Clark, 03] Clark, A.: *Natural-born cyborgs: Minds, technologies, and the future of human intelligence*. Oxford, UK: Oxford University Press.
- [De Moor 02] De Moor, A., Keeler, M., & Richmond, G.: Toward a pragmatic web. In U. Priss, D. Corbett, & G. Angelova (Eds.). *ICCA 2002*, LNAI 2393, 235-249.
- [Davidson, 01] Davidson, D.: *Subjective, intersubjective, objective*. Oxford, UK: Clarendon Press.
- [Donald, 91] Donald, M.: *Origins of the modern mind: Three stages in the evolution of culture and cognition*. Cambridge, MA: Harvard University Press.
- [Engeström, 87] Engeström, Y.: *Learning by expanding*. Helsinki: Orienta-Konsultit.
- [Engeström, 05] Engeström, Y., & Blackler, F.: On the life of object. *Organization*, 12, 307-330.
- [Engeström, 96] Engeström, Y., Virkkunen, J., Helle, M., Pihlaja, J., & Poikela, R.: The Change Laboratory as a Tool for Transforming Work. *Lifelong Learning in Europe*, 2/1996. Pp. 10-17.
- [Grobelnik, 08] Grobelnik, M., Brank, J., Fortuna, B. & Mozetic, I.: Contextualizing Ontologies with OntoLight: A Pragmatic Approach. *Informatica* 32, 79-84.
- [Gruber, 81] Gruber, H.: *Darwin on man: A psychological study of scientific creativity*. 2nd ed. Chicago: The Chicago University Press.
- [Hakkarainen, 04] Hakkarainen, K., Palonen, T., Paavola, S. & Lehtinen, E.: *Networked expertise: Educational and professional perspectives*. Amsterdam: Elsevier.
- [Hakkarainen, 04] Hakkarainen, K., Lonka, K., & Paavola, S.: Networked intelligence: How Artifacts and Communities Expand Intellectual Resources. A paper presented at the Scandinavian Summer Cruise at the Baltic Sea (theme: Motivation, Learning and Knowledge Building in the 21st Century), June 18-21, 2004 (Organized by Karoliniska Institutet, EARLI SIG Higher Education, and IKIT). http://www.lime.ki.se/uploads/images/517/Hakkarainen_Lonka_Paavola.pdf
- [Hakkarainen, 06] Hakkarainen, K., Muukkonen, H., Markkanen, H., & the KP-Lab Research Community.: Design principles for the Knowledge-Practices Laboratory (KP-Lab) project. In S. Barab, K. Hay, & D. Hickey (Eds.) *Proceedings of the International Conference of the Learning Sciences 2006* (pp. 934-935). Mahwah, NJ: Erlbaum.

- [Hakkarainen, 09] Hakkarainen, K.: A knowledge-practice perspective on technology-mediated learning. *International Journal of Computer Supported Collaborative Learning*, 4, 213-231.
- [Honkela, 00] Honkela, T., Leinonen, T., Lonka, K. & Raike A.: Self-organizing maps and constructive learning. *Proceedings of ICEUT2000, International Conference on Educational Uses of Communication and Information Technologies* (pp. 339–343). IFIP
- [Honkela, 05] Honkela, T.: Von Foerster meets Kohonen - approaches to artificial intelligence, cognitive science and information systems development. *Kybernetes*, 31(1/2): 40–53, 2005.
- [Honkela, 08] Honkela, T., Könönen, V., Lindh-Knuutila, T. & Paukkeri, M.-S.: Simulating processes of concept formation and communication. *Journal of Economic Methodology*, 15(3): 245–259, 2008.
- [Knorr-Cetina, 01] Knorr-Cetina, K.: Objectual practices. In T. Schatzki, K. Knorr-Cetina, & E. Von Savigny (Eds.) *The practice turn in contemporary theory* (pp. 175-188). London: Routledge.
- [Kohonen, 01] Kohonen, T.: *Self-Organizing Maps*. Third, extended edition. Springer.
- [Lakkala, in press] Lakkala, M., Paavola, S., Kosonen, K., Muukkonen, H., Bauters, M., Markkanen, H.: Main functionalities of the Knowledge Practices Environment (KPE) affording knowledge creation practices in education. To appear in *Proceedings of the CSCL 2009 conference*, Rhodos, Greece, July 2009.
- [Latour, 05] Latour, B.: *Reassembling the social: An introduction to actor-network theory*. New York: Oxford University Press.
- [Lave, 91] Lave, J. & Wenger, E.: *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- [Law, 05] Law, J., & Singleton, V.: Object lessons. *Organization* 12, 331–355.
- [Lindqvist, 07] Lindqvist, L., Honkela, T., & Pantzar, M.: *Visualizing practice theory through a simulation model*. Helsinki University of Technology, Publication in Computer and Publication Science. Report E9 (available at: <http://www.cis.hut.fi/Publications/E9.pdf>).
- [Nicolini, 04] Nicolini, D., Gherardi, S., & Yanow, D.: Introduction: Toward a practice-based view of knowledge and learning in organization. In D. Nicolini, S. Gherardi, & D. Yanow (Eds.), *Knowing in organization: A practice-based approach* (pp. 3–31). London: M. E. Sharpe.
- [Paavola, 04] Paavola, S., Lipponen, L., & Hakkarainen, K.: Modeling innovative knowledge communities: A knowledge-creation approach to learning. *Review of Educational Research*, 74, 557-576.
- [Perez, 02] Perez, C.: *Technological revolution and financial capital: The dynamics of bubbles and golden age*. Cheltenham, UK: Edward Elgar.
- [Pickering, 95] Pickering, A.: *The mangle of practice: Time, agency, and science*. Chicago: The University of Chicago Press.
- [Pike, 07] Pike, W. & Gahegan, M.: Beyond Ontologies: Towards situated representations of scientific knowledge. *International Journal of Human-Computer Studies*, 65. 659-673.
- [Schaffert, 08] Schaffert, S.: Semantic Social Software: Semantically Enabled Social Software or Socially Enabled Semantic Web. In Resch, J. et al. (Eds.) *Emerging Technologies for Semantic Work Environments: Techniques, Methods, and Applications* (33-46). London: IGI Global.

- [Schatzki, 02] Schatzki, T.: *The site of the social: A philosophical account of the constitution of social life and change*. University Park, PA: Pennsylvania University Press.
- [Schoop, 06] Schoop, M., de Moor, A., & Dietz, J.: The pragmatic web: A manifesto. *Communications of ACM*, 49, 75-76.
- [Scribner, 81] Scribner, S., & Cole, M.: *The psychology of literacy*. Cambridge, MA: Harvard University Press.
- [Sfard, 98] Sfard, A.: On two metaphors for learning and the dangers of choosing just one. *Educational Researcher* 27(2), 4-13.
- [Singh, 02] Singh, M. P.: The pragmatic web: Preliminary thoughts. In *NSF-OntoWeb workshop on Database and Information Systems Research for Semantic Web and Enterprises*, 82-90.
- [Skagestad, 93] Skagestad, P.: Thinking with machines: Intelligence Augmentation, Evolutionary Epistemology, and Semiotic. *The Journal of Social and Evolutionary Systems*, 16(2), 157-180.
- [Sterelny, 04] Sterelny, K.: Externalism, epistemic artifacts, and the extended mind. In R. Schantz (Ed.), *The externalist challenge* (pp. 239-254). New York, NY: Walter de Gruyter.
- [Tuomi, 02] Tuomi, I.: *Networks of innovation: Change and meaning in the age of the Internet*. Oxford, UK: Oxford University Press.