

TOWARDS THE USE OF KNOTWORKING FOR INCREASING INNOVATION IN CONSTRUCTION PROJECTS

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Knotworking is an emerging collaboration form in the built environment, which promises to encourage innovation at Construction project level. This study of knotworking processes is part of a larger research program about collaboration in the built environment. In this study of Knotworking, the focus has been on how the participating organizations and professionals can learn how to participate in knotworking. A facilitator was introduced to establish how facilitators can assist the participating organizations in a construction project to learn to produce knowledge and innovation through knotworking. The theoretical foundation is Activity Theory, the data collection method derives from applied ethnomethodology using a blend of video recording and participant observation. The data has been collected in a series of planning meetings and one workshop about building a new kindergarten. The analysis of data shows that the open-endedness of the process was difficult to handle for the participants, as they wanted to return to old norms and routine that overrule the knotworking process. The major result is that the use of a facilitator can function as a catalyst helping the participant exploiting the openings for knotworking by encouraging people to bring in their resources and tools in new ways and in this way increase innovation.

Keywords: activity theory, construction industry, facilitation, knotworking.

INTRODUCTION

A wish to develop new methods, tools and production for facilitating efficient buildings is the background for the EU project called Green Building A-Z. The collaboration form ‘knotworking’ has been chosen as a method to develop this. The desirable type of innovation is pragmatically and analytically categorized as “product innovation (changes in the things (products or services) that an organization offers) and process innovation (changes in the ways in which they are created and delivered)” (Tidd and Bessant 2009: 21). Much of the innovation in the construction industry is co-developed at project level, found Xue *et al.*, (2014) in their review on innovation in the construction industry. They continue to recommend more research into how innovation is managed at project level. Research into innovation in project-based organization has so far been little (Taylor *et al.*, 2004). Knotworking is a collaboration form, which combines the use of Activity Theory’s way of understanding human behaviour with the concept of Expansive Learning.

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Expansive Learning happens, when “learners learn something that is not there yet” (Engeström and Sannino 2010: 2). In this way, they learn something new, i.e., some knowledge that was not there, when they started their collaboration. Knotworking allows for an understanding of how to “sketch the contours of [how to perform] knowledge- and innovation-driven production” (Engeström 2008: 20). It is a “core activity” in order to promote learning and innovation when different “kinds of knowledge are combined” (Wegener 2014: 249). On this background, the choice of knotworking as a collaboration form becomes appropriate for situations where innovation is the aim.

Knotworking allows for participation of many experts to cope with emerging situational challenges. The participating experts form what is called ‘a knot’ and will be working towards an object. The members of the knot do not remain stable, but are changed as the knot works towards its object. An object can be defined as ‘the raw material’ or ‘problem space’ at which “activity is directed” (Engeström and Sannino 2010: 6). This process has typical no clear deadline or fixed endpoint (Engeström 2008). Collaboration between the organizations in the knot is of “vital importance, yet it takes shape without rigid, predetermined rules or a fixed central authority” (Engeström 2008: 20). This was exemplified in Finland where a lack of common goal was an issue that questioned the prevailing way of collaborating and motivated the initiation of knotworking (Kerosuo 2015). Similarly, the use of knotworking in a Danish case showed that the exploitation of digital technology such as information exchange between disciplines/domains and the underlying data models and interfaces, in some cases, challenged the provision of data. The Client ended up being unable to compromise company procedures and demanded the deliverables in predefined formats, which caused a relapse into known methods and procedures instead of supporting new ways of collaboration and documentation (Buhl *et al.*, 2017).

There are hindrances to successful Knotworking. Kerosuo (2015) discovered that simultaneous membership in a knot and a firm might restrict performance in the knot. A similar point is observed by Scaratti *et al.*, (2017), who report on troubles with the power dynamics in the knot related to mandate, coordination and work methodology. These barriers may be due to the structure of the inter-organizational networks, an organization form we often see in construction projects. The interorganizational network encounters difficulties in facilitating expansive learning while working on goal-fixed projects, Klitgaard *et al.* (2016) showed that a strong focus on a specific goal by a project’s activity system hinders expansive learning. A construction project requires the involvement of a broad range of actors with different competences and specialties (Eriksson 2013). The participating organizations are used to networking which is fundamentally different from Knotworking. Knotworking encourages “upsetting traditional boundaries and improvising new co-configurations of work and object of activity”, argue Scaratti *et al.*, (2017: 18) and differs from the traditional way of looking at a network with “focus on maintaining and nurturing existing relations. Knotworking is very different to the traditional collaboration in the construction industry.”

The construction industry with its project-based nature with a goal specific nature and networking practices may seem to contrast with the knotworking collaboration form. In order to meet opportunities and increase innovations at project level, we have chosen to work with Knotworking in the "Nordic project, Green Building A-Z". However, knotworking is still a new collaboration form for the construction industry, so to spread knowledge about knotworking as well as how to facilitate change with knotworking the role of a facilitator is being tested and researched.

The focus of a facilitator can be to move the project forward. He will adjust the need for assistance and enablement depending on the contingencies (Freytag and Storvang, 2016). However, as Rasmussen (2011:398) describes the use of interactive methods and facilitation for change, where “the primary objective of facilitation is to support participants to transcend ‘business as usual’ conventions and help them to think in terms of new modes of behaviour and perspectives...The facilitators enable groups to be creative and to collaborate more effectively”. The focus of the facilitator depends on the purpose of the facilitated.

A knotworking facilitator seems like a contradictory function. Knots are expected to form when collaboration between organizations is needed. They should perform “without rigid, predetermined rules or a fixed central authority” (Engeström 2008: 20), which contrasts with giving the facilitator the function to set up rules and authority. On this backdrop, we decided to investigate the role of the facilitator in a Knotworking process and pose the question: "How can a facilitator assist the participating organisations in a construction project in their efforts towards producing knowledge and innovation through knotworking?"

KNOTWORKING - THEORETICAL FRAMEWORK

The theoretical perspective of this research is AT and Expansive Learning. This analytic combination allows the research to examine what the participants learn together (Engeström and Kerosuo 2007). Activity Theory (AT hereafter) brings an understanding of human activity, which is often depicted as an activity system that entails the relations between subjects, objects, and instruments involved in production as well as the social aspects of an activity such as rules, division of labour and community. Expansive learning is initiated by a questioning stage which happens when subjects in an activity system are “questioning, criticizing or rejecting some aspects of the accepted practice and existing wisdom” (Engeström and Sannino 2010: 7). Analytically and pragmatically this questioning stage is followed by analyzing the historical development into the present situation, as well as the analysis of the actual situation, modelling of a new solution, examining the new model, implementing the new model, reflecting on the process and consolidating the new practice in what is called the expansive learning cycle (Engeström 2000: 970). All stages may not be completed, and it shouldn’t be considered a linear process. In this way, the questioning of the accepted practice can be developed through expansive learning into new models and practices. Therefore, expansive learning can be used to analyze the processes whereby new knowledge and new mediating objects of activity are collaboratively created (Paavola *et al.*, 2004: 573). The work practice of ‘knotworking’ in the construction industry finds its origins in this approach. Five analytic principles have been derived from AT. These five principles have been adapted and re-interpreted from AT which form the foundation of knotworking within the activity system and issues concerning the intervention and facilitation of knotworking processes (Kerosuo 2015):

The first principle of Knotworking, performing actions in groups as human activity, is the object-orientation. Objects of activity are both material and cognitive constructions that entail directionality, purpose, and meaning to collective activity (Engeström 2008). The collective activity system determines how the subjects decide and react while performing actions designed to reach the object (Foot 2002). In this way, the object becomes a representation of the collective motive of the activity systems’ subjects (Toivainen 2007). As the subjects learn more about their object, it will change (as subjects’ accommodate their motivation to changes of purpose). In this way, learning is not “manifested as changes in the subject” but as “changes in the object of the collective

activity” (Engeström and Sannino 2010: 8). The object will create meaning and motive for all the subjects in the knot. The flexibility of who is participating in the knot may deal with Young’s (2001) concerns about Expansive Learning; motivation and power. He argues that not all subjects will have the same motivation to enter the Expansive Learning cycle and that power issues may deter some subjects to participate. An awareness of how object changes may be signs of learning, and not signs of not sticking to the agenda, is needed for the facilitator of the knotworking process.

The concept of mediation in human actions and activity is the second principle of Knotworking; the elements of an activity system mediate human activity. For instance, various instruments such as manual and software tools, building plans, building schedules, and meeting procedures mediate a building project. New tools may be developed and adapted to reach an object. A new tool changes the subjects' views of the object concluded Virkkunen and Newnham (2013), and it affects the inter-action between the subject and object as well as the subject's role, self-understanding, and identity. Facilitating knotworking gives subjects the freedom to work with their tools because it is through the use and development of the tools learning and innovation is happening. This may seem contradictory to the traditional facilitator's role of ensuring the right tools are available.

The mutual constitution of actions and activity is the third principle. Expansive Learning can happen, if the activity system is directed its’ activities against a durable object. (Engeström 2000: 961). However, if the Activity System is pursuing a short-lived goal the Expansive Learning cycle may never be entered into. An object may not be clearly defined from the beginning but, through cycles of Expansive Learning, it will be transformed into a result. It is the intention of Knotworking to work on abstract objects and through Expansive Learning enter into a process of product and/or process innovation. It is not the intention to solve concrete problems or specific goals. Facilitation of knotworking should support activities directed towards abstract object, although it may seem contradictory to the traditional facilitator's role of assisting with contingencies.

Examining contradictions as sources of change is the fourth principle of Knotworking. Contradictions are historically accumulated tensions between and within different activities that manifest in disturbances, gaps as well as innovative solutions (Engeström 2008). For instance, a contradiction may emerge between the adoptions of new digital technologies such as BIM and organizational structures developed during a prior technological paradigm (Kerosuo *et al.*, 2015). Tensions in a knot can be turned into the Expansive Learning cycle. Engeström (2008: 36) observed a team which stagnated and resisted change and innovation. This happened because they did not react to tension by "attempting or completing an innovation". Facilitation ensures that openings for innovation is kept open, although the subjects of the knot may attempt to solve the tensions by other methods than innovation.

The historicity of human activity is the fifth principle of Knotworking. Engeström connects Knotworking to the emerging historical type of work called co-configuration. The features of co-configuration involve: Integrated product and/or service combinations; Continuous relationships and mutual exchanges between customers; Producers and products and/or service combinations; The customization of products and/or services over a lengthy period of time; Multiple collaborative producers operating in networks within and between organizations (Engeström 2008: 195-196). Co-configuration requires input from different participants and so the facilitator should have some focus on that everyone’s opinion is important, not just the traditional experts.

A facilitator with knowledge of the five knotworking principles may be able to assist the participants in their knotworking.

METHODS, DATA, AND ANALYSIS

The method of the study is applied ethnography, which is a practice-oriented approach to contribute to change processes (Chambers 2000). Applied ethnography is often used in action research projects that serve public good and/or decision-making, and can involve analysts as facilitators. It emphasizes collaboration with the participants of the change projects and those involved as subjects in fieldwork. Applied ethnography resembles developmental approaches drawing from the methodology of expansive learning with regard to its orientation to practice and participation in change processes. The focus of developmental approaches on tensions and disturbances is also similar to applied ethnography. The idea of both these methods is that researchers make the tensions and disturbances of the work practice visible (Kerosuo 2006).

The method of the data collection was participant observation (Hammersley and Atkinson 1983). Five dimensions when performing participant observation must be considered according to Patton, stresses Warming (2009); while she adds a further three dimensions. Dimension (1) regards the level of researcher's level of participation. The research team decided that the researchers should engage in the knot if they thought it could be beneficial. Dimension (2) and (3) concern the participant's awareness of the research. It was decided, that the participants should know about the research and that its' focus was the facilitator's role. Duration of the observation (4) was decided to be during all meetings and the focus to be the facilitator (5). The researchers have to be present to sense and feel the observed (6) so the recordings will be used to recall the experience. The researchers will observe both the spoken words as well as body language (7) and finally by carefully describing the observed (8) the researchers give their readers the opportunity to evaluate the objectiveness of the observed.

The use of applied ethnography allows for a study into how processes are changing from traditional routines to knotworking. In reading the data, episodes of these occurrences need to be identified. We call this kind of unit of analysis a transitional learning episode or in our case "change process episodes" where we are analysing how the facilitator assists the participants in knotworking. Our definition of an episode resembles the way Kerosuo's (2011) study of critical episodes of successful change, the transition from individually experienced contradictions to collaborative change, drawing on theoretical concepts, models, and methods from AT (Engeström 2008; Virkkunen 2013) to study the critical transition in meeting and workshops.

The data is collected from one of the Green Building A-Z's pilot project, a kindergarten. The client/developer is a Danish council, so first of all the research team had a meeting with staff from the building department to introduce the general idea of knotworking. This was followed by a meeting, where it was discussed, which theme/object the council wanted to have in centre of a later workshop. A meeting with participants from the Green Building A-Z project followed where the framing of the later workshop was discussed. Finally, the knotworking workshop was held, see figure 1 for a timeline.

A member of the research team was chosen as facilitator for the knotworking workshop as a sound understanding of the knotworking principles are required to facilitate the process. This facilitator also needs to have a sound knowledge of the construction industry.

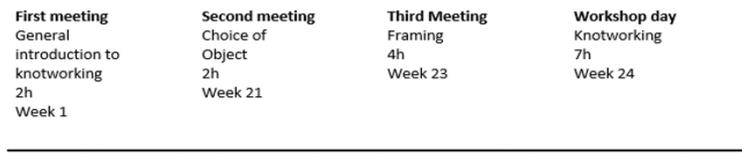


Figure 1: Timeline for meetings

Video recordings of the meetings three and four took place as it was during the meetings participants from different organizations within the industry was present. The purpose of the framing meeting (meeting no. 3) was to set up the conditions for the later workshop. The participants were asked to further discuss the object for the workshop, the rules for the workshop, how they would allow for different disciplinary communities' presence at the workshop, the division of labor during the workshop as well as which tools they wanted to have present and use during the workshop. These questions are inspired by the categories in the activity system. Nine participants were present at the meeting which took four hours. A week later, the workshop day took place, which was video recorded. Eleven participants from 6 different organizations participated. They were representatives from the client, the client consultant, the user, the commissioning consultant, project management and half of the day a contractor was present. The workshop lasted 6 hours and 45 minutes. During the day, the participants split up in 3 smaller discussion groups for 45 min. Members of the research team observed these group discussion, although they were not recorded. 534 minutes of video recording on 2 different cameras were made, along with 552 minutes of voice recording, also on 2 different recording devices. Selected episodes of analytic interest were transcribed.

FINDINGS AND ANALYSIS

The first meeting with between the council staff members and the research team was an exchange of information. The research team was informed of the progress of the pilot project, the kindergarten and the council staff was introduced to the knotworking collaboration form. The second meeting between the client and the research team, the object of the later workshop was discussed. The leader of the council's building division expressed a wish to develop some sort of procedures for good collaboration between participants in a construction project. He had found on previous occasion that once a contract had been signed between the client (himself) and the design and build contractors, all intentions of good collaboration seemed to dissolve. The facilitator agreed that this was an appropriate object for knotworking as it based on a historic contradiction in how to designing a good project (use value for the client) for as little money as possible (exchange value; as the project is build using design and build procurement, the chosen contractor will have a huge interest in keeping costs low and so maximizing his profits). During the framing meeting (no. 3), the participants for the later workshop were called in to discuss the conditions for the later workshop. They agreed on the object. However, they wanted to be able specify it to a degree that it could be used in the coming tender material. A list of tools for the workshop was decided including actions to minimize the presence of different disciplinary communities. It was decided, who was going to be the moderator of the day as well as who was to write down the day's results.

The workshop day was held a week later. In the beginning of the day, the participants discussed the topic good collaboration. The discussions were very loose and moved back and forward across the themes; time, resources, expectation, demands and more. Later in the day, the participants had to turn these discussions into specific criteria for a tender material. This caused some change processes. The figure in the table shows sequences of disturbance and their influence changing between "present project routines" (rules and

norms) and knotworking (co-configuration). Reported in table 1 below. In this way, the participant did knotwork and by entering into questioning stages; they did in the end come up with a specific tender criterion for collaboration. The content of this criterion was new for them and so they did display the knotworking learning process during the workshop. However, the research team has been informed that this criterion was not included in the tender material after all. The reason for this is at present unknown.

Table 1: The findings

Timeline of the "transitional episodes"

Sequence	Quotes and analytic remarks
<p>A: Returning to known routines and procedures</p>	<p><i>I just need to make sure. We create a catalogue of ideas now, and then later we find out, what specifically we should include in our tender material - or should we discuss that now too? - client advisor</i></p> <p><i>So, now we really will begin to discuss what should be included in the tender material? - client advisor</i></p> <p>As it became clear that the participants were to discuss the tender material, they switched away from the previous open discussion and wanted to go back to negotiation the present routines. One of the participants want to read aloud some tender material he had prepared before the workshop. The facilitator attempted to stop this:</p>
<p>B: No effect of the facilitator's question</p>	<p><i>I am very sorry to disturb...but I have noticed that you have focused a lot about collaboration today but is a bit unclear what you mean. I would really like if you [...] discussed this and found, what it is specifically you want to write" - facilitator</i></p> <p>However, the participants do not want to follow the facilitator's advice. They want to hear what had been prepared before the workshop. It is an example on how the participants react to knotworking and how easily they revert to old routines and norms.</p> <p>The participants heard the pre-prepared tender criteria about collaboration between tradesmen on site (no representatives from these were present) and agreed that it seems "existing" and "makes sense". This is followed by silence. The participants seem unsure what to do. At this stage, the intended manager of the kindergarten says:</p>
<p>C: Switch to knot-working</p>	<p><i>But, I understand [that collaboration between actors on the building site is important] but I am also becoming interested, when we are speaking about collaboration, then I am also interested in collaboration, in what could be called the process as a whole. What, you describe now. All that is when the project is planned ... maybe we [participants in the room] should have defined our collaboration, I think [...] Can you follow my idea? And that collaboration will become very important? And I think that is what you write into the material. What does that collaboration build on?- the council's pedagogical leader for all kindergarten in the council</i></p> <p>This input from an outsider of the construction industry is questioning the collaboration between the client, client advisor, commissioning manager and project manager as well as their collaboration with the tradesmen onsite. It is questioning the existing division of labor.</p> <p>They start negotiating the need for being able to evaluate collaboration with contractors.</p>

D: Switch to knot-working	<p>At a point, the facilitator suggest that they may need a new tool and perhaps it would assist them to see some tender material. In response to this, the intended leader of the kindergarten replies:</p> <p><i>"I think, that we are beginning to get there [...]I do think, that we begin to have a fair understanding, Right? Don't we? I have. - the council's pedagogical leader for all kindergarten in the council</i></p> <p>The participants seem to react to this. They question the object of the day, which might not have been clear for them until now.</p>
E: Staying with knot-working	<p><i>" I am wondering....is this just something we do for fun....this knotworking discussion should, in a way help us, or?" - sustainability manager</i></p> <p><i>"I think we can learn from this process, but we should hopefully be able to take something with us..." -project manager</i></p> <p><i>"Yes, something concrete." - client advisor</i></p> <p>This willingness to have an outcome of the day is interrupted by the discovery, that a prequalification advertisement for a design and build contractor has already been published. A discussion about the possibility for working on tender material for describing the kindergarten project begins:</p>
F & G: Switch to present project routines	<p><i>"It need to be done by tomorrow at nine" - client advisor</i></p> <p><i>"I would like to write the prototype, but not for tomorrow."- commissioning manager</i></p> <p><i>"...after Friday, it will only be details I will take into the project or I simply can't make it" - client advisor</i></p> <p>The participants accept the time constraint and switch away from the willingness to develop further on the criteria.</p> <p><i>"Today we are doing a lot of things, which we can also use in the future...Nothing is wasted, even if we don't get it into the tender material" - project manager</i></p> <p><i>"It won't come in this time,...it is the beginning of a process" - client advisor</i></p>
H: Switch to knot-working	<p>The facilitator steps in and asks:</p> <p><i>But, let's pretend you had the time for it. Then that is closed. If you had to find criteria. We need to get something on paper..." - facilitator</i></p> <p>This prompted co-configuration. Criteria for the upcoming tender material was created in spite of the close deadline. It is not clear at what point the participants discovered that it was feasible. They say:</p> <p><i>"...we have actually reached our goal. Then we just need to remember to look at all the rest [more discussion on the foundation for good collaboration]...it became very specific there..." - the council's sustainability manager</i></p> <p><i>""Don't you agree, that we reach the goal? Ready for tender material?"- commissioning manager</i></p> <p><i>"Yes, I just need to copy and paste" - client advisor</i></p>

On reading the above data, it can be seen that the facilitator did assist the participants in their effort to knotwork. Interestingly, it seems as though the pedagogical leader responded more to the facilitator than the construction professionals, as two of her questions seem to be reflections of a previous question by the facilitator. It could be due to her educational training, or because she does not have the same project routines to switch back to as the rest of the participants.

The facilitator first demonstrated knowledge of knotworking, when the object of the workshop was decided. It was based on a historic contradiction in how to design a good project (use value for the client) for as little money as possible (exchange value; as the project is build using design and build procurement, the chosen contractor will have a huge interest in keeping costs low and so maximizing his profits). The facilitator did initiate the beginning of some questioning stages, which prompted the participants to switch into knotworking with the possibility for the occurrence of expansive learning. The first question about collaboration is based upon the tension in dividing task and responsibility (division of work) in the construction industry. It refers to the fourth principle of knotworking. The question if they wanted to see some tender material was made based on the second principle relating to mediation. The third principle of actions and activity was used by the facilitator when attempting to eliminate the focus on a tight deadline.

CONCLUDING REMARKS

It is possible to innovate and create new requirements and expectations to the collaboration in a construction project as the above episode of a transitional learning process shows. It was achieved by creating a workshop, which allowed for knotworking. By combining workshops with the use of a facilitator with focus on knotworking, it may become possible to perform knotworking in the construction industry even if it seems contradictory to the nature of knotworking to introduce a facilitator. Facilitation as suggested in this paper is far from completed and stabilized. The challenge for the facilitator is to manage their functions so that they are catalysts.

The findings indicate that it is possible to facilitate knotworking processes, seeking to build collaboration in knot-like ways, beyond the models of stable, well-bounded institutions and project norms and rules. New ways of working shall emerge and by facilitating construction processes it is possible to innovate, so participants from the build environment leave old routines within construction project - roles and assignments - and engage in knotworking (co-configuration), creating new solutions to old problems and conflicts. The implementation of the knotworking process is an innovative method of collaboration in the construction industry, which entails the disruption of the present norms, practices and rules. The use of a facilitator functions as a catalyst helping the participant exploiting the openings for knotworking by encouraging people to bring in their resources and tools in new ways and in this way increase innovation.

ACKNOWLEDGEMENT

The authors wish to thank Hannele Kerosuo for encouragement and constructive comments.

REFERENCES

- Buhl H, Andersen M and Kerosuo H (2017) A Knot - breaking the inertia in construction? In: Buser, M Lindahl, G and Räisänen (Eds.) *9th Nordic Conference on Construction Economics and Organization*, 13-14 June, Chalmers University of Technology, Sweden.
- Chambers, E (2000) Applied ethnography. In: N K Denzin and Y S Lincoln (Eds.) *Handbook of Qualitative Research 2nd Edition*. Thousand Oaks, London and New Delhi: Sage Publications, 851-869.
- Engeström, Y (2000) Activity theory as a framework for analyzing and redesigning work. *Ergonomics*, **43**(7), 960-74.
- Engeström, Y (2001) Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, **14**(1), 133-56.
- Engeström, Y (2008) *From Teams to Knots: Activity-Theoretical Studies of Collaboration and Learning at Work 1st Edition*. New York: Cambridge University Press.
- Engeström, Y and Kerosuo, K (2007) From workplace learning to inter-organizational learning and back: The contribution of activity theory. *Journal of Workplace Learning*, **19**(6), 336-42.
- Engeström, Y and Sannino, A (2010) Studies of expansive learning: foundations, findings and future challenges. *Educational Research Review*, **5**(1) 1-24.
- Eriksson, P E (2013) Exploration and exploitation in project-based organizations: Development and diffusion of knowledge at different organizational levels in construction companies. *International Journal of Project Management*, **31**(3) 333-341

- Foot, K A (2002) Pursuing an evolving object: A case study in object formation and identification. *Mind, Culture, and Activity*, **9**(2), 132-49.
- Freytag, P V and Storvang, P (2016) Dynamics of a facilitator's role: Insights from the Danish construction industry. *Management Revue - Socio-Economic Studies*, **27**(3), 117-138.
- Hammersley, M and Atkinson, P (1983) *Ethnography: Principles in Practice*. Cambridge: Cambridge University Press.
- Kerosuo, H (2006) *Boundaries in Action: An Activity-Theoretical Study of Development, Learning and Change in Health Care for Patients with Multiple and Chronic Illnesses*. Helsinki: University Press.
- Kerosuo, H (2015) BIM-based collaboration across organizational and disciplinary boundaries through knotworking. *Procedia Economics and Finance*, **21**, 201-8.
- Kerosuo, H, Mäki T and Korpela J (2013), Knotworking - A novel BIM-based collaboration practice in building design projects. In: *Proceedings of the 5th International Conference on Construction Engineering and Project Management*, 9-11 January, Anaheim, USA.
- Klitgaard, A, Nissen, S B, Beck, F, Jeppesen, R D, Buhl, H (2016) Expansive learning in construction projects - A contradiction in terms? In Chan, P W and Neilson C J (Eds.): *Proceedings of the 32nd Annual ARCOM Conference*, 5-7 September 2016, Manchester UK: Association of Researchers in Construction Management, 709-717.
- Korpela, J (2015) significance of knotworking from the client's point of view. *Procedia Economics and Finance*, **21**, 209-16.
- Paavola, S, Lipponen, L and Hakkarainen, K (2004) Models of innovative knowledge communities and three metaphors of learning. *Review of Educational Research*, **74**(4), 557-576.
- Rasmussen, L B (Ed.) (2011) *Facilitating change: Using interactive methods in organizations, communities and networks*. Denmark: Polyteknisk Forlag.
- Sannino, A, Daniels H and Gutiérrez, K D (2009) *Learning and Expanding with Activity Theory*. Cambridge: Cambridge University Press.
- Scaratti, G, Ivaldi, S and Frassy, J (2017) Networking and knotworking practices: Work integration as situated social process. *Journal of Workplace Learning*, **29**(1), 2-23.
- Taylor, J E and Levitt, R E (2004) Understanding and managing systemic innovation in project-based industries. In: D P Slevin, D I Cleland, J K. Pinto (Eds.) *Innovations: Project Management Research, 2004*. Newtown Square, PA: Project Management Institute, 17.
- Toiviainen, H (2007) Inter-organizational learning across levels: An object-oriented approach. *Journal of Workplace Learning*, **19**(6), 343-58.
- Virkkunen, J and Newnham, D S (2013) *The Change Laboratory - A Tool for Collaborative Development of Work and Education*. Rotterdam: Sense Publishers.
- Warming, H (2009) Deltagende observation. In: L Fuglsang, P Hagedorn-Rasmussen, and P Bitsch Olsen (Eds.) *Teknikker I Samfundsvidenskaberne*. Frederiksberg: Roskilde Universitetsforlag, 314-331.
- Wegener, C (2014) 'I don't know why I'm here': From knot-working to not-knowing. *Journal of Organizational Ethnography*, **3**(2), 246-58.
- Young, M (2001) Contextualizing a new approach to learning. *Journal of Education and Work*, **14**(1), 157-161
- Xue, X, Zhang, R, Yang R J and Jason D (2014) Innovation in construction: A critical review and future research. *International Journal of Innovation Science*, **6**(2), 111-26.