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Knotworking: An emerging form of multi-party collaboration between clients, users and designers in school design

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INTRODUCTION

Recent guidelines prompted by new conceptualizations of learning and methods of instruction and the discontinuance of norm-based governance require a renewal of the school design process. These transitions bring about new responsibilities for all parties involved in the design, construction and operation of school facilities, but institutionalized formal practices often still define the multi-party collaboration in school design. Knotworking is a new form of collaboration in the construction industry. Knotworking is connected to a co-configuration type of production that can better respond to the changing needs of a client and users than previous collaboration methods (Victor and Boynton, 1998). Engeström (2008) suggests that knotworking might have the potential to become an emerging interactional core of co-configuration. The notion of a knot refers to a temporary combination of loosely connected actors and activity systems in collaborative performance. According to its metaphor, knotworking represents the movement of “tying, untying, and retying the seemingly separate threads of activity” (p. 194).

The idea of knotworking was created in Finnish health care projects at the end of the 1990s (e.g., Engeström, Engeström & Vähäaho, 1999; Engeström, Engeström & Kerosuo, 2003; Engeström, 2008). Since then, knotworking has been applied in studies of inter-organizational collaboration in areas such as the defence sector (Blackler & McDonald, 2000), city planning (Kangasoja, 2002), school–university relations (Fenwick, 2007) and libraries (Engeström *et al.*, 2012). The aim of knotworking is to address the challenges caused by the fragmentation of design activity in the construction industry (Kerosuo, Mäki & Korpela, 2015).

A building project represents organizationally and technologically complex multi-disciplinary activity that requires intensive collaboration between different

practitioners. The design, construction and operation of buildings is fragmented among various specialists from different design disciplines, design offices, construction companies and firms contracted to work together in a project (Bresnen & Marshall, 2000). Each design discipline tends to prioritize its own responsibilities in a building project (Crotty, 2012). The functional and disciplinary division of work and the hierarchical command and control type of management configure the project work and act as a barrier in the collaboration within project teams (Chioccio, Forgues, Paradis & Iordanova, 2011; Dossick & Neff, 2010).

The new building information modelling (BIM) technology using 3D/4D digital tools is expected to improve the collaboration between different players in the field (Eastman, Teicholz, Sacks, R. & Liston, 2011). BIM enables the information exchange and interoperability of different computer programs and software applications in multi-disciplinary design and construction. The adoption of BIM has promoted the development of integrated project organization and multi-functional design teams working side by side in co-located spaces such as the 'Big Room' or the 'iRoom Lab' (Fischer, Ashcraft, Reed & Khanzode, 2017). Multi-functional teams can share information with each other effectively, work within the process with other experts and receive rapid feedback from others. The collaboration between project management, designers and clients is based on fulfilling project goals and outcomes set by integrated project delivery (IPD) contracting, in which the risks and rewards are shared among the parties. The shift from the use of non-IT to 3D tools or the hybrid combination of these tools may, however, exclude a wide range of actors in the industry (Harty, 2008). For instance, those clients and users who are not familiar with digital technologies are in danger of being excluded.

The adoption of 3D/4D information technologies has also advanced the development of design collaboration with clients and users. For instance, residents, users, citizens and other stakeholders are able to give feedback and comments through "social media platforms" during the design phase of a building project (Suwal, Jäväjä & Porkka, 2013). Traditionally, user-centred design has been practiced from an expert perspective in which the users have the passive role of commenting on the concepts and plans generated by designers (Sanders & Stappers, 2008). Since the 1970s, the role of the user has expanded, and users have exchanged their ideas, needs and requirements in the pre-briefing stages of building design (Luck, 2003; Lee, 2008). The northern European approaches have also connected a broad democratic philosophy to user-centred design, especially to decision-making in design processes (Binder, Brandt & Gregory, 2008). Recently, entire school communities have been involved in the design of schools (Parnell, Cave & Torrington, 2008). However, new kinds of settings and methods

are needed to enable more intensified collaboration between designers, clients and users (Lee, 2008; Degnegaard, 2014).

A multi-disciplinary group of practitioners and researchers introduced the idea of knotworking to construction in a large development and research programme (PRE) organized by the industry from 2010 to 2014 (Kerosuo, Mäki & Korpela 2015). The representatives of nine industrial partners and two universities initiated a work package called Model Nova (or, here, the group). The aim of the group was to create a method that would intensify the collaboration between the main actors in BIM-based building projects. The members of the group felt that the development of technology or co-located design teams was not enough but new social forms of collaboration were also needed. The group planned and organized a two-day knotworking workshop to test the idea of knotworking in the early design phase. The aim of the workshop was to create alternative architectural plans and energy design solutions for a school project for the client and users to assess. The representatives of the client and the users were expected to have an active role in the experiment. They were able to discuss their goals, needs and requirements for the building. They were also able to reflect on the alternative architectural plans and energy designs created in the workshop.

The process of multi-party collaboration is examined using resources from design studies and cultural-historical activity theory (CHAT or activity theory from now on). What does knotworking offer to the collaboration between the client, users and designers in building design? How is the multi-party collaboration organized in a knotworking workshop? What kind of concerns do the client and the users express at the workshop? How do the designers respond to the client's and users' concerns? The study brings new knowledge about the potential of knotworking in the early phase of building design. The process of developing knotworking for the construction industry is described in detail elsewhere (see Kerosuo, Mäki & Korpela, 2015).

THE THEORETICAL AND METHODOLOGICAL FRAMEWORK

School space can be studied from physical, material, virtual and social perspectives. Physical space contains all the physical aspects in a building. Material space is a complex concept that includes physical space and its representations. Social space involves all spaces commonly understood as social and inseparable from human activity. Social space is produced within activity in a dialectical relationship between the material and the historical and cultural environments (Lefebvre, 1991). Endurance across differences of time and space distinguishes material space from social spaces (Leonardi, 2012, p. 31). However, space has often been taken for granted unless it somehow distracts from activity (Leander, 2002a; Kreiner, 2010). Following Gibson's (1986) idea of the

complementarity of environmental affordances and living beings, Kreiner (2010) defines the concept of affordance to “specify why and how organizational spaces matter ... what space might *potentially* afford with a notion of how it is actually engaged and used” (Kreiner, 2010 p. 205).

The physical, material and social dimensions of space are interpenetrated in this study. First, the physical space of a future school building is examined. Secondly, the digitally produced representations of building plans and the estimates of its future behaviour in terms of energy are constructed, presented and discussed. Thirdly, the social space for the multi-party collaboration of designers, clients and users is constructed. These three layers, together with four specific perspectives represented by different groups of actors, create a “border zone” (Kerosuo, 2001) for the development of knotworking, which is the unit of analysis of the study (see Figure 1). The two-way arrows represent the potential actions of collaboration between different parties in the figure.

Figure 1. The unit of analysis for studying multi-party collaboration in school design

1

A ‘border zone’ is an area of change and development in which multiple relations are in motion and the exploration of alternative and competing negotiations and perspectives can take place (Kerosuo, 2006). In design studies this type of space has been examined as an ‘in-between space’. An in-between space can become a constitutive space for design participation in which the abstract space for experts

and the concrete space to be designed can be constituted (Lee, 2008). A border zone in multi-party collaboration is a hybrid space that enables the inclusion of the client's and users' voices in the analysis of school design. It is important to hear voices such as those of pupils and teachers—which are not always heard (e.g., Parnell *et al.*, 2008; Leander, 2002b). These subjects have undeniably in-depth knowledge about the school activity taking place in the building. Following Vygotsky's (1978) original idea of the zone of proximal development, an in-between space may become a terrain of possibilities. The zone of proximal development is a space that expresses the distance between everyday actions and the historically new form of activity that can be collectively generated as a solution to contradictions emerging in a current activity (Engeström, 1987, p. 174).

The dialectical relationship between the school space and the design activity is studied here from an activity-theoretical perspective. Human activity is understood as mediated by historically, culturally and socially constituted tools, signs (representations), rules and the division of labour in a community (Engeström, 1987). Actors orient towards collective objects of activity and carry out activity through actions and automated operations. For instance, design actions such as imagining, sketching, visualizing, weighting, generating or rejecting produce design activity (van Amstel, Hartmann, van der Voort & Dewulf, 2016). An individual or a group of designers usually produce a new object through coordinated actions in design activity within one or more activities (Bødker & Grønbæk, 1986). The client and user involvement encompasses a rich array of communicative and collaborative actions such as presenting, discussing and negotiating in a design activity.

The collective motive of an activity is embedded in the object of activity, and it gives the activity sense and meaning to those involved (Leont'ev, 1978). An object of activity refers simultaneously to its materiality and to the human needs and motives reflected in it. According to Leont'ev, an entity becomes an object of activity when human needs and the material-cognitive formations of the world meet. Engeström (2008) says that an object of activity cannot be reduced to a single task, but it can be constituted of interconnected tasks. In design studies, an object of activity can be defined as a design space under construction that involves a “set of shapes and functions for a particular object or kind of object” (van Amstel *et al.*, 2016, p. 200). Design drawings and other representations can also be “knowledge or information carrying objects which are used by different actors at different intervals throughout the project” (Luck, 2010, p. 641). Luck emphasises the role of artefacts in the creation of a shared understanding in design collaboration (Luck, 2007).

Luck (2010) connects the notion of design space directly to “shared discursive space in which design moves are made to change the status (i.e., properties,

attributes, etc.) of an artefact that is being designed” (p. 643). By design moves she refers to the transformations and translations that an object undergoes during a design process. According to Luck, the mediation of design drawings and other material representations is often instrumental in the communication and exchange of information among various actors involved in a construction project. The knowledgeable actors in the project can only “read” the codified knowledge in design drawings. However, the stakeholders of a design project can explore and negotiate new possibilities through design moves in co-design workshops (van Amstel *et al.*, 2016).

The main focus of this research is on knotworking as a collaborative activity between designers, clients and users. The shared or overlapping object of participating activities is the design space, which will host school, pre-school, day care and after-school activities. However, the views on the object of activity may also differ among the actors representing different activities. For the architects the object is the design space, whereas the design engineers focus on the structures or the energy solutions of the building. The object of the client and users depends on the goals and needs reflected in the future building. The different views on the object of activity may implicate some contradictions between different parties. Contradictions are historically accumulated tensions between opposing forces in an activity (Engeström, 1987). In design studies, contradictions are often examined as restrictions of design that manifest as constraints such as requirements, needs and other limitations (van Amstel *et al.*, 2016). The research interest here is to examine the co-constitution of a design space and what kind of affordances the constitution requires and creates for the different stakeholders in early design.

THE METHODS AND THE DATA OF THE STUDY

The method of participative observation was applied to get an in-depth analysis of the multi-party collaboration in school design (Hammerley & Atkinson, 1983). The degree of each researcher’s participation alternated from an active researcher involved in the co-constitution of knotworking and a passive researcher sitting amongst the audience in meetings or behind a desk during design work at the knotworking workshop. A research group of three researchers (two civil engineers and the author of this paper) conducted the research (Kerosuo, Mäki & Korpela, 2015). The main focus of the research was on BIM-based collaboration in a design group, but the opportunity emerged to be involved in the entire process of developing knotworking. In this study, the author as a single researcher is revisiting the research data from the client and the user perspectives from a new angle.

The ethnographic field notes containing information about the sites, participants, time and key issues and the documents of the BIM-based architectural plans and other materials provided by the design engineers were saved on computer disks. The researchers saved all data digitally about the interactions in the meetings and the design work with video cameras and recorders to enable returning to the data for analysis. The data retrieved for this study consists of four planning meetings organized by the researchers and active members of the Model Nova group (altogether 9h, 23min), the two meetings organized with the client and users (altogether 4h, 3min), and the design work and the reflection on it in two parallel groups and two groups together (altogether 17h). A research assistant transcribed the data of the meetings *in verbatim*. Two members of the research group created logs about the work in the two design groups. The method of constituting the logs involved the content analysis of the actions of each design group member in five-minute intervals.

The return to the research data for this study began with compiling the data. The transcripts of the planning meetings were analysed for the case description. The analysis of the meetings with the client and users was based on the transcripts and design documents. The design logs and original video recordings were used in the analysis of the actual design work. The focus of the analysis was on how the designers responded to the client's and users' needs and concerns presented at the meetings. The concepts of the border zone, object of activity and voice introduced in the theoretical and methodological section of this chapter were used in the analysis.

THE FINDINGS OF THE STUDY

The findings of the study are reported in four sections. Firstly, the planning of the knotworking workshop is explained. Secondly, the introduction of knotworking to the client and users at the knotworking workshop is described. Thirdly, the process of designing the alternative architectural and energy plans is outlined, and finally, the discussion of alternative designs with the client and the users at the workshop is reported.

The planning of the knotworking workshop

The knotworking workshop was planned, and preparations were made in four meetings during the spring of 2012. The process of the two-day knotworking workshop, the technical process and the basic information for developing the building were listed during the planning meetings. The building plan was expected to fulfil various common goals, technological expectations and requirements set for the Finnish school system. The number of instruction spaces is usually determined by the teaching hours per week, and the size of a study group defines

the size of the instruction space in the Finnish recommendations for school space planning. Local authorities have also created protocols for planning school spaces in their area. Recently, it has become common to plan flexible school spaces. For instance, halls and corridors are sometimes counted as instruction space.

The school under focus is located in a small village in central Finland. Many families with young children have recently moved to the village; previously the population was mainly constituted of pensioners and holiday residents. The school to be built would be small with different grades taught in two integrated classrooms. The pre-school and a day-care spaces would also be included in the facility. The premises centre in charge of the school properties had reserved two alternative lots for the building in the general plan. An old building protected by the board of historical buildings was located in one of the lots, and the other was an empty lot.

The purpose of the Model Nova group was to engage an extensive number of participants in the workshop. Besides the designers, the representatives of the client and users were invited to the workshop. The design team involved architects, energy and cost analysts, and structural and HVAC (heating, ventilation and air-conditioning) designers. A coordinator led the design group, and a visualizer presented alternative plans to the representatives of the client and users.

The members of the Model Nova group wanted to create new ways of working with the client and the users early in the design project. A multi-voiced discussion took place about this cooperation and the methods of mapping the client and users' needs in the first planning meeting. Some members thought that this was the architects' responsibility only, but others were more open to new ideas. For instance, one building consultant reflected:

"It could be possible to give a traditional briefing process a hiding ... Each professional group has their own way of understanding life, you know. That is the big question here. Usually we get the information through an architect at this phase. It would be good to get that in a new way." (Planning meeting, March 12, 2012, turn 511)

The researchers suggested that the voices of the client and users could be made available by "going there" in order to "bring the users" close to the design activity. The researchers met three representatives of the client, the headmaster of the school, four representatives of the client and six members of the village community before the workshop. The headmaster brought up the need to have many small rooms for integrated instruction. The members of the village wanted to have a multi-activity school space to be used in different community activities (e.g., sports, theatre performances, a meeting place etc.). The preference of the community members was also to have the school located in the middle of the

village and the architecture respecting historically derived community values. The client and the users also expressed their willingness to participate in the workshop. The results of the discussions with the client and the users were explained to the members of the design group before the knotworking workshop.

The introduction of knotworking to the client and users in the knotworking workshop

The design team, representatives of the client and two user groups constituted an interactive space for discussions and negotiations. The actors of different stakeholders are depicted in Figure 1. Not all community associations and clubs were represented at the workshop. Those associations and clubs whose actors participated in the workshop are bolded in Figure 2.

Figure 2. The actors of the design team, the client and two different user groups in the knotworking workshop

The researchers and the coordinator of the design group introduced the aims and purpose of the knotworking workshop to the client and users at the beginning of the workshop. The coordinator of the design group explained:

"The knot means a method of working ... we have experts in cost calculation, energy and architecture and the users. We get feedback right away and the expertise of all parties ... we provide an illustrative presentation of the school plan in the light of important measures on one A4." (Introductory meeting, May 2012)

The city planner presented the status of the school project and the available lots. One of the researchers reflected on the photos of the historical building on the wall. The coordinator showed the first 3D models of the architectural space plans of the historical building and the new building that represented the shared object to the participants of the workshop. In this case the space design (or space plan) was provided as a 3D mass model containing the shape, volume and area of a building. Both plans followed the space programme directing the planning of schools, pre-schools and day care in the city.

The participants were able to make comments and raise questions during the presentations. The community members were concerned about the small size of the gymnasium in both building plans. They also noted the heavy traffic on the road to be crossed on the way to the football grounds. One vision of the community association was to have a multi-function building to serve the entire community, from toddlers to grandparents. Furthermore, public and private health care providers would need a space for providing their services, the village theatre needed a cafeteria for 300 spectators during summer performances, and space was needed for conferences, community members' celebrations and other events. The client's concern was to use the school space for these needs and not a multi-space structure that would add to the costs of the school. However, the size of the gym had the potential to be larger than ordinary in order to meet the demands of the community.

The life-cycle specialist explained the technological plan for the creation of alternative plans. He said that it was possible to provide several alternative energy solutions for each architectural space plan. The information created would be used for the visualization of alternative design solutions at the workshop. The design team had created key performance indicators for the evaluation of the life-cycle economy, architectural and cultural values, ecological values, the functionality of the building, and the use values of the building. Setting other indicators than those not based on numbers or mathematical formulas was a challenge. For instance, how can the cultural value of a historical building be measured? A general meeting was organized for the discussion of the alternative design plans on the afternoon of the second day.

The process of designing the alternative architectural and energy plans in a knot

The designers were divided into two design groups, and both groups had a coordinator, an architect, a structural designer, a HVAC designer, a cost analyst, a visualizer and a contractor. One group was responsible for the creation of alternative architectural and energy plans for the new building, and the other group designed the renovation of the historical building.

The technical process involved the creation of the architectural space plan and energy solutions for each architectural plan. The costs of energy consumption and the investments for each energy solution were also estimated for the building's life cycle. The architectural mass model contained information about the location and connections of the school space. Planning different energy solutions, whether based on electricity, ground heat or something else, consisted of the requirements for HVAC-E designs, such as the carbon footprint. Energy simulations for charting the airflows, cooling demands and standard service luminance of different forms of energy were also estimated for the building's life cycle. The different values were able to be transferred from the architectural model to HVAC-E designs and energy simulation applications. The designers had decided which computer programs the architect and design experts would use at the workshop. However, the cost analyst could not transfer the values from the architectural model because his application was incompatible with that of the architect, and he had to feed in the values by hand.

The collaborative design process followed a cycle with the architect delivering the mass model of the first architectural design to the HVAC designer, the life-cycle specialist and the cost calculation expert. The HVAC designer and life-cycle specialist worked together and created three to six energy solutions for each architectural design. The cost analyst worked by himself and provided calculations of the costs for each energy solution. He was able to ask for clarification from the architect, the HVAC designer and life-cycle specialist as he worked. The structural designer was also available for questions during the entire period. The architect was working on the second architectural model in parallel with the design engineers and the cost analyst. After he delivered the second architectural model, the others started to work on the second set of energy design and cost calculations, and he began to design the third architectural mass model. The group designing the new building also provided a third architectural model, its energy plans and cost calculations.

The architects mainly addressed the users' needs and concerns in the space plans they created. For instance, one principal designer (an architect) planned several small rooms for integrated instruction. One of the three plans he created for the new building included a larger gym that could be used in after-school and community activities. However, providing responses was not only his concern, as his design moves also affected the work of others. The cost analyst began to calculate the costs of a larger gym, and the HVAC designer and life-cycle expert continued estimating the increase in energy costs for a larger gym. The contractor together with the group coordinator reflected on the possibility of covering the costs by charging rent from some private users.

The design groups used a great deal of time for the creation and discussion of the tools to be used for the presentation of the results to the client and users. They also reflected on how to improve their joint working through knotworking in the future. The designers felt that the joint co-located work of different design disciplines speeded up the design process and enabled the examination of different designs from various points of view. The transfer of information was quick and efficient, and each designer's competence fed into that of the others in the design work. There were multiple instances in which some members or the whole group worked together, allowing each expert to assess from their respective point of view the possible design problem. The members of the design groups agreed that a series of knotworking sessions would probably be the most efficient solution: a group would assemble to work on a joint design object at times, then return to their own offices and later resume working again in a knot.

The discussion of alternative designs with the client and the users

A general meeting with the client and users was organized on the second day of the workshop. The architect of one design group presented three architectural plans for the new building, and the coordinator of the other group presented two renovation plans for the old building. The HVAC designer and life-cycle specialist explained the design process behind the energy solutions in the new building. For instance, the values for energy, circumstantial factors and investment costs were evaluated in relation to the goals and requirements set for the building project. The coordinator clarified the main differences between the costs of different solutions. The designers of the old building were not able to provide exact energy solutions because the basic information they needed was not available. The representatives of the client and the users asked clarifying questions and comments when alternatives were presented. However, their questions and comments were short exchanges of concerns and comments that interrupted the rather long presentations.

The functionality and the use of the building and the preservation of the old building were the main concerns of the users. For example, the director of the amateur theatre inquired how the space plan of the new building meets the philosophy of serving the public from toddlers to grandparents. The architect explained that the versatility of space would enable the use of the gym for other events than school celebrations and that the carpenter's workshop would be available after school hours too. However, he admitted that the new building would not have the same synergy for shared uses as the old building. The chair of the community association commented that the renovation of the old building would be a good way to preserve the old, beautiful building. Another discussion was carried out between a member of a community association and the architect

about the number of people that could be present in the gym at the same time. The architect explained that the number depended on the type of use, and he estimated that 250 people could possibly be packed in if the stadium seating system was not too big.

The city planner was concerned about whether only some parts of the building could be separated for after-school use. The architect of the new building assured her that it could be done. She was also concerned about the function and the costs of the HVAC systems in the evenings and on weekends. Furthermore, the representatives of the client and the designers discussed the potential energy forms of the building. The city planner said that the use of geothermal energy was currently favoured compared to district heating among the city authorities.

Both the client and the users commented on the tools used in the presentation. A member of the community association said,

“These tools felt very remote for a layman. I cannot assess their advances or disadvantages. But they are certainly very brilliant tools for this kind of planning.” (Discussion of alternative designs, May 2012)

Another member of the community association inquired about the accuracy of the quickly created calculations. The coordinator of the experiment explained that the alternatives can be compared and the best solutions can be identified even though the results are not necessarily accurate. However, the designers admitted that they had to act on the basis of too many assumptions due to the lack of some basic information. The coordinator also reflected,

“We should have scheduled more time for the definition of the use of spaces together.” (Discussion of alternative designs, May 2012)

From the client’s perspective, the use of BIM proved to be beneficial. It enabled the fast creation of the alternative design solutions needed at the time in city planning. The client representative explained,

“The city has decided to use building information modelling in [another case], so this was illustrative of how it can be done using this kind of fast analysis.” (Discussion of alternative designs, May 2012)

All in all, the participants thought that the pilot was a success and that collaborative design is a good direction for developing new forms of design work. However, the members of the design groups considered that more learning about and development of knotworking was needed. They regarded the opportunity to learn from other’s work as an advantage of knotworking.

“It was great to see what someone else was doing; one could quickly get the hang of the goals and the needs of others working on them.”

The two design groups using BIM and working approximately eight hours each produced and analysed altogether five architectural plans as well as 15 to 20 alternative energy solutions and the costs of these at the knotworking workshop.

DISCUSSION

Multi-party collaboration was examined in a process of experimenting with the idea of knotworking in the early design of a school. The adoption of the new BIM tools pushed forward the development of new methods for collaboration within the construction industry. Besides intensifying the collaboration among architects and design experts, the client and users also participated in the design process in the experiment. The client and users were able to express their needs, concerns and requirements to the designers through interviews before and at the beginning of the workshop. The actual design work was conducted in two design groups and discussed in a final meeting. The headmaster and the teachers were concerned about having functional spaces for integrated instruction. The members of the village community needed spaces for uses such as sports, theatre performances, community celebrations and meetings. The interest of the client was to provide a school, pre-school and day-care facility with some allowances in its use after school hours. The designers provided several architectural plans, alternative energy solutions and estimations of costs to the client and users to discuss.

The participation of users has been reported to extend the social process of design beyond design activity in previous studies (Luck, 2003). The architects and designers certainly had this in mind when they tested the new, more intensive method of collaboration early in the design process. However, it was not easy for users and even for the representatives of the client to become involved in the new practices. Still, clients and users can become engaged as experts of their own experience in a design process (Sleeswijk Visser, Stappers, van der Lugt & Sanders, 2005), but they need appropriate tools to support their participation (Sanders & Stappers, 2008). The designers put extensive effort into developing the tools for the comparison of alternative design solutions. The users were able to use the representations of architectural space plans to clarify their concerns and needs, but the comparison of energy solution alternatives functioned better for the client.

Activity theory emphasizes the part that human needs play in the construction of an object of activity (Leont'ev, 1978). Human needs emerge and are created in their cultural-historical contexts. But sometimes it is difficult for actors to envision the possibilities of new contexts from the perspective of their needs. The users especially expressed very commonplace needs and concerns in the study. The

needs brought up by the client were formal but became more detailed regarding the energy solutions and costs during the designers' presentation of design alternatives. It is evident that epistemological differences emerge between designer experts and users as laymen in the co-constitution of knowledge for design, and the users' ability to participate depends on the level of their "lead user" expertise in design (Sanders & Stappers, 2008).

The successful participation of users would require a development process of its own in order to be able to concretize their needs for the design of a school space (Lallimo, 2014). The method of knotworking could then be profitably used to knit together the development of school activity and design activity in such a way that the future school activity would also be collectively envisioned. All relevant actors need to be invited to join this kind of process. This was not the case in the knotworking experiment. For instance, the school staff and pupils could not be reached due to the limited schedule of the experiment. The participation of the teachers was also light for the same reason.

The active participation of users not only extends the social process in school design, but the role of the architect and designers might also change in the near future. Sanders and Stappers (2008) think that designers might not be providing "stand-alone" design products but can become involved in the design of environments and systems of delivering different activities. The creation and testing of new methods of collaboration within a design team and with other stakeholders in the design process also mark the extension from single design offices to work carried out in more collaborative constellations of co-design such as knotworking.

The constraints of a project may also mean that all needs are not fulfilled, but it is worth expressing what the end users Parnell *et al.*, 2008, p. 215).

CONCLUSIONS AND THE FURTHER DEVELOPMENT OF KNOTWORKING

Knotworking can considerably intensify the early design processes. It is important to organize encounters in which different parties are able to learn about each other's objects of activity. An effective dialogue between different parties could increase understanding about the needs of other parties. However, client and user tools and processes require further development to enable the full participation of clients and users early in the design process. The organization of design processes in parallel with the development of school activity is also needed to ensure the functionality of spaces in the future. The pupils, students and the entire staff of the school need to be involved to be able to include their experiences of school activity into school design.

Units of analysis such as the border zone are important locations for examining the (inter)action, dialogue and power relations between designers, clients and users in a school design. The potentials of activity theory were not, however, taken into full use in this study. Further developments could provide a fertile ground for studying the emergence of contradictions not explicit at this phase of the design process. The development of knotworking has continued among big public estate agencies and private companies in Finland. One company has created a service product in which knotworking plays a central part. Knotworking has also been experimented with in the Danish defence sector, and currently knotworking is being applied in public organizations such as day cares in Denmark.

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