

Complex Design Problems: An Impetus for Learning and Knotworking

Jonna Kangasoja

Center for Activity Theory and Developmental Work Research, Po Box 47, FIN-00014 University of Helsinki

Tel: +358-50-5274779, Fax: +358-9-1914844

Email: jonna.kangasoja@helsinki.fi

Abstract: The paper discusses learning as joint creation of new knowledge and new practices in settings in which very little is shared by the participants from the outset. The type of work, which spans across multi-organizational fields, and in which collaborations are problem oriented, improvised, and discontinuous in time, has been tentatively called *knotworking* because the collaboration seems to tie and untie knots between otherwise separate threads of activity (Engeström, Engeström & Vähäaho 1999). The paper highlights the dual nature of learning challenges involved in knotworking. On one hand, learning is related to the creation of new knowledge, or re-conceptualizations of the problem, allowing a construction of a partly shared object of work, and on the other, to creating new forms of collaborative practices among the stakeholders. The paper draws from findings of a research-in-progress on the design and construction of a broadband telecommunications infrastructure in the city of Helsinki, Finland. The paper discusses the instrumental and communicative aspects of joint activity by presenting an analysis of a strategy meeting between telecommunications firms and the public works department of the city.

Introduction

One of the challenges of contemporary learning research is to account for processes, which make it possible for people in their workplaces to continually cope with tasks that go beyond them as individuals, and even beyond the scope of expertise or responsibility of their organizations. This paper takes as a starting point the question of how we can understand and conceptualize learning in the context of ever more complex forms of collaborative work in multi-organizational settings. Organizational studies approach the question in the light of historical change in the modes of production and the emergence of flexible, interdependent, and distributed production networks. Victor and Boynton (1998) call the new production mode *co-configuration*. This mode is characterized by shifting from a particular instantiation of a product or service to adaptive, intelligent products that are the result of an interactive relationship, alliance or partnership between the user, different participants in the producer network and the product or service itself.

Co-configuration implies new forms of work and learning, and thus adds a new layer to the learning challenges of the contemporary work place. Engeström Yrjö, Engeström Ritva and Vähäaho Tarja (1999) introduced the concept of *knotworking* to depict the work type related to the rise of co-configuration. In knotworking *the center does not hold*, in other words the tying and dissolution of a knot from separate threads of activity is not reducible to any specific individual or fixed organizational entity as center of control or authority. The picture gets slightly more complicated when the problem is framed in disparate ways, and the preferred solution or outcome reflects the conflicting commitments and values of the participants. Gerhard Fisher (2001) calls heterogeneous design communities *communities of interest*, highlighting the fact that they bring together stakeholders from different communities of practice to solve a particular problem. Fisher discusses the nature of complex design problems in the context of negotiations around a public transportation system. He uses the notion of *symmetry of ignorance*, which means that no one stakeholder or stakeholder group, has all the relevant knowledge regarding the problem, but the knowledge of all stakeholders is equally crucial in satisfactory resolution.

Theorizing on learning as joint creation of new knowledge and new practices

Paavola & al. (2001) proposed adopting the metaphor of collective *knowledge creation* when examining developmental phenomena on the community level (1). They discuss three theories addressing explicitly the question of how new knowledge is created. These include the theory of knowledge creation by Nonaka and Takeuchi, the theory of expertise by Carl Bereiter and the theory of expansive learning by Yrjö Engeström (1987) building on the tradition of cultural-historical activity theory (Vygotsky 1978; Leont'ev 1978; see Engeström, Miettinen & Punamäki 1999 for a history of the tradition). The theory of expansive learning, as it is presented in

Engeström 1987, focuses on developmental transitions of local cultural practices, taking an *activity system* as the unit of analysis. Later Engeström (1999) proposed that the minimal unit of analysis should include at least two interacting activity systems in their network relations (2). Both the subjects and the objects are created in a co-constitutive process (following Marx's use of the category of "praxis"). Learning is a collective concept formation process rooted in the material practices of working collaboratively with tools and objects (3). Activity theoretical methodology is object driven, researchers follow the evolution and transformation of an object of collaborative work (4) (Engeström 1987; 1990).

Engeström uses Vygotsky's concept of *zone of proximal development* and drafts the dynamics of expansive learning by reworking the zone into a collective journey towards qualitatively new forms of practice. Contradictions are the driving force of development. They are manifest in the daily practices as breakdowns, tensions, ruptures and innovations. They call for re-working, both conceptually and very concretely, the objects and motives that sustain the activity, and for re-mediating the activity system by way of improving and inventing new tools. Notions of *disturbance*, *rupture*, *discoordination* and *unexpected event*, have been linked with expansive transitions (Engeström & al. 1991; Wehner, Clases & Bachmann 2000; Clases & Wehner 2002). However, the idea of disturbance assumes a script, whether consciously reflected or unconscious, whereas a script has little, or no meaning in settings where there are no established practices of collaborating. Innovation and the design of new technologies are typical examples of activities in which a previously non-existing object and a network which will sustain it are being formed simultaneously. Hasu (2001) and Miettinen (1998) suggest that we can gain understanding of the dynamical and developing nature of emerging networks of technology design, production and implementation by looking at the tensions and contradictions of each of the activity systems involved.

New telecommunications infrastructure as a complex design problem

The case example in the paper is a from the boarder zone between the public sector and commercial telecommunications services. The prolifically expanding fiber-optic networks play a crucial role in ICT business as a transmission medium and a product. From the public service perspective, the cable networks are an integral layer of the basic infrastructure of information society, which however, as a newcomer, overlaps and conflicts with existing public infrastructures, most notably the streets and other cable in the underground spaces. The *user* must in this case be understood also as a citizen and a taxpayer who uses and values both the commercial telecommunications services and the public infrastructure. The installing of the fiber-optic cables has become the crux of the tension between the management of the city of Helsinki and the telecommunications companies (TCs) (5). The tension is a fairly recent one, and results from the full scale restructuring of the telecommunications field after the national legislation started to reflect the European Union level de-regulation policies, in 1997.

Up until five years ago, the field was extremely stable, consisting of local cooperatives owned by the phone owners of the region. Each of these public tele-operators (PTTs) had a tele-operating monopoly for its area. In this short period, the field has turned into a multi-actor setting with fierce competition, and the Finnish markets have seen the appearance and the disappearance of several new international and a few domestic companies. Currently in the Helsinki region, there are approximately ten companies offering phone and internet-services, either delivered via their own cables, or by leased transmission capacity from another TC's network. The situation is problematic in areas of high demand, such as downtown Helsinki, where several parallel telecommunications networks have been constructed, each with the capacity to handle all of the demand. One street might be opened several times, when each of the competing TCs install their own networks without co-ordination between other the companies. This practice has crowded the underground structures, but more importantly, created costs and annoyance to the street users as stretches of streets have been opened for the installation works.

The *design problem* requiring learning and knotworking in the case example is to find a practical as well as principled solution on how the broadband telecommunications infrastructure should be brought about in the Helsinki metropolitan region. The complexity of the problem is magnified by the fact that the *society* has contradicting ways of defining costs, benefits and preferred outcomes regarding the matter. The national level de-regulation policy and the new legislation on telecommunications secure the TCs a right to install cable networks on public and private land. The idea is that open competition will create best outcome for the end users and thereafter societally. The regional concerns, however, are in sharp conflict with this policy. There is considerable frustration on the municipal level because unlike with other construction projects involving the use of public land and resources the municipalities have no legal control over the activities of the TCs. The situation was articulated by a representative of the Finnish association of the TCs like this:

“Telecommunication services have become *information society services*, and in that way they have stepped up a ladder in the hierarchy of social policy. The Finnish society, by its government, has already taken a stand, which is that we need these services. That means we need those cables underground. For the municipalities it is a question about the streets, for the telecommunication companies is a questions about their business. But it’s the same person who walks on the streets and uses telecommunications services. Costs and benefits cannot be looked from the perspective of one service only.”

What happens in a *knot*?

A meeting was called by the Public Works Department (PWD) in order to negotiate and discuss the future strategy openly with the representatives of different TCs. The meeting can be conceptualized as an instance of tying a knot between the stakeholders. The meeting took place on December 11, 2000 (6). The central themes discussed are indicated below in table 1.

Table 1. Central themes discussed in the meeting.

Theme 1: Problems of present practice	Theme 2: First proposed solution	Theme 3: Second proposed solution
<ul style="list-style-type: none"> -Articulations of the dissatisfaction of the city. -Open questioning of the viability and sensibility of the present network building practices. <p>Focus on:</p> <ul style="list-style-type: none"> -Scarcity of space -Opening of streets -Unnecessary overcapacity -Rising expenses of constructing and maintaining the networks. 	<ul style="list-style-type: none"> -Proposal that the TCs would start to lease capacity from a broadband network owned by the city and installed by the city’s energy company into a pilot area. -Example from Sweden. -TCs ask questions about technical details, prices and leasing terms and express concern for handing over responsibility of service delivery to a third party. 	<ul style="list-style-type: none"> -Proposal for a new model of coordination between the TCs and the public works department: -A shared cable channel, which would be constructed by the PWD simultaneously with new stretches of street in the area under construction to get the expenses down. -PWD asks questions regarding TCs’ needs in order to know what size the channel should be and how many tubes should be reserved.

Shared cable channels as an expansive solution and a re-conceptualization of the problem

One of the ruling themes of the meeting was the so-called *Stokab* model, which comes from Stockholm Sweden. The model is tested in Finland in one pilot project in Helsinki in one city district under construction called Arabianranta. The model defines the fiber-optic networks as part of the municipal infrastructure, the building and maintaining of which is the responsibility of the city. The TCs oppose the *Stokab* model, because from their perspective an unfair competitive situation is created if the municipalities start to take on tele-operating functions. In the meeting the technical details and pricing of the broadband network in the pilot area were discussed at length in question and answer fashion. The representatives of the city’s energy company provided the factual answers.

Another solution to the tension, the idea of a *shared cable channel* was presented in the midst of the discussion. The representatives of the PWD, whose main concern in the ongoing debate is street-keeping, presented diagrams and calculations, which justified the idea of a shared underground channel. The structure is essentially a receptacle made from two concrete troughs, the lid and the bottom. The structure would contain empty plastic tubes, in which each of the TCs could place their own cables. The shared-channel structure was an attempt, from the part of the PWD, to create an expansive vision for the emerging infrastructure, which would meliorate the paralyzing tension between the market logic and the public service logic. The shared cable channel was a compromise between the present practices and the original *Stokab*-proposal advocated mainly by the city’s energy company.

The new solution included new roles and a new division of labor between the city and the TCs: The PWD would take up the task of constructing the receptacles as part of the underground layers of new streets, the city would lease the channels on non profit basis, and the TCs would start to behave more like public service organizations; to make plans, reservations and to co-ordinate their activities. In this way the new model reworks the tension between the stakeholders. The idea of a more coordinated joint practice was sketched later into the following flowchart (figure1.):

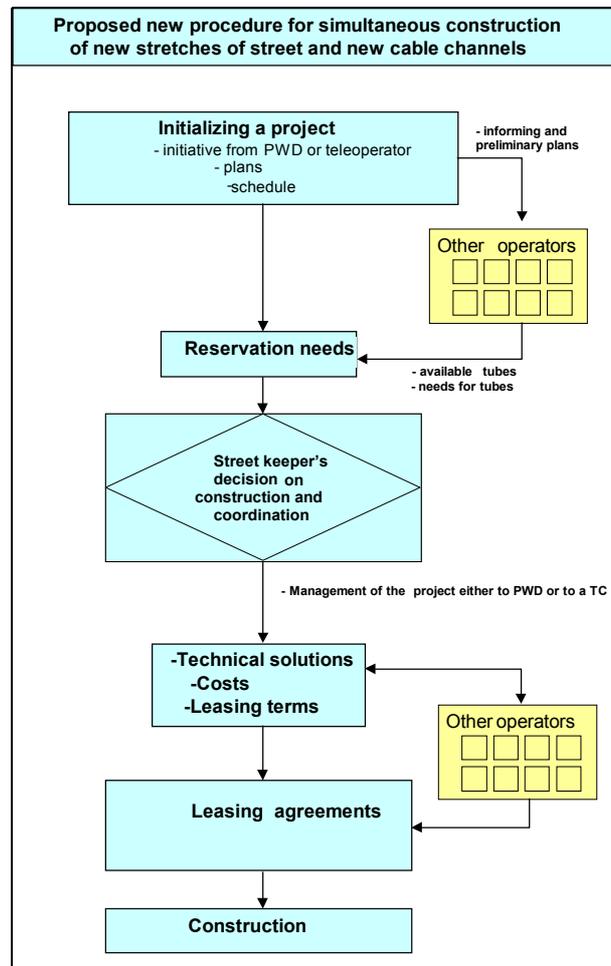


Figure 1. The proposed coordination model for future construction projects.

Discrepancy between progressive solution and regressive interaction

Analyzing the interaction dynamics of the meeting is very revealing. Table 2. shows that the representatives of the city use twice as much turns (277/138), and most of the time of the 93 minute meeting. In addition to asking short questions and clarifications, the role of the representatives of the TCs was mainly to listen to the affirmations, justifications and factual accounts given by the representatives of the city. This finding turns attention to the communicative aspect of learning challenges involved in knotworking.

The meeting started by framing the problem from the PWD's perspective:

“As a background for the discussion I can show a few diagrams. Let's have a look at the area where the construction is going to start first. So here are the different cables: district heating, electricity, telecommunications, and water. Here is a cross section of the street. You can see that electricity and telecommunications are systematically under the sidewalk on one side of the

roadway. Water is directly under the roadway and district heating is under the sidewalk on the other, narrower side. So you can see that into this space here both electricity and telecommunications must be fitted. There is exactly a three-meter space there. We did a report on the possibility to build a shared channel structure for all telecommunications cables, and it was very clear that we would save a lot in the construction fees and also save a lot of space if we directed all the cables in one shared channel. And here, you can see how it will look like if there is no collaboration between the operators...you can see how difficult this situation is for the use of underground space alone! And this picture only shows four sets of tubes...there are ten operators building their networks in Helsinki at the moment. All these structures require wells and you can see, that in this case, there would be no space left for those. This is the problem, and...the frightening picture we have seen in the municipal technology meetings, where at least three operators have expressed an interest to build networks of their own in the area.”

The representative of the PWD said there is “no sense” to build overcapacity in hopes of gaining all of the market. A representative of one of the TCs explicated, that once a cable network is being installed they rather build overcapacity precisely to avoid opening stretches of street several times. Despite the evident need to re-negotiate the very concepts of *sense* and *sensibility* in order to establish common ground for a shared strategy, the discussion merely touched the underlying tension. One representative of the TCs wanted to work around the whole question, and asked for clear-cut directions. This reflects the traditional mode of collaboration between the city and the TCs. The excerpt illustrates how demanding the transition towards knotworking is when traditional rules, divisions of labor and power positions are strongly present, but no longer sufficient to guide the collaboration. The script and the roles must be re-written as the play proceeds.

PWD: Our concern is that the services are affordable, that the service providers compete with price and content of services. I believe that this is a healthy situation for the society.

TC: Well, I am not here to talk philosophy.

PWD: No, but...

TC: There are many opinions on that...the philosophy is a completely different matter. Just tell us what are the terms that the city has for us.

PWD: Well...

TC: And when do you except our reservations of the cable space. When is the number of tubes decided? Where are the decisions made? Who decides?

Table 2. Summary of the meeting

Participants	Speech turns
Representatives of the city: Street department 2 Helsinki energy company 3 Development unit 1	277
Telecom companies 4	138
Other service providers 3	37
Persons total: 13	Speech turns total: 453

Conclusions

The paper illustrated what kind of work knotworking is, and what kind of learning challenges are embedded in the transition towards these particular collaborative modes of work. In the participatory tradition of Developmental Work Research recent more exploratory studies have focused on the questions of how knotworking can be facilitated and supported (Engeström 1999; 2000). Interventions have aimed at expanding the conceptual frameworks through which problems have been previously framed, for instance by bringing concretely in the missing voices (e.g. patients) and perspectives to the collective knowledge creation process.

The case example discussed in the paper is interpreted as an ongoing negotiation process, in which a partly shared object is being constructed discursively and materially. Negotiation is central in knotworking because no single motive or homogeneous objective can be assumed to explain or guide the collaboration. The *object* in the case discussed can be understood broadly as a future infrastructure, which will in its material and organizational dimensions integrate the public service and the business aspects and transcend the present gridlock. The proposal for a shared cable channel is an example of the kind of a solution, which carries technical as well as organizational implications, which will change the participating actors and their relations.

If knowledge is understood to be located in shared practices rather than individuals' minds, we must go very close to those practices in order to understand learning (Toulmin 1999; Hutchins 1999; Cole & Engeström 1993). The field of learning research must aim to address the methodological challenges of combining the understanding of micro-level interactions and socio-material transformations of practices in a meaningful way. Cultural-historical activity theory stresses the material aspects of practices, and therefore offers promising conceptual tools for looking at learning as joint creation of new knowledge. The framework sees knowledge in action, as shared conceptualizations and artifacts, which in turn transform the practices that gave rise to them.

Endnotes

- (1) *Participation* is currently the mainstream metaphor when conceptualizing learning on the community level. In its time Jean Lave's and Etienne Wenger's work (1991), challenged the view on learning as acquisition. These three metaphors are complementary and highlight different aspects of the phenomena of collective learning.
- (2) A rich body of recent empirical work builds on Engeström's theory of expansive learning, but with a focus on the *horizontal dimension* of learning and development in divided organizational terrains (e.g. Kerosuo 2002).
- (3) See Bertelsen & Bødker 2000 for case studies using activity theory in looking at the role of information technology as an object and tool in local activities.
- (4) The concept of *object* has a particular meaning in the activity theoretical tradition. The notion of object signifies both the material instantiations at hand, and the ideal layers of more longstanding motivations that drive a particular activity and give it meaning (Ilyenkov 1977).
- (5) Telecommunications companies are referred to here on in the paper as TCs. The terms *operator* or *tele-operator* signifying telecommunications companies are used interchangeably in the data excerpts and in figure 1.
- (6) The data presented in the paper has been gathered as part of a doctoral dissertation research-in-progress mainly by using participant observation in municipal planning meetings regarding the broadband telecommunications infrastructure in the city of Helsinki.

References

- Bertelsen, O. & Bødker, S. (2000). *Scandinavian Journal of Information Systems, Special Issue on Information Technology in Human Activity 2000*, vol. 12. <http://iris.informatik.gu.se/sjis/>
- Clases, C. & Wehner, T. (2002). Steps Across the Border – Cooperation, Knowledge Production and Systems Design. *Computer Supported Cooperative Work (CSCW) 11* (1-2): pp. 39-54.
- Cole, M. & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salamon (Ed.) *Distributed Cognitions. Psychological and educational considerations*. New York: Cambridge University Press.
- Engeström, Y. (1987). *Learning by Expanding. An activity - theoretical approach to developmental research*. Helsinki: Orienta konsultit.
- Engeström, Y. (1990). When is a tool? In *Learning, Working and Imaging*. Orienta Konsultit, Helsinki.
- Engeström, Y., Brown, K., Christopher, L.K., Gregory, J. (1991). Coordination, Cooperation and Communication in the Courts: Expansive Transitions in Legal Work. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, October 1991, Vol. 12, Number 4*, pp. 88-97 [Published again in 1997 In Cole, M., Engeström, Y. & Vasquez, O. (Eds.) *Mind, Culture and Activity: Seminal Papers from the Laboratory of Comparative Human Cognition*. Cambridge: Cambridge University Press.]
- Engeström, Y., Engeström, R., Vähäaho, T. (1999). When the Center Does Not Hold: The Importance of Knotworking In S.Chaiklin, M.Hedegaard and U.J. Jensen (Eds.) *Activity Theory and Social Practices*. Aarhus: Aarhus University Press.
- Engeström, Y. (1999). Expansive Learning at Work: An Activity-Theoretical Perspective. *Computer Supported Cooperative Work 8*: 63-93, 1999.
- Engeström, Y. (2000). From individual action to collective activity and back: developmental work research as an

- interventionist methodology. In P. Luff, J. Hindmarsh & C. Heath (Eds.) *Workplace Studies. Recovering Work Practice and Information System Design*. Cambridge: Cambridge University Press.
- Fisher, G. (2001). *Communities of Interest: Learning through the Interaction of Multiple Knowledge Systems*. 24th Annual Information Systems Research Seminar in Scandinavia (IRIS'24), Ulvik, Norway. Proceedings, pp.1-14.
- Hasu, M. (2001). *Critical Transition from Developers to Users. Activity-Theoretical Studies of Interaction and Learning in the Innovation Process*. Doctoral dissertation, Department of Education, University of Helsinki, Finland. Espoo: Otamedia.
- Henriksson, K. (1999). *The Collective Dynamics of Organizational Learning. On Plurality and Multi-Social Structuring* Doctoral dissertation. The Institute of Economic Research. Lund University. Lund Studies of Economics and management 49.
- Hutchins, E. (1995). *Cognition in the wild*. Cambridge: The MIT Press.
- Ilyenkov, E. V. (1977). The concept of Ideal. In *Philosophy in the U.S.S.R., Problems of Dialectical Materialism*. Moscow: Progress Publishers.
- Kerosuo, H. (2001). Boundary encounters as a place for learning and development at work. *Outlines: Critical Social Studies*, 3, pp. 53-65.
- Lave, J. & Etienne, W. (1991). *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs: Prentice-Hall.
- Miettinen, R. 1998: Object construction and networks of research work: The case of research on cellulose degrading enzymes. In *Social Studies of Science*, 38, 423-463.
- Paavola, S., Lipponen, L. & Hakkarainen, K. (2001). *Epistemological Foundations for CSCL: A Comparison of Three Models of Innovative Knowledge Communities*. Paper presented at the CSCL conference at the University of Boulder, Colorado 2001. <http://newmedia.colorado.edu/cscl/228.html>
- Strauss, A. (1978). *Negotiations. Varieties, Contexts, Processes and Social Order*. Jossey-Bass Publishers, San Francisco.
- Toulmin, S. (1999). Knowledge as Shared Practices. In Engeström, Y., Miettinen, R., & Punamaki, R. (Eds.) *Perspectives on Activity Theory*. Cambridge, UK and New York, NY: Cambridge University Press, 1999.
- Victor, B. & Boynton, A. C. (1998). *Invented here: Maximizing your organization's internal growth and profitability*. Boston: Harvard Business School Press.
- Vygotsky, L. S. (1978). *Mind in Society. The Development of Higher Psychological Processes*. Cambridge, Massachusetts, London, England: Harvard University Press.
- Wehner, T., Clases, C. & Bachmann, R. (2000). Cooperation at work: A process-oriented perspective on joint activity in inter-organizational relations. *Ergonomics*, Vol. 43, 7, pp. 983-997.