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Cognitively central actors and their personal networks in an energy efficiency training program

Kaisa Hytönen[a], Tuire Palonen[a], Kai Hakkarainen[a]

[a] University of Turku, Finland

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Abstract

This article aims to examine cognitively central actors and their personal networks in the emerging field of energy efficiency. Cognitively central actors are frequently sought for professional advice by other actors and, therefore, they are positioned in the middle of a social network. They often are important knowledge resources, especially in emerging fields where standard knowledge exchange mechanisms are weak. By adopting a personal network approach, we identified the cognitively central participants of a one-year energy efficiency training program, studied the structure and heterogeneity of their personal networks and determined which features were relevant to achieving these cognitively central positions. At the end of the training, the social networking questionnaire was sent to 74 course participants. Semi-structured interviews were conducted for the six most-central actors, whose personal networks were larger than those of the other participants. These six actors differed from each other in many respects; there did not appear to be a single explanation for why these persons achieved their central positions. In conclusion, we propose that becoming a cognitively central actor is an intricate process. It cannot be explained only, for instance, by actors' educational backgrounds, the level of their previous energy efficiency knowledge or their field of know-how. To understand this phenomenon, we must examine which organizations such people come from and how their expert profiles, which are related to their fields and competences, fit into the wider context of energy efficiency. More research is needed to determine whether the results are only typical of emerging fields.

Keywords: Personal Networks; Cognitive Centrality; Advice Seeking; Social Network Analysis; Emerging Fields; Energy Efficiency Training Programme

Corresponding author: Kaisa Hytönen, Department of Education, 20014 University of Turku, Finland, sakahy@utu.fi
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1. Introduction

In rapidly changing and complex environments and their associated emergent knowledge-laden global problems and challenges, professionals must share their knowledge and expertise (Hakkarainen, Palonen, Paavola, & Lehtinen, 2004) rather than rely on mere individual competencies. This study focuses on examining key experts who have crucial roles in adaptively coping with novel challenges and changing professional requirements emerging from swiftly transforming professional fields. The key experts are often considered to be exceptionally valuable networking partners and collaborators because they have strategic knowledge and competence as well as in-depth meta-level vision regarding a transforming multi-professional field. Their knowledge and competence is likely to be seen valuable by colleagues because they are deliberately building personal networks to interconnect heterogeneous social resources, expertise and know-how and reaching beyond their immediate peers and bridging professional fields, thereby changing the ecology of their professional learning. As a consequence, the key experts are most often sought for advice and assistance by those struggling with novel professional challenges.

Personal networking connections with key professionals and the expert cultures they represent are important in updating the expertise and skills needed for responding to the professional challenges of future working lives, especially in turbulent environments (Lehtinen, Hakkarainen, & Palonen, in press). Professionals must be able to solve unforeseen complex problems and to share knowledge and competences, often breaking the boundaries of traditional disciplines. Energy efficiency is one of the rapidly developing fields that has emerged through the intersection of several professional domains. Therefore, there does not appear to be one unified system to direct professional activity, and the standard knowledge exchange mechanisms are weak. Cooperation between professionals from diverse fields, who master varying bodies of expertise and pursue divergent professional tasks and projects, plays an important role in energy efficiency work. Extensive professional experience alone does not automatically guarantee a central professional position; deliberate and sustained efforts to work at the edge of competence and cultivate expertise play a critical role as well (Bereiter & Scardamalia, 1993). Although developing efficient energy usage practices and meeting global and national standards and directives regarding energy efficiency are some of the most important challenges of the 21st century, there are no established educational methods and practices for cultivating associated expertise in Finland. Therefore, efforts to create multifaceted personal expert networks and informal learning seem to play a significant role in professional development and updating expertise (see the similar situation regarding magicians' expert networks in Rissanen, Palonen, Pitkänen, Kuhn and Hakkarainen, 2013).

In our previous study (Hytönen, Palonen, Lehtinen, & Hakkarainen, 2014), we examined whether a training model that we call Academic Apprenticeship Education initiated in Finland in 2009, could help increase professional networking ties among participants. The study revealed that this energy efficiency training program, organized for actors who were already working on expert-level tasks, did not effectively support comprehensive networking or the creation of a knowledge exchange forum among the participants. However, there were some key professionals who were able to create valuable personal networking connections and contribute to professional collaboration during the training. This paper focuses on them.

1.1 Conceptual background

In complex and changing professional environments, targeted knowledge or competence is not always easily found or verified. In order to acquire new knowledge and appropriate novel professional practices as well as find required professional help and advice, professionals have to deliberately build and extend their personal networks (see Pataraia, Margaryan, Falconer, & Littlejohn, 2013). Resources obtained through personal networks can benefit professional development by providing access to networking partners and associated professional support and opportunities for informal learning. In order to obtain new knowledge, many key experts have to rely on their personal social networks, reaching beyond the boundaries of their workplace organizations rather relying merely on traditional institutional resources (Nardi, Whittaker, & Schwarz, 2000). However, to benefit from personal professional learning networks, workers must have cultivated networking competencies in terms of having the capability of finding and creating

useful connections, as well as maintaining and activating these connections when needed (Gruber, Lehtinen, Palonen, & Degner, 2008; Rajagopal, Joosten-ten Brinke, Van Bruggen, & Sloep, 2012).

The factors influencing the choices involved in building, maintaining and activating personal professional networks are related to (a) the trajectories of an actor's personal professional interests and needs, (b) the features of the contacts, such as the like-mindedness, benevolence and the potential learning and collaboration value of the relationship, and (c) the characteristics of the work environment (Rajagopal, Joosten-ten Brinke, Van Bruggen, & Sloep, 2012). According to the homophily principle, people often interact and create strong ties with those who have similar characteristics to themselves (Kleinbaum, Stuart, & Tushman, 2013; McPherson, Smith-Lovin, & Cook, 2001; Reagans, 2011). It follows that networks are often homogeneous in nature; people are more likely to create contacts with others who share the same gender, age, educational level, professional group and structural position. Therefore, homophily often impacts the information people receive from their personal social networks, the attitudes they form and the interactions they experience (Lozares, Verd, Cruz, & Barranco, 2013; McPherson, Smith-Lovin, & Cook, 2001). Professionals functioning in such networks often share a great deal of their knowledge and practices, immediately understanding each other (Wenger, 1998). Homogeneous professional networks do not, however, provide an adequate way of coping with the challenges involved in profound transformations of professional practices extending across multiple fields, such as in the case of energy efficiency work; personal networks are rich repositories of professional knowledge if they involve people with heterogeneously distributed knowledge and expertise and, thus, provide access to the resources embedded in these social relations (Lin, 2001).

Cultivating strategic competence in complex and extended professional fields, such as energy efficiency, appears to require deliberate efforts of creating networking connections across the boundaries of several fields of professional activity (Akkerman, Admiraal, Simons, & Niessen, 2006). Such efforts of crossing boundaries between professional cultures are likely to characterize networking activities of key experts, allowing them to mediate knowledge across the borders of different cultures and environments and bridge various fields of expertise with one another. Key persons are positioned in the middle of the communication structure and therefore have access to extended pools of knowledge and diverse sources of information. In the literature, actors with strategic networking positions mediating, translating and transmitting knowledge and good practices and creating connections between diverse people between different cultures (Meyer, 2010) are referred to as knowledge brokers (Sverrisson, 2001), gatekeepers (Morrison, 2008), stakeholders (Krueger, Page, Hubacek, Smith, & Hiscock, 2012; Svendsen & Laberge, 2005), stars (Borgatti, Mehra, Brass, & Labianca, 2009) and hubs (Barabasi, 2002). Sverrisson (2001) has distinguished between three approaches to knowledge brokering. Networking brokerage refers to connecting people, knowledge orientated brokerage relates to translating concepts and theories across disciplines that are critical to applying knowledge in complex projects, and organizational or technological brokerage involves facilitating novelty and innovation. Overall, people in the middle of the social network often disseminate knowledge culture by sharing information with people around them and between workplace organizations and their surrounding environments, and by building bridges among people and between bodies of knowledge (Burt, 1999).

To cope with the challenges of rapidly transforming environments of professional activity, key experts have to cultivate practices of adaptive expertise (Hatano & Inagaki, 1986). Such practices involve the cultivation of competency in successfully dealing with challenging, novel and unanticipated professional problems instead of clinging to old routines. Adaptive experts are those who deliberately invest resources released by accumulating experience in new learning and seek challenges that assist and elicit their learning and the development of expertise. Toward that end, many participants create deliberately novel networking connections and engage in inspiring encounters with heterogeneous networking partners. The creation of versatile networking connections and sustained sharing of professional expertise elicits the development of relational expertise, which is understood as the capability to productively tailor and fine-tune personal expertise to create joint or shared competence within communities and organized groups of experts and professionals (Edwards, 2010). People working in the emerging fields often come from different working sectors and representing various fields of know-how when combining different fields of expertise appears to

be important (see Mieg, 2006). Relational expertise recognizes the importance of resources provided by the different actors and the relevance of generating mutual understanding and shared goals over the borders of different fields of expertise, enabling collaboration (Edwards, 2010).

One way of assessing key experts' positions within a social network is the number of networking partners seeking their advice. Advice networks are comprised of relations through which participants share resources, supporting the completion of their assignments (Sparrowe, Liden, Wayne, & Kraimer, 2001). Who people contact when needing knowledge and advice and the reasons for seeking advice from these people has been studied (Creswick & Westbrook, 2010; Nebus, 2006), as has the kind of knowledge sought in advice networks (Cross, 2004; Cross, Borgatti, & Parker 2001). Motivations for asking for professional advice from someone seem to be related to the relevance and value of their information, the level of interpersonal trust (Levin & Cross, 2004), the advice seeker's perceptions of the knowledge source's expertise and credibility, accessibility, the expectations on how the contact will respond, and the assessed value and costs of seeking advice (Nebus, 2006). Investigations have revealed that information and advice relationships cultivated by people provide several types of knowledge, such as answers to know-what, know-how and know-who questions as well as meta-knowledge concerning where information needed for answering these questions may be found. In addition, knowledge received from advice networks might help to think differently about problems faced as well as validate and legitimize solutions and plans made (see Cross, 2004). Attainment of a central networking position in advice networks is often related to personal characteristics, such as an in-depth professional commitment, motivational engagement (Aalbers, Doflsma, & Koppius, 2013), a high level of professional performance (Sparrowe, Liden, Wayne, & Kraimer, 2001) and transformational leadership (Bono & Anderson, 2005).

In this study, we adopt a personal (egocentric) network approach to identify and examine key experts in an energy efficiency training program whose professional knowledge the other course participants frequently sought to share. We call such key experts, whose cognitive achievements are shared by their professional peers, cognitively central actors. The concept of cognitive centrality is derived from studies on group decision making in a social network framework (Kameda, Ohtsubo, & Takezawa, 1997). Kameda, Ohtsubo and Takezawa (1997) suggested that the more knowledge and competence a person shares with the other group members, the more cognitively central position he or she has in the group. Cognitively central group members who contribute intensively in collective problem-solving efforts are more influential in decision-making situations than peripheral members (Stasser, Abele, & Vaughan Parsons, 2012). Here, the concept of cognitively central actors will be used to refer to course participants who were positioned in the middle of the social network, have valuable, extended and heterogeneous networking connections, and, therefore, provide other participants with new and relevant knowledge, competences and assistance more often than others (see Kameda, Ohtsubo, & Takezawa, 1997; Palonen, Hakkarainen, Talvitie, & Lehtinen, 2004). In many cases, they appeared to have a high level of relational expertise in terms of having meta-knowledge regarding the social distribution of relevant knowledge across professional networks (i.e., knowing who knows what in a professional network). Traditionally, it is thought that persons who are often sought for professional and work-related advice are more knowledgeable and have more expertise than others. However, this is not necessarily the case in the emerging fields of complex professional activity where expertise needed for solving emerging problems is radically distributed or may not exist to begin with. More symmetric advancement of heterogeneously distributed knowledge (Scardamalia, 2002) by different participants may characterize such situations. Under such conditions, participants having a comprehensive vision of the future of their field as well as a high level of discernment, that is, a capability of assessing knowledge relationally in context (Facer, 2011), may become cognitively central participants.

This paper examines more closely who the cognitively central participants are in the field of energy efficiency, and it attempts to determine the possible reasons or personal features for achieving this kind of important networking position in the emerging field. We aim to understand why certain key persons are contacted and asked for knowledge and advice more often than others. Personal networks offer illustrative ways to examine knowledge exchanges and communication in complicated environments by enabling the integration of individual and community level attributes. Therefore, they enable the analysis of the properties of the one person "owning" the network (ego) and the properties of people belonging to his or her network

(alters), as well as the attributes of ego-alter ties and alter-alter ties (Hakkarainen, Palonen, Paavola, & Lehtinen, 2004). As a unit of analysis, personal networks, supplemented by other techniques, enabled us to look at network connections from different angles and across several levels and thus achieve a more accurate picture of multi-faceted and complicated social structures (Fuhse & Mützel, 2011). In all, we shall examine cognitively central actors' personal, social and organizational features relevant to achieving a central, strategic position among the participants in the energy efficiency training.

2. The aim of the study

The purpose of this study is to examine the personal networks of those key energy efficiency professionals who are often sought for professional information and advice by other actors working in the field, in other words, the cognitively central actors. Our specific focus is analysing how knowledge and competence sharing regarding energy efficiency issues was organized around particular persons and whether there were some features explaining why certain persons achieved a cognitively central position. The study was carried out in the context of a year-long energy efficiency training program.

Our hypotheses are as follows:

1) At the overall network level, cognitively central participants can be identified using an advice size indicator, that is, from whom the participants ask advice regarding their energy efficiency related problems.
2)
   a) At the ego-alter level, the structure of the cognitively central participants' personal networks differs from that of other course participants' so that their networks are bigger, denser and they have more broker capacity, that is, they connect the members in their personal networks.
   b) The central participants' personal networks are expected to be diverse in relation to their members' genders, university divisions, working sectors, educational backgrounds, previous experience-based knowledge of energy efficiency and the fields of their know-how.
3) At the ego level, the cognitively central participants have certain features that explain their prominent networking position. Such features can be expected to relate to their personal attributes and affiliations.

3. Methods

3.1 Energy Efficiency Training Program

This study was conducted in the context of the one-year Academic Apprenticeship Education program in the field of energy efficiency (Hytönen, Palonen, Lehtinen, & Hakkarainen, 2014). It was a pilot educational program organized for the first time in Finland in 2010–2011. The energy efficiency training aimed to support the cultivation of energy efficiency expertise in the public and private sectors, promote professional networking between the actors in the field and encourage the sharing of good professional practices. Three technical universities organized the training collaboratively: Universities A (n = 29) and B (n = 28) organized education mainly for actors working in the public sector, and University C (n = 30) organized education for actors working in the private sector. Fourteen participants working in the private sector participated in the educational training organized by Universities A and B because there were not enough spaces for all willing private-sector participants at University C. Altogether, 74 of 87 course participants completed the training program; 13 participants dropped out for various reasons.

The energy efficiency training was based on real-life working practices and included theoretical studies and workplace learning. The theoretical studies were organized into seven contact days, including lectures, small group work and discussions. The first three and the last contact days were organized jointly for all course participants, but the remaining three days were organized separately for the public and private sector actors. The three separated contact days involved themes that were relevant especially to either the public or the private sector. The timespan and practices for organizing the contact days were the same for all three universities. About 70–80% of the active time in the training program was assumed to take place in the participants' workplaces, where the participants conducted a developmental study project. The developmental study project aimed to support participants' professional development as well as the development of the workplaces' energy efficiency practices. On the last contact day, each participant presented his or her developmental study project.

Networking between the participants was supported by small group work. In each university, the course participants were organized into five small groups of five to six members according to their places of residence. In addition to small group work taking place during the contact days, the small group members were advised to meet at least three times during the training to discuss their developmental study projects and provide peer support. In addition, the course participants were encouraged to use the virtual learning environments provided by each university to support open discussion and knowledge exchange. However, the small group meetings and the use of the virtual learning environments were not controlled by any means. Furthermore, each participant was assigned an academic expert advisor on behalf of the universities and a workplace supervisor from his or her workplace organization. Their role was to provide professional support for participants in their developmental study projects and the process of workplace learning. The practices of the energy efficiency training are presented in further detail in Hytönen, Palonen, Lehtinen and Hakkarainen (2014).

3.2 Participants

At the overall level of analysis, all course participants were asked to participate in this study. Participation was voluntary, and the energy efficiency training was independent of this research. The participants were engineers, architects and other professionals with a masters- or bachelors-level education and varied lengths of experience in professional practices related to energy efficiency. At the ego-alter level of analysis, the participants were the 40 members (alters) of the central participants' personal networks in the context of the energy efficiency training. Personal networks included only other course participants; the academic expert advisors, the workplace supervisors and other colleagues were not investigated. Twenty-four of the alters were male and 16 were female. Fifteen of the alters participated in the education organized by University A, 12 participated in the education organized by University B and 13 participated in the education organized by University C. More detailed information regarding the alters is provided in the results section. At the ego level of analysis, the participants in the study were six cognitively central actors from the energy efficiency training who were identified from all the course participants by analysing advice-seeking in the first section of the analysis. They are described in more detail in the results section.

3.3 Social network methods

Network data were collected by administering an online social networking questionnaire to all 74 course participants (males, 50; females, 24) at the end of the training, out of whom 52 responded; the response rate was 70%. We also collected networking data in a similar way in the beginning of the training, but this study is based only on the latter data. The results concerning the changes in networking ties during the training are reported elsewhere (Hytönen, Palonen, Lehtinen, & Hakkarainen, 2014).

The networking questionnaire involved a list of the names of all course participants, and in relation to one another, the respondents were asked to assess the following: 1) from whom they sought advice regarding energy efficiency and 2) with whom they collaborated in terms of energy efficiency activity. To measure the strength of the networking relations, the respondents were asked to rate each of these items on a valued scale of 0 (no connection), 1 (a connection) or 2 (a strong connection).

A social network analysis (SNA) was conducted via UCINET 6 (Borgatti, Everett, & Freeman, 2002). We examined both the advice-seeking network, that is, how the participants sought energy efficiency information from one another, and the collaboration network, that is, how the participants collaborated with one another regarding energy efficiency issues. SNA was conducted at the overall network level and the ego-alter level. The different levels of analysis provided complementary dimensions for examining the cognitively central participants' networking. Regarding the overall network, multidimensional scaling (MDS) and advice size variables were used. In relation to the ego-alter level, the structure of connections between ego and alters was examined using different networking methods. Information about the features of alters was collected by a networking questionnaire that was developed according to earlier studies (Palonen, 2003).

At the overall network level of analysis, both the advice-seeking and collaboration networks were examined. From these two, the advice-seeking network was used to identify the cognitively central participants in the training because it is asymmetric in nature and does not require reciprocal networking connections. Therefore, it functions well as an indicator of a person's cognitive centrality (Palonen, Hakkarainen, Talvitie, & Lehtinen, 2004; Sparrowe, Liden, Wayne, & Kraimer, 2001). The cognitive centrality of the course participants was examined by calculating the centrality value (advice size), which indicates the amount of information that a person provides to the other members of the network. This was done using Freeman's in-degree measurement, which revealed how many course participants sought energy efficiency advice from the actor in question, that is, the number of incoming networking linkages based on peer evaluation. The analysis indicated how significant a role an actor's expertise played in the social network and thereby allowed one to identify the cognitively central actors among the participants. The analysis was conducted for the dichotomized network, so the frequency of communication was not analysed. Further, the network cohesion for the overall advice-seeking network was analysed via a density measure that characterized the number of existing networking ties in relation to all possible ties. To illustrate the structure of the overall network of all course participants and the structural position of the cognitively central participants, the advice-seeking and collaboration networks were visualized using the Spindel visualization tool (see www.spindel.fi) using the participants' network distances, which were provided by MDS techniques.

At the ego-alter level, to deepen the analysis, the structure and heterogeneity of the central participants' personal networks were examined. The advice-seeking and collaboration networks were merged for the following analyses by summing them up, and the merged network was dichotomized (cut point 0). The egocentric network was used as the unit of analysis. The structure of the central participants' personal networks was analysed by size, density and a brokering index. Size indicates the number of alters the ego is directly connected to; central members are expected to have a high number of contacts. Density was calculated among the central participants' network members; the number of ties was divided by the number of pairs multiplied by 100. A high density in the alter network indicates a low brokering or mediating role for a given ego. On the other hand, a low density indicates that the ego's position in the alter network is crucial. The brokering index is the number of times an ego lies on the shortest path between two alters. It is a parallel indicator for knowledge mediating. An undirected type of ego neighbourhood was used, meaning that all actors connected to and from an ego were considered (Borgatti, Everett, & Freeman, 2002). The Mann-Whitney U-test was used to analyse whether the structure of the central participants' personal networks differed from the structure of all other course participants' personal networks.

The heterogeneity of the central participants' personal networks was analysed by comparing the various properties among alters, as well as the properties between the egos and alters. First, we identified the alters by examining the egos' neighborhood in advice-seeking and collaboration. Second, we classified all participants in terms of the university they belonged to, educational background, working sector, gender, level of previous experience-based knowledge in energy efficiency and field of know-how. The estimation of the alters' previous energy efficiency knowledge was based on their self-reports. The central participants' personal networks were visualized using Cytoscape. The advice-seeking and collaboration networks were merged for the visualizations.

3.4 Semi-structured interviews and qualitative content analysis

Semi-structured interviews were conducted with all the cognitively central actors to complement the social networking data at the ego level of analysis. The interviews were carried out to examine the features of the cognitively central participants and the possible reasons they achieved a central networking position among energy efficiency workers. Data collection was carried out in two phases. Four of the six central participants identified were interviewed, both in the beginning and at the end of the training, as a part of broader data collection. After we conducted SNA and identified the cognitively central participants, we complemented the interviews by asking them to assess the possible reasons for their central networking positions. At this stage, the two remaining central participants were interviewed as well. The interview themes addressed the participants' educational backgrounds, work experiences, current work assignments and professional roles in relation to energy efficiency; their reasons for attending the training; their views on the energy efficiency field; their networking with the other course participants and other energy efficiency professionals, future prospects of developing energy efficiency expertise and their own opinions regarding the possible reasons for their cognitive centrality.

The interviews were audio recorded and transcribed by the first author. Qualitative content analysis was performed using ATLAS.ti 6.2. The analysis was conducted by identifying expressions related to the themes of adaptive expertise, relational expertise, disseminating knowledge culture and knowledge brokering. Content was identified and clustered independently by two researchers.

4. Results

4.1 Identifying the cognitively central participants at the overall network level

At the overall network level, we identified the cognitively central actors of the energy efficiency training program. The density analysis for the overall network revealed that 5% (SD = 21.8) of all potential networking linkages were present in the advice-seeking network. All course participants' cognitive centrality was analysed via Freeman's in-degree measure in the advice-seeking network. The measure is based on peer evaluation, and it reveals how many course participants have selected the actor in question as an information source. The cognitively central participants were selected on the basis of their high in-degree value, i.e., a minimum of seven linkages, as compared to the average for all course participants (M = 3.7; SD = 2.0) in the advice-seeking network (see Table 1). We selected six actors (A20, A26, B2, B21, C17 and C23) who were most often sought advice by their peers. There were two central actors from each university.

Multidimensional scaling (Figure 1) representing the overall network of all course participants revealed that the central actors from the public sector universities (A20, A26, B2 and B21) were located in the middle of the network, indicating that they were in close connection with participants from both public sector universities (see the video of Figure 1). Central participant C17 from University C appeared to be connected mainly with the other private sector participants. However, the other central participant from the private sector (C23) was positioned between the private and public sector universities. Overall, the course participants from Universities A and B were clustered more closely than the participants from University C.

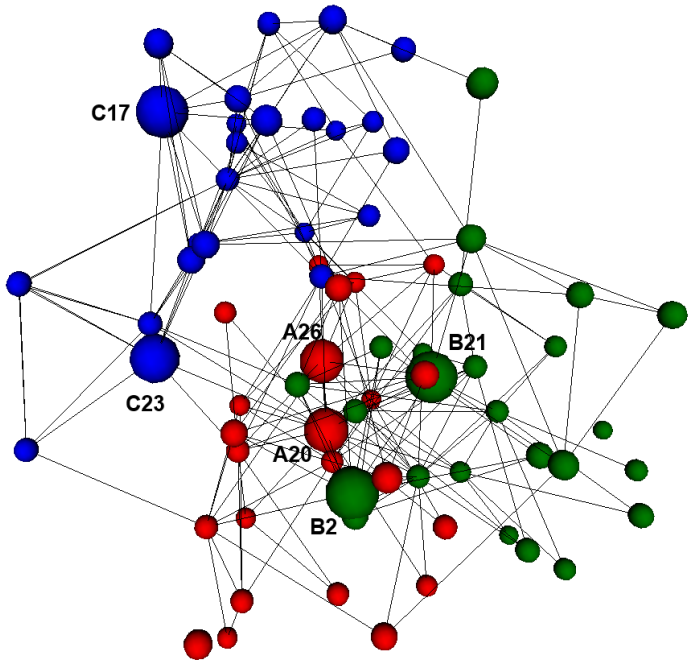

Figure 1. Overall network. The MDS figure is based on collaboration ties, whereas lines reflect advice ties. The figure, visualized using Spindel tools (www.spindel.fi), reveals how the central participants were positioned in the network of all course participants. The colour code in the graphs represents the university that the person comes from: red, University A; green, University B; blue, University C. The central actors are indicated by the large nodes and personal numbers. Click here to start the video.

4.2 Central participants' personal networks at the ego-alter level

At the ego-alter level of ties, we examined the structure and heterogeneity of the central participants' personal networks. The structure of the personal networks was assessed using the ego networks' basic measures, which are reported in Table 1. Two of the central participants, A26 and B21, did not respond to the networking questionnaire. Thus, their measures are based only on information provided by other course participants.

We used a Mann Whitney U-test to analyse whether the structure of the central participants' personal networks differed from the structure of all other course participants' personal networks. It appeared that there was a statistically significant difference in relation to the size ($z = -3.368$; $p = .001$), which was self-evident, and density ($z = -2.009$; $p = .045$) of the personal networks, as well as the brokering index ($z = -3.275$; $p = .001$).

To conclude, in addition to the fact that central members were most often asked for advice (that was the defining criterion), they had larger networks that were relatively sparse, indicating their own mediation role, which was also shown by the broker indicator. A20 had an especially large network, in which her own contribution was important and her brokering role was essential.

Table 1.

In-degree and Ego Network Measures

	In-degree measures	Size	Density (%)	Broker
A20	9	19	8	158
A26*	10	10	13	39
B2	7	11	23	42.5
B21*	9	9	8	33
C17	7	9	39	22
C23	8	11	22	43
M	8.3	11.5	18.8	56.3
SD		3.8	11.9	50.5
Measures for all other course participants (does not include central participants' measures)				
M	3.7	5.8	38.7	16.0
SD	2.0	3.7	29.7	29.7

* A26 and B21 did not respond to the networking questionnaire, and, therefore, their measures are based only on information provided by other course participants.

The heterogeneity of the central participants' personal networks was examined by analysing the network alters' university divisions, working sectors, educational backgrounds, genders, previous experience-based knowledge of energy efficiency (self-reported) and field of know-how. In Table 2 (see Appendix 1), we have provided the frequencies of alters belonging to each central participant's personal network, indicating the heterogeneity of the networks.

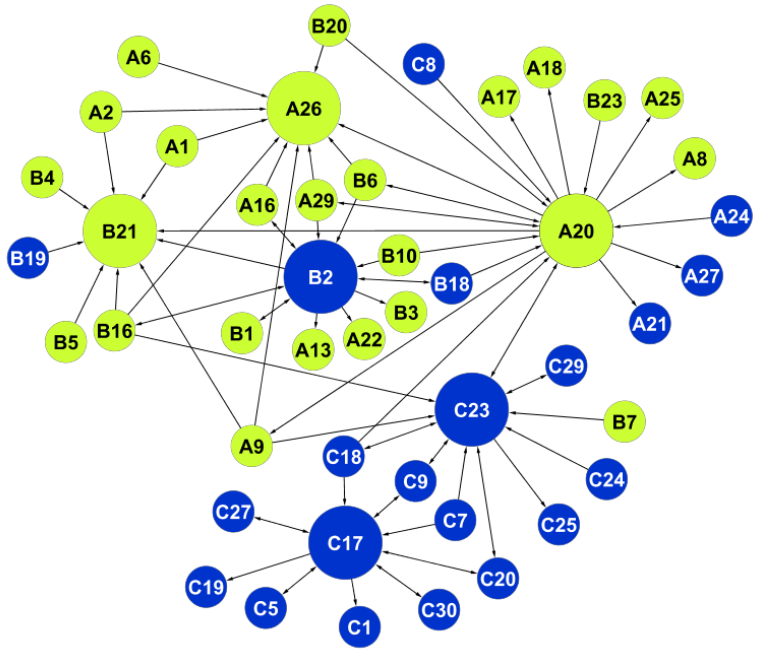

Figure 2. Network members' working sector. The colour code represents the working sector of the participants: green, public sector; blue, private sector. The large spheres represent the cognitively central participants and the small ones represent their network alters. For every participant, we have provided a personal number and a code identifying the university. The six central participants' personal networks are merged for the visualization. Alter-alter ties are not represented in the figure.

Figure 2 is a visualization of the central participants' personal networks in terms of their alters' working sectors. All personal networks have been merged into the same figure. The results indicate that the heterogeneity of the central participants' networks varied in terms of alters' home universities and working sectors, that is, whether they came from the public or private sector (see Table 2 and Figure 2). A20's and C23's personal networks were the most heterogeneous in this respect; they included rather even amounts of actors from both the public and private sectors and from all three universities. B2, who worked in the private sector but participated in the public sector education, had contacts with only the participants from the public sector universities. Obviously, participating in home university activities had more influence than the working sector as such.

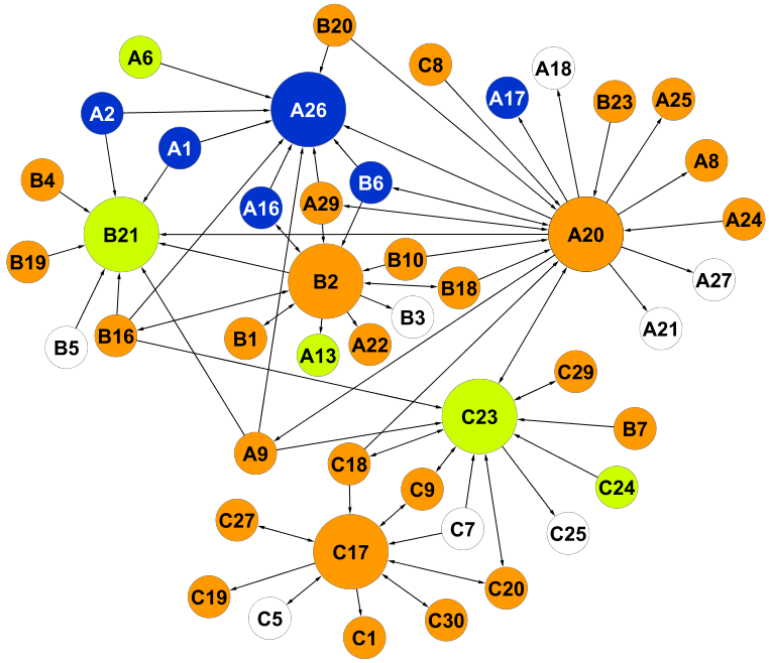

Figure 3. Network members' educational background. The colour code represents the educational background of the participants: orange, engineer; blue, architect; green, other; white, information missing. The large spheres represent the cognitively central participants and the small ones represent their network alters. For every participant, we have provided a personal number and a code identifying the university. The six central participants' personal networks are merged for the visualization. Alter-alter ties are not represented in the figure.

Furthermore, the public sector actors (A20, A26, B2 and B21) had varied educational backgrounds (see Figure 3 and Table 2), as did their alters, whereas the personal networks of C17 and C23, who worked in the private sector, had low levels of variety in this respect. With one exception, they included only engineers. The personal networks of A20, B2, B21 and C23 were rather heterogeneous in respect to their alters' know-how, whereas A26's and C17's personal networks were more homogeneous; in the personal network of A26, there were many alters doing either land use planning or construction planning in the public sector, and the majority of C17's alters were industrial planners in the private sector (see Figure 4 and Table 2).

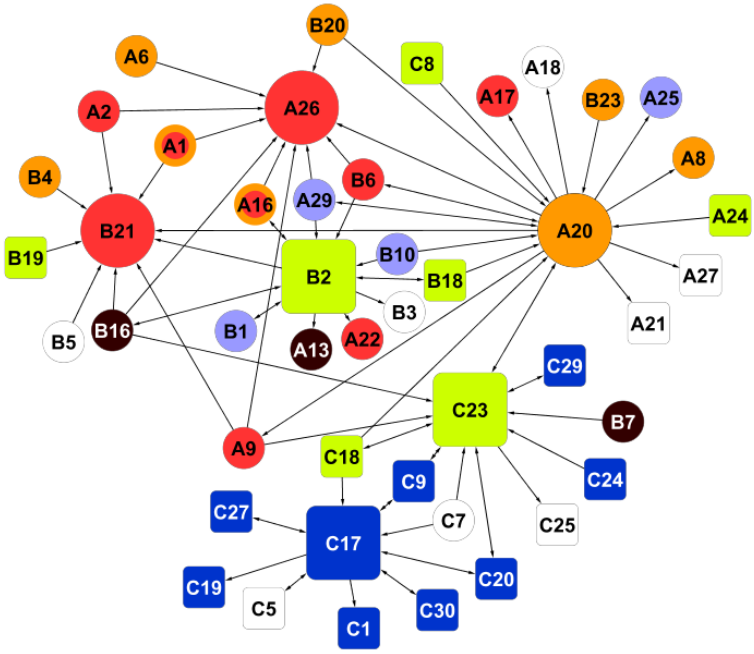

Figure 4. Network members' filed of know-how. The shape and colour code represent the field of know-how of the participants: Circle: red, land use planning; orange, construction planning; brown, environmental surveillance; violet, other; white, information missing. Square: blue, planning for industry; green, consultant/surveillance/planning; white, information missing. The large spheres represent the cognitively central participants and the small ones represent their network alters. For every participant, we have provided a personal number and a code identifying the university. The six central participants' personal networks are merged for the visualization. Alter-alter ties are not represented in the figure.

Figure 5 reveals that in the personal networks of A20, A26, B21 and C23, there were nearly the same number of female and male alters (see also Table 2). In the networks of B2 and C17, there were more participants from their own gender group. It appeared that in the private sector, the central participants' personal networks were more male-oriented. This could be explained by the fact that in the context of this particular energy efficiency training, males worked in the private sector more often than females.

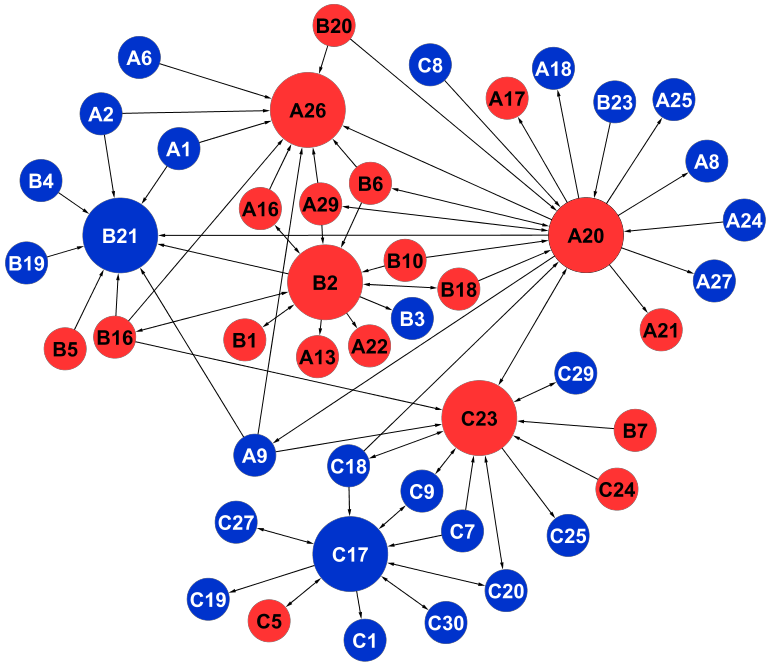

Figure 5. Network members' gender distribution. The colour code represents the genders of the participants: blue, male; red, female. The large spheres represent the cognitively central participants and the small ones represent their network alters. For every participant, we have provided a personal number and a code identifying the university. The six central participants' personal networks were merged for the visualization. Alter-alter ties are not represented in the figure.

Figure 6 visualizes the central participants' personal networks in terms of their alters' previous self-reported, experience-based energy efficiency knowledge. The figure reveals that two of the central participants (A26 and B2) had little or no previous knowledge of energy efficiency (see also Table 2). Obviously, their central networking position is explained by something else. Overall, in each central participant's personal network, there were alters with varying amounts of previous energy efficiency knowledge. In this respect, the personal networks of inexperienced participants did not differ from those of experienced participants.

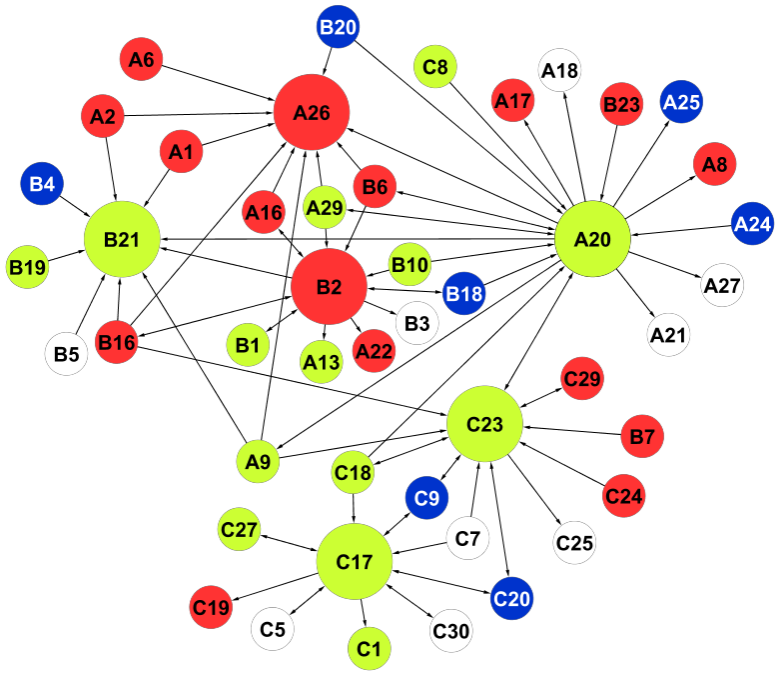

Figure 6. Network members' previous experience-based professional knowledge of energy efficiency. The colour code represents the level of participants' previous knowledge of energy efficiency: green, strong; blue, some; red, minor or none; white, information missing. The large spheres represent the cognitively central participants and the small ones represent their network alters. For every participant, we have provided a personal number and a code identifying the university. The six central participants' personal networks are merged for the visualization. Alter-alter ties are not represented in the figure.

4.3 Ego level: Features for achieving the cognitively central position

At the ego level of analysis, using the interview data, we examined who the cognitively central actors were and which features were relevant to achieving a central position in more detail. The cognitively central actors differed from one another in terms of age, educational background and the length of work experience (see Table 3). In addition, they had different levels of previous energy efficiency-related knowledge in terms of their job description. The interviews revealed that there was not one common explanation as to why these six participants achieved cognitively central positions. Instead, various features were emphasized. It is obvious that a central position was not achieved based only on the strength of personal characteristics but also on the basis of what kind of information the other participants were requesting from the cognitively central actors. Therefore, the features relevant to achieving the central position are related to the nature of the central participants' expertise, their knowledge brokering roles or positions between various fields or cultures, the nature of their employers and their own attitudes towards energy efficiency. In addition, they appeared to be interested in pursuing careers in the energy efficiency field.

Central participant A20, "a knowledge-sharing representative of an important organization", had strong and wide-ranging working experience in energy efficiency in both the public and private sectors. In her current workplace, a significant public organization, she worked as an energy efficiency expert. As the organization's "internal help", she was responsible for ensuring that energy efficiency was taken into account in the organization's approaches and decisions, and she advised fellow workers on energy efficiency issues. A20 appeared to have versatile professional connections that supported her daily work, and she emphasized the importance of professional collaboration. Her employer functioned as a forerunner in developing and implementing energy-efficient practices and operational models in the public sector. She

considered it crucial to openly discuss and share the newest knowledge and experiences among actors working with energy efficiency issues in order to promote the development of the energy efficiency field, energy efficiency consciousness and good operational practices: "I've pretty openly adopted the orientation that I'm just going to talk and give those ideas." In her experience, it is important to freely discuss both successful and unsuccessful undertakings because this benefits the development of the entire domain. A20 herself assessed that her open attitude towards sharing all types of energy efficiency knowledge was the most important reason for her cognitively central position. By performing research, A20 deliberately aimed to expand her own know-how regarding energy efficiency as well as to produce new information. She highlighted the fact that even though plenty of theoretical and technical energy efficiency knowledge and expertise exists, it is important to produce more practical knowledge and real-life examples to help steer the work of actors working with energy efficiency issues. The challenge is also to produce intelligible energy efficiency knowledge for common people: "About 80 percent of the others [populace] don't understand anything about basic facts if you don't translate them into images, and they don't need to, because I don't understand anything about basic medication. It's the doctor who tells me what I have to eat to cope with those symptoms."

Table 3.

Background Information for the Central Participants

	Age	Gender	Education	Work experience (years)	Job description in relation to energy efficiency
A20	35–39	Female	Engineer	11–15	A central part of the job description
A26	55–59	Female	Architect	36–40	In the background
B2	40–44	Female	Engineer	11–15	In the background
B21	30–34	Male	M.Sc.	1–5	About half of the job description
C17	25–29	Male	Engineer	1–5	A central part of the job description
C23	30–34	Female	M.Sc.	1–5	A central part of the job description

Central participant A26, "an experienced worker and 'missionary'", was an architect by training and, like A20, worked at a remarkable organization in the public sector. She did not have any actual experience in energy efficiency issues before participating in the energy efficiency training but did have a great deal of work experience in her own field. By participating in the energy efficiency training and other available education, A26 aimed to become a kind of "internal energy efficiency consultant" in her employing organization: "It's like I have this kind of a model currently in my mind, or that's developed, about how I can first get this workplace community educated about taking the importance of energy efficiency into consideration." In this way, she wished to be able to raise the awareness of energy efficiency practices and deliver them to her employer; she described herself as "a kind of a missionary", though she reported holding a peripheral position in her workplace, without any support from her superintendent.

Central participant B2, "a gatekeeper for electrical engineering", worked in a small private company, although she participated in education that was organized mainly for the public sector actors. She had strong technical know-how related to electrical engineering. As an electrician, she worked with assignments that were not directly related to energy efficiency, and her previous energy efficiency knowledge was minor. However, she highlighted the fact that awareness of energy efficiency matters is increasing in electrical engineering because of changing legislation and the increasing demands of customers; in the future, designs will have to be sustainable in the long term and not "only such easy fixes". B2 emphasized that in electrical engineering, actors are "contemplating their navels" too much instead of collaborating with other domains. Participating in the training and networking with the other course

participants widened B2's own professional viewpoint and convinced her of the importance of networking and collaboration across the borders of professional fields: "We often considered, together with the planners, before the basic elements of a construction project, how could energy efficiencies be defined and such, even before the building is on the table." The field of electrical engineering was unfamiliar to the most of the other course participants, and therefore B2 herself was able to provide them with a new kind of knowledge, presenting a novel perspective on energy efficiency.

Central participant B21, "a liaison and eco-man", was a M.Sc. by training. His job description and know-how comprised mainly of eco-efficiency, thus including many aspects of energy efficiency: "I am some sort of eco-man, so in a sense, when situations emerge in which I have to take a position on climate or energy issues, then I'm involved in such projects." In his workplace, B21 functioned as a coordinator and knowledge mediator between land-use-planning actors and environmental authorities regarding issues related to energy efficiency: "It is just this kind of role of 'combiner', because of course I don't know about energy issues as much an engineer from City Energy [name changed]. On the other hand, he doesn't know anything about land-use planning. Still, I'm not such a great land use designer either, so we have several architects, but then again, they don't necessarily know anything about energy efficiency." Overall, B21 emphasized that cross-administrative and versatile professional network connections are important in dealing with daily assignments. His employer was a significant public organization that functioned as an example for smaller municipalities. B21 emphasized that, as a large organization, it has better resources with which to develop energy-efficient operational models than smaller municipalities: "We have really been able to do the kind of development work that not many municipalities can afford or even have time for maybe, so in that sense, we've got a pioneering role." Therefore, B21 had profitable energy efficiency related knowledge and advice that he could share with the other course participants working with similar questions.

Central participant C17, "an adaptive expert in the industrial sector", worked in a private company. Although he had only three years of working experience, he had developed strong expertise in energy efficiency issues in a particular industrial field in which his daily work assignments were directly related. C17 had acquired his current energy efficiency knowledge through a few years of purposeful and deliberate efforts toward self-development, and further, he aimed to achieve a comprehensive understanding of all kinds of energy efficiency matters: "Since I started working in this company, I've tried to find an extensive vision for the industrial air pressure systems, their energy efficiency and industrial energy efficiency in general." C17 highlighted the extreme importance of increasing the awareness of efficient energy usage in the industry so that energy efficient behaviour will become a natural and axiomatic part of daily routines, instead of being "a mandatory chore". Overall, C17 wished for more openness and interaction between those actors dealing with energy efficiency issues in order to promote the diffusion of good ideas and, more generally, the development of the entire energy efficiency field: "My overall opinion, outside of this training in general, is a desire to pursue openness and open communication, like exchanging ideas and not holding back information." He aimed to promote this himself by sharing new energy efficiency knowledge, information and perspectives with his colleagues, as well as to customers and other actors in the industry. He had a mission of "starting, so to speak, to declare our message to our customers and collaborators and other possible parties".

Central participant C23, "a bridge between the public and private sector", had a degree in environmental technology. Therefore, she had a different educational background than the majority of her colleagues and other course participants, who were mainly engineers, and a less technical perspective on energy efficiency. She had become acquainted with energy efficiency matters in her current workplace, a private company; her job description included consultancy and planning related to various energy efficiency issues and projects. C23's clients were actors and organizations from both the private and public sectors, and therefore, she had gained wide-ranging knowledge and experience in various kinds of energy efficiency issues that could be exploited in industrial and public sector assignments. Because of her professional position in the intersection of these two sectors, many participants already knew her before the training: "I work on both the municipal and the industrial sides, which is probably why, in my training, the people on the municipal and industrial sides knew me. I was probably in the middle there." C23 emphasized that networking and collaboration are required in the diverse energy efficiency field; she stated that it is

important to have a network of professionals with various kinds of know-how to consult when help and advice are needed—a kind of meta-knowing about who-knows-who-knows-what (Borgatti & Cross, 2003): "Nobody can be an expert in everything, so it's good to know about people who know about some issues and to be able to create such [connections] if you end up working on some projects for customers."

To sum up, becoming a cognitively central actor is an intricate process that cannot be reduced to personal characteristics. It is related to the organizations that the actors represent, the expert profiles or competences that they have and how these complement the wider context. Cognitive centrality is therefore not only an individual-level capacity.

5. Discussion

In this study, we relied on the personal network approach to examine which features were relevant to achieving a cognitively central networking and knowledge sharing position in the Academic Apprenticeship Education program in the field of energy efficiency. In emerging fields such as energy efficiency, where standard knowledge exchange mechanisms are still weak, cognitively central members, whose professional knowledge is frequently sought by other actors, are expected to be very important knowledge resources for other members in the network in terms of mediating knowledge and creating connections between different professional cultures. The analysis revealed that the six most central participants differed from each other in many respects, including the length of their work experience, educational background, how much they were involved in energy efficiency and what kind of organizations they came from. Whatever the reason, these participants were asked for energy efficiency-related information more often than the other participants, and their knowledge mediating role in energy efficiency issues was essential. Thus, the results revealed that there was not a single shared feature that can explain why certain participants became more cognitively central than their peers.

According to the homophily principle, people tend to interact more frequently with those who have similar characteristics to themselves, such as those with similar educational levels or members of a joint professional group (McPherson, Smith-Lovin, & Cook, 2001). The present analysis of the central participants' personal networks, in contrast, revealed that many of the networks were rather heterogeneous in nature, including a rich variety of people with different educational and working backgrounds, as well as professional and energy efficiency-related experiences. In particular, the personal network of central participant A20, who had the most important knowledge sharing position in the training, was outstandingly heterogeneous in nature. Such heterogeneous resources are obviously needed for coping with a continuously changing environment. Even though our previous study (Hytönen, Palonen, Lehtinen, & Hakkarainen, 2014) indicated that the energy efficiency training did not support participants in comprehensive networking, the creation of an occupational knowledge-exchange forum and the use of one another's complementary expertise on a large scale, the results of this study revealed that some course participants were able to find valuable new connections with people who had novel perspectives on energy efficiency and to cross the boundaries of their immediate professional fields (Akkerman, Admiraal, Simons, & Niessen, 2006). Apparently, the cognitively central actors possessed knowledge that other course participants found usable, even though they did not necessarily represent the same professional context or culture (see Edwards, 2010).

Cognitive centrality is obviously not related only to personal attributes, such as a high level of professional experience, previous energy efficiency-related knowledge or personal characteristics. It is also related to social contexts, for instance, the nature of the operational environments and employing organizations that the participants represented. In addition, the results indicated that the participants' forms of expertise and competence were relationally and contextually assessed (Mieg, 2006); their fields of know-how were not necessarily energy efficiency, but they had strategic and special knowledge in some particular area, such as electrical engineering, that was found useful by other course participants. In addition, the participants representing significant public sector organizations appeared to possess advanced and trustworthy knowledge that was valued by the other participants and that they needed in their own professional contexts (Levin & Cross, 2004).

In advice-seeking networks, help is often asked for from persons presumed to be the most knowledgeable and having the strongest experience in the issue in question (Nebus, 2006). Cumulative individual experience is expected to increase individual proficiency (Reagans, Argote, & Brooks, 2005). However, this investigation revealed that it is not only lengthy professional experience or strong expertise in energy efficiency that make a person cognitively central. Other factors such as personal enthusiasm or energy efficiency awareness were, in some cases, more important than strong professional competency or an extensive experience in the field. It seemed to us that young workers with rather limited working experience may quickly acquire relatively strong expertise and become cognitively central knowledge mediating professionals if they deliberately attempt to increase their expertise and succeed in reaching considerable professional capability (Ericsson, 2006; Hatano & Inagaki, 1986). This can be the case especially in emerging fields, in which there are no strong established paradigms and working cultures and where good operational practices are still developing.

Recent changes in the working world highlight the importance of multi-professional collaboration (Edwards, 2010) and a role as a boundary-spanning knowledge broker for professionals (Johri, 2008). In addition to mediating knowledge, the key persons acting as knowledge brokers often produce a new kind of brokered knowledge that has been assembled based on knowledge collected from different cultures (Meyer, 2010). One essential reason for achieving a cognitively central networking position in the energy efficiency training program was obviously bridging the gaps between various professional cultures and working environments, that is, those between the public and private sectors and between disciplines. In these positions, the cognitively central participants were able to process, build and even create new energy efficiency knowledge to be utilized in novel situations and tasks. It appears to us that the three brokering roles introduced by Sverrisson (2001) were present at least in some forms in the central participants personal networks; they obviously connected people working with the energy efficiency issues (networking brokerage); created and translated concepts, theories and new knowledge of energy efficiency (knowledge oriented brokerage); and facilitated innovations and good operational practices and new operational models (brokerage of organizational or technological novelties) in and between the public and private sector organizations. The results indicated that the knowledge mediating role of the central participants was important both in the energy efficiency training and in their larger working environments in terms of aiming to increase awareness of energy efficiency practices and disseminating them to their workplaces. In addition to efforts towards purposeful and continuous self-development (Ericsson, 2006; Hatano & Inagaki, 1986), some cognitively central participants showed a strong willingness to promote the overall development of the energy efficiency field by systematically creating and sharing knowledge and working for the diffusion of good energy efficiency practices. In this, the importance of socially shared professional goals appeared to have essential role (Edwards, 2010).

In emerging fields, there is often a lack of a stable knowledge base and formal education, as is the case in the field of energy efficiency in Finland, and therefore, professional learning takes place through informal and incidental learning (Watkins, Marsick, & Fernández de Álava, 2014; Palonen, Lehtinen, & Boshuizen, 2014). Finally, it is presumably not possible to determine all possible reasons why someone is a hub for communication. The interviews revealed that informal networking connections and collaboration had important roles in professional activities and development. One example of this was found in the context of participants' joint discussions related to everyday energy-efficient practices, such as cooling gardens in the summertime. Informal and incidental learning happens without much external facilitation and often occurs unsystematically, and it is therefore difficult to elicit and understand from an outside perspective.

5.1 Limitations and further steps

One of the limitations of this study was that two of the central participants did not respond to the networking questionnaire. Therefore, their data were based only on information given by the other course participants, and we were not able to examine those relationships that they themselves may have had with others, that is, outgoing linkages. In addition, only a limited number of the course participants were interviewed, and, therefore, more research is needed to generalize the results. However, this study demonstrates the potential value of the personal network approach in the study of professional knowledge

exchange in complex environments. SNA provided a useful multi-level approach for determining the cognitively central actors possessing strategic competence in multi-professional fields, studying their role in professional networking and knowledge exchange and examining both the social context and the characteristics of individual actors in these processes. Personal networks are often studied via egocentric network interviews in which the participants (egos) are asked to list the alters belonging to their personal networks and to evaluate the relationship between themselves and the alters as well as between each individual pair of alters. In this study, we used the overall network data to study the cognitively central participants' personal networks. This approach allowed us to use ties incoming from other course participants to estimate cognitive centrality and to analyse the structure of the personal networks (McCarty & Govindaramanujam, 2005) and to visualize the networks on both the overall (sociocentric) and personal levels (see McCarty, Molina, Aguilar, & Rota, 2007).

Our study contributes to professional learning research by elaborating the concept of cognitive centrality and widening its use outside a small group research. This approach is useful, especially for extension studies. Future studies should examine in detail what kind of advice is sought from the cognitively central participants and how it is related to the nature of their expertise. In addition, more research is needed to better understand the phenomenon of cognitive centrality and to discover whether the results found are typical for emerging fields but not generalizable to other contexts.

Keypoints

- Methods of analysing personal social networks provide a functional unit of analysis for studying the personal and social features of knowledge exchange in complex environments.
- This study introduces a concept of cognitive centrality and the diverse reasons behind this phenomenon.
- The article explains how cognitive central actors can be identified and how the flow of advice is centralized in the context of professional networks.
- This study addresses professional development in an emerging field (i.e., energy efficiency) where the knowledge base is not yet stable or consolidated.
- The paper focuses on learning processes in the context between working life and higher education institutions and explicates the features that are essential there.

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Appendix 1

Table 2.
Heterogeneity of Personal Networks

	University			Working sector		Education				Gender		Previous energy efficiency knowledge			
	A	B	C	Public	Private	Engineer	Architect	Other	Not known	M	F	Strong	Some	Minor	Not known
A20	10	6	3	12	7	11	3	2	3	10	9	7	4	5	3
A26	7	3	0	10	0	5	4	1	0	4	6	3	1	6	0
B2	7	4	0	10	1	6	2	2	1	2	9	5	1	4	1
B21	4	5	0	7	2	6	2	0	1	5	4	3	1	4	1
C17	0	0	9	0	9	7	0	0	2	8	1	3	2	1	3
C23	2	2	7	4	7	8	0	1	2	7	4	3	2	4	2

	Field of know-how							
	Public sector					Private sector		
	Land use planning	Construction planning	Environmental surveillance	Other	Not known	Industrial planning	Consulting, surveillance, planning	Not known
A20	5	3	0	3	1	0	5	2
A26	5	5*	1	1	0	0	0	0
B2	5	1*	1	3	1	0	1	0
B21	3	3*	1	0	1	0	2	0
C17	0	0	0	0	0	5	2	2
C23	1	1	2	0	0	4	1	2

[a] The number in each column indicates how many alters the central participants have in their personal network in relation to specific indicators (university, working sector, educational, gender, previous energy efficiency knowledge and field of know-how).
[b] * For land use planning and construction planning the expertise areas are overlapping and there are 2 persons that have been added to both columns.