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Does academic apprenticeship increase networking ties among participants? A case study of an energy efficiency training program

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Abstract In order to address the requirements of future education in different fields of academic professional activity, a model called Academic Apprenticeship Education was initiated in Finland in 2009. The aim of this article is to analyse the development of expert networks in the context of a 1-year Academic Apprenticeship Education model in the field of energy efficiency, which is a new and rapidly developing knowledge-intensive field. We examined the creation of networking ties among all course participants, the process of networking in small groups, and individual participants' networking activity. Data was collected by administering a social networking questionnaire in the beginning and at the end of the training to all course participants (n = 87) and analysed using social network analysis and repeated measures ANOVA. In addition, semi-structured interviews were conducted with organizers of the training to examine how the operational practices of the training supported networking. The results indicated that there was little change in the networking ties among all course participants. However, those small groups that were able to communicate appeared to create internal linkages. At the individual level, more new ties emerged for private sector actors than for public sector actors. In conclusion, we propose that a consolidated educational model should be created for the Academic Apprenticeship Education model in general. The quality of education might be better assured if the current ad hoc networks were not the only way to organise knowledge exchange among participants.

Keywords Academic Apprenticeship Education model · Expert networks · Energy efficiency · Social network analysis · Change in network ties

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Introduction

Professions are not static entities. Established professions continuously evolve in conjunction with new professions, emerging and gradually becoming mainstream as a function of developing societal challenges and interests, technological breakthroughs, and changing legislations. The driving forces of professional transformations are change in the global environment of professional activities, gradually diversifying professional practices, perceived limitations of prevailing practices for addressing novel challenges, reconsideration of available alternatives, and the need to create novel and more stringent professional standards (Dower et al. 2001; Talwar and Hancock 2010). However, in new professions, professional pathways for developing expertise are not yet established, and professional development partially occurs at workplaces as part of one's own work assignments. Therefore, becoming and being an expert professional actor requires individuals to collaborate effectively with people facing similar challenges as well as negotiate across disciplinary boundaries (Edwards 2010). The more complex, changing and uncertain the operational environment is, the greater the need to collaborate and create professional networking connections that ensure access to critical know-how and competencies (Nooteboom 2004).

The present study examines the development of expert networks in the field of energy efficiency. Energy efficiency is a new, rapidly developing knowledge-intensive field of professional activity that requires actors to significantly deepen their expertise to meet emerging demands for and changing legislations on efficient energy usage. The EU and other multinational organizations are creating novel standards, and finding solutions to problems related to efficient energy usage that is one of the most important challenges of the twenty-first century. In energy efficiency, as in many other domains, the logic of professional development has become defined in global terms so that there are connections to shared standards and work-based practices that are routinely used at the local level (Fourcade 2006). Despite this, there are no specific education and training programs for developing general expertise; therefore, professionals have to rely on diffused knowledge resources and ad hoc practices. Energy efficiency is an excellent example of a new domain in which professional development is embedded in deliberate creation and cultivation of versatile network relations (see Hakkarainen, Palonen, Paavola and Lehtinen 2004).

Networks provide access to social capital—resources, information and support of other actors—that is embedded in social relations (Lin 2001; see also Hytönen, Hakkarainen and Palonen 2011). They enable people with different types of expertise and professional competence to share and receive knowledge and know-how, as well as to gain new ideas which they can utilize and develop in their own specific contexts and frameworks; thus, networks enable professional development (Gruber, Lehtinen, Palonen and Degner 2008).

However, the networking connections that are available can be fully utilized only when the participants are aware of each other's knowledge and expertise, in other words, when they have meta-knowledge about where and from whom the information can be obtained (Borgatti and Cross 2003; Cross et al. 2003; Hakkarainen et al. 2004). Such relational knowledge of 'who knows what' enables knowledge to flow across the boundaries that appear in the network (Cross et al. 2003). By bringing together complementary resources provided by participants, it is possible to work collectively towards shared goals and cultivate mutual expertise. This, in turn, requires participants to recognize the boundaries of their own competence as well as those of others (Edwards 2010; Akkerman and Bakker 2011). Nooteboom (2004) argued that learning through networking is likely to occur when participants possess sufficiently varied know-how, but, simultaneously, sufficient similarity to engage in productive dialogue.

Wide-reaching and heterogeneous network connections support hybridization of expertise; such connections combine and integrate previously independent domains and fields of know-how (Howells 1998). The hybridization of expertise appears to play a crucial role in emerging knowledge-intensive professional fields that require integrating previously separate bodies of knowledge and competence in the present, changing the global environment of activity. In multidisciplinary fields, a particular professional may provide core competence that integrates other domains of knowledge and competence. Rapid changes in the world and working environments require a new system of education for professionals, who will, in the future, face novel challenges and complexities—for example, those related to energy efficiency (Adams et al. 2011; Vest 2008).

The current investigation focuses on examining a new academic education program in the field of energy efficiency. In order to address the requirements of future education in different fields of professional academic activity, a new model for further education was begun in Finland in 2009, funded by the Ministry of Education and Culture. The funding was given to universities to develop the extensive further education programmes; annually, 1,200 participants participate in professional training activities related to the model (Presentation memorandum, Ministry of Education and Culture 2011). The model is aimed at professionals that already work in expert tasks, which are often multi-scientific and rapidly growing, but face a need to update and expand their expertise. Therefore, the group of participants tend to be heterogeneous. The model fits in fields that are located in the boundary zones of universities and working-life organisations or institutions, and cope with complexity by capitalizing on both practical and scientific knowledge. It aims to strengthen the cooperation between working-life and higher-education institutions, thereby integrating learning within the framework of academic education and work (see Billett and Henderson 2011). Consequently, it appears to us that the Finnish model that is closely related to practice bears features of apprenticeship type of learning (Lave and Wenger 1991). Apprenticeship type of learning has traditionally been used in vocational education but, recently, applied to knowledge workers and knowledge-intensive fields as well (Fuller and Unwin 2010). Overall, it appears to be an evolving model of learning and, lately, new approaches in the field of apprenticeship policy and practice have been actively developed in different countries (Fuller and Unwin 2011); apprenticeship is no longer seen just as an age- or phase-specific model of vocational formation but, instead, a social model for formation and reformation of professional expertise (Guile 2011). To distinguish the new Finnish apprenticeship model from the traditional one (Lave and Wenger 1991), we term it the Academic Apprenticeship Education model.[1]

The Academic Apprenticeship Education model is not imparted based on a consolidated curriculum but is informal in nature. Each program comprises 30 credit units and, according to guidelines given by organizing universities, approximately 70–80 % of the active time usage is expected to occur at the participants' workplaces; however, this is not a strict criterion or controlled by any means (Presentation memorandum, Ministry of Education and Culture 2011). Workplace learning is complemented with six to ten contact days organized by universities, which include lectures, workshops, group work and online study. Ideally, higher education institutions guiding the training of professional experts provide solid research-based knowledge that assists in deepening and higher-level integration of the skills and competencies appropriated and cultivated at workplaces. In order to facilitate integration of workplaces and academic learning, as is characteristic of the apprenticeship type of learning,

[1] The Finnish name of the education model is Oppisopimustyyppinen täydennyskoulutus (Gröhn 2011).

each participant is assigned a professional supervisor from his or her workplace organization as well as an academic expert advisor on behalf of the universities.

The added value of the Academic Apprenticeship Education model in the field of energy efficiency is to create a network forum for participants to cultivate their skills and share expertise in their domain. Because the field is new and emerging, there are rarely other experts in the same workplace, and, therefore, creating supportive occupational learning environment and becoming a member of a professional network (see Fuller and Unwin 2010) would be especially important. Especially networks that are organized on the interface of different working cultures may provide a forum for sharing of knowledge and creating new professional connections (Hytönen and Tynjälä 2005; Roxå et al. 2011). Our study is developed on the basis of Social Network Analysis that is particularly focused on uncovering the patterns of people's interaction. Thus, our approach needs to be distinguished from the theories that treat objects as a part of social networks and shed light on socio-cultural artifacts, such as the Actor-Network theory that is currently very popular in the field of education and development.

In some ways, creating novel networking connections as tools for maintaining skills and knowledge in a rapidly changing environment, beyond formal education, may be considered the most important outcome of education. However, it is often taken for granted that professional education promotes the creation of ties among participants, even though it is only seldom that investigators have sought specific evidence supporting this expectation. Recent studies have received opposite results regarding the emergence of learning networks in blended learning environments (Rienties et al. 2013; Rienties et al. 2013). Consequently, it would be important to understand the type of learning settings in which networking relations evolve and why. In the current investigation, we examined whether one specific instance of this new Academic Apprenticeship Education model was capable of widening professional networks for a set of energy efficiency experts with heterogeneous expertise, facing wide-ranging issues and operating in diverse working environments.

Research aims

The broad aim of the current study is to analyze the development of expert networks within the emerging field of energy efficiency in the context of the 1-year-long Academic Apprenticeship Education model. The study has the following four objectives: (1) to examine whether participants establish professional ties with other course participants at the overall network level, that is, among all course participants, (2) to analyze structures and processes of networking at the small-group level and (3) to examine networking activity at the individual level. The networking ties among all participants were expected to increase at all levels across the training. Further, it was expected that new ties would be created, particularly within small groups because teamwork was used as a central method for promoting informal interaction and formation of networking ties among participants.

Method

Context and participants

The present investigation was conducted in the context of the 1-year-long Academic Apprenticeship Training in the field of energy efficiency in Finland in 2011. The training was organized for the first time and aimed at supporting the cultivation of energy efficiency expertise, promoting sharing of good practices and professional networking, as well as identifying practices to educate future professionals in this growing field. It was organized in collaboration with three universities of technology. Universities A (n = 29) and B (n = 28) organized education for actors in the public sector presumably characterized by collaborative sharing of knowledge and University C (n = 30) for actors in the private sector that collaborate within a more competitive environment. However, some actors working in the private sector participated in the education program organized by Universities A (n = 6) and B (n = 8) because there were more willing private sector participants than University C could accommodate. The intended participants of the training were engineers, architects and other professionals having college or master's-level education and varied lengths of professional experience in practices related to energy efficiency. Mainly, there was only one participant from the same organization or department. During the research period (1 year) 13 of 87 participants dropped out of the training for varied reasons (University A: n = 5; University B: n = 3; and University C: n = 5). The fact that the training was free for participants and their employers might be related to the relatively high dropout rate as some participants may have begun the course but not had sufficient motivation to finish it. All course participants were sent an invitation to participate in the current investigation in the beginning and at the end of the training. However, the training was independent of conducting the research, and participation was voluntary.

Overall, the energy efficiency training was based on real-life working practices and all tasks assigned to participants were authentic in nature. The training included theoretical studies that were organized in seven contact days that involved lectures, small group work and discussions. The first 3 days and the last day were common for all participants but the remaining 3 days were organized separately for public and private sector participants. In their workplaces, participants pursued a developmental study project that was aimed to support combining practical and theoretical aspects of energy efficiency expertise. The projects were presented in a seminar on the last contact day with poster sessions. In addition, participants were supposed to write a learning diary during the training. Every university provided a virtual learning environment for course participants to facilitate open discussion. In addition, networking among participants was supported by small group work. The course participants who belonged to different parts of Finland were organized into 15 small groups of 5–6 members according to their place of residence; there were five small groups in each university. In addition to small group work during the contact days, each small group was advised to meet at least three times during the training. The participants were asked to write a memo about the meetings. Small group work aimed to foster the sharing of knowledge and experience among the participants and engage them in discussing their developmental projects, thereby, supporting learning from peers. Each small group was provided a private forum for discussion in the university's virtual learning environment. Moreover, each participant was assigned a workplace supervisor from one's workplace organization and an academic expert advisor on behalf of the organizing universities. The workplace supervisors were expected to support participants in the processes of workplace learning and promote professional development in the context of one's own assignments. The role of academic expert advisors was to support participants in their developmental study projects by providing knowledge, conversational help and information about valuable source books.

Social network methods

We collected network data by administering an online social networking questionnaire (SNQ) to all course participants twice during the energy efficiency training. The pre-SNQ was sent to 87 course participants (59 males and 28 females) in the beginning of the training, out of whom 63 responded (42 males and 21 females); the response rate was 72 %. After excluding 13 participants who had dropped out of the course, the post-SNQ was sent to 74 course participants (50 males and 24 females) at the end of the training; out of these, 52 responded (35 males and 17 females) and, thus, the response rate was 70 %. Overall, 82 % of the participants responded to one or the other SNQ, which is considered to be sufficient even if SNA methods require a high response rate. The missing data was partly handled by symmetrizing the data, for example by calculating multidimensional maps. Networking data was also collected from the academic expert advisors (these results will be reported elsewhere). Collecting the networking data repeatedly allowed us to examine how the networking relations changed across the training. The SNQ involved a name list of all course participants, and the respondents were asked to assess—in relation to each participant—(1) from whom they seek advice regarding energy efficiency and (2) with whom they collaborate in terms of energy efficiency activity. The strength of networking relations was measured by asking respondents to rate each on a valued scale from 0 (no connection), 1 (a connection) and 2 (a strong connection).

We used UCINET 6 program (Borgatti et al. 2002) to analyze the network data. We examined both advice-seeking, that is how the participants sought energy efficiency information from each other, and collaboration networks, that is how participants collaborated with each other on these issues. In the current investigation, both networks were treated as not reciprocal, that is not necessarily acknowledged by both participants. All analyses were conducted for the data provided by the pre- and post-SNQ to examine the development of network relations.

To answer the first research question, the network cohesion of advice-seeking and collaboration networks was analysed by density and centralization measures at the overall network level. Density characterises the general cohesion of the network, that is the number of networking ties, whereas centralization indicates the tie distribution among participants. For the analyses, the networks were dichotomized. The overall network connections were visualized using the Spindel visualization tool (www.spindel.fi) by relying on participants' geometric network distances provided by multidimensional scaling (MDS) techniques. For the analysis, the advice-seeking and collaboration matrices were combined. Further, we used multiple regression quadratic assignment procedures (MRQAP) to analyse how much of the variance in creating new ties during the training was explained by participants' background or prior ties. The procedure is used to model a social relation, in the form of matrices, using values of other relations. The algorithm proceeds in two steps. In the first step, it performs a standard multiple regression across corresponding cells of the dependent and independent matrices. In the second step, it randomly permutes rows and columns of the matrices and re-computes the regression, storing resultant values of r-square and all coefficients. This step is repeated 2,000 times to estimate standard errors for the statistics of interest. For each coefficient, the program counts the proportion of random permutations that yielded a coefficient as extreme as the one computed in step 1 (Borgatti et al. 2002).

At the small group level, to answer the second research question, the density of advice-seeking and collaboration networks was calculated among small group members. This analysis relied on dichotomized networks. In addition, hierarchical cluster analysis (Scott

1991, p. 126–130) was used to determine subgroups that existed among participants in the beginning and at the end of the training. The distance among clusters was calculated as the average similarity value weighted by cluster size. The calculation was conducted using a dichotomic and symmetric matrix.

We answered the third research question by examining patterns of advice-seeking and collaboration at the individual level. We calculated Freeman's degree measurement, which revealed how often and for how many colleagues the participant provided pieces of advice (Borgatti et al. 2002). The analyses were focused on peer evaluation—that is the number of incoming networking linkages—that provides a more reliable estimation of a person's centrality than the self-evaluations (In Degree). Further, a repeated-measures ANOVA was used to analyse the change in the number of advice-seeking and collaboration ties at the individual level across the training.

Interviews and their analysis

We conducted semi-structured interviews with the three organizers of the training (OA from University A, OB from University B and OC from University C) to examine how the operational practices of the training shaped and supported networking among the participants. The interviews were conducted after the training and the networking results were presented to the organizers. The organizers were asked to describe how the training course was implemented and what types of changes were made in the initial plans. They were also asked to comment on the networking results. Audio-recorded interviews were transcribed and content analysed by two independent coders. Further, 16 course participants, 8 academic expert advisors and 8 workplace supervisors were also interviewed. The results based on these interviews will be reported elsewhere.

Results

Social networks at the overall network level

We examined whether the participants created networking ties with one another across the three universities by analysing the change in the density and centralization of the advice-seeking and collaboration ties. Table 1 provides the density and centralization measures for the advice-seeking and collaboration networks from the beginning (I) to the end of the training (II) for the overall network and each university. The analysis revealed that the density for the overall networks remained sparse. Further, the densities remained the same for University A and decreased in University B for both measures; the density measures increased only in the case of University C, which was the densest. In addition, the analysis indicated that overall networks and each university's networks were only slightly centralized and that the centralization of interaction increased slightly in University A and C's collaboration network, but not in that of University B. However, the centrality values were very low and networking relations were rather evenly distributed across the participants.

In addition, the networking relations among the course participants were examined by visualization. Multidimensional scaling of the overall social networks in the beginning (1a) and at the end of the training (1b) are presented in Fig. 1. It is evident that, according to the measured dimensions, participants who are located close to one another are engaged in

Table 1 Overall network density and centrality measures (%) across pre- and post- measurement

	Advice-seeking network I[a]	Advice-seeking network II[a]	Collaboration network I[a]	Collaboration network II[a]
Overall network				
Density	4	5	2	3
Centralization	6	9	7	7
University A				
Density	11	11	7	7
Centralization	10	20	11	16
University B				
Density	12	11	7	4
Centralization	10	11	5	5
University C				
Density	8	16	3	10
Centralization	10	14	8	11

All measures are presented as percentage values

[a] represents dichotomized

I: in the beginning of the training

II: at the end of the training

denser networking interaction than remotely located actors. The lines between the actors represent advice-seeking networks. Figure 1a indicates that in the beginning of the training, the universities were not entirely separated because some participants had connections across the university borders. While the participants of University C were widely distributed over the network and their advice-seeking and collaboration networks were rather scattered and sparse, the participants of Universities A and B were clustered more closely, thereby indicating more initial intensive networking interaction. Across the training, participants from University C engaged in more intensive networking interaction than those of the other two universities whose networking density decreased. Figure 1b indicates that some University B participants had only a few ties with other actors; there were two isolates without any advice-seeking or collaboration networks with their peers.

Further, we used multiple regression quadratic assignment procedures (MRQAP) to analyse how much of the variance in creating new ties during the training was explained by a similar educational background, working sector (public or private), gender, university, small group and prior networking ties (see Table 2). Advice-seeking at the end of the training was primarily explained by belonging to the same small group ($\beta = .309$; $p < .001$) as well as existing advice-seeking ($\beta = .209$, $p < .001$) and collaboration ($\beta = .140$, $p < .001$) networks in the beginning of the training. Participants created more advice-seeking networks with those of the same gender ($\beta = .072$, $p < .001$). These variables explained 35 % of the variance. Prior collaboration, ($\beta = .429$, $p < .001$) same working sector ($\beta = .053$, $p < .01$), same small group membership ($\beta = .102$, $p < .01$), and same gender ($\beta = .044$, $p < .05$) explained the total number of collaboration ties at the end of the training, which accounted for 24 % of the variance. To conclude, prior ties and belonging to the same small group were the most important predictors of the total number of advice-seeking and collaboration ties at the end of the training.

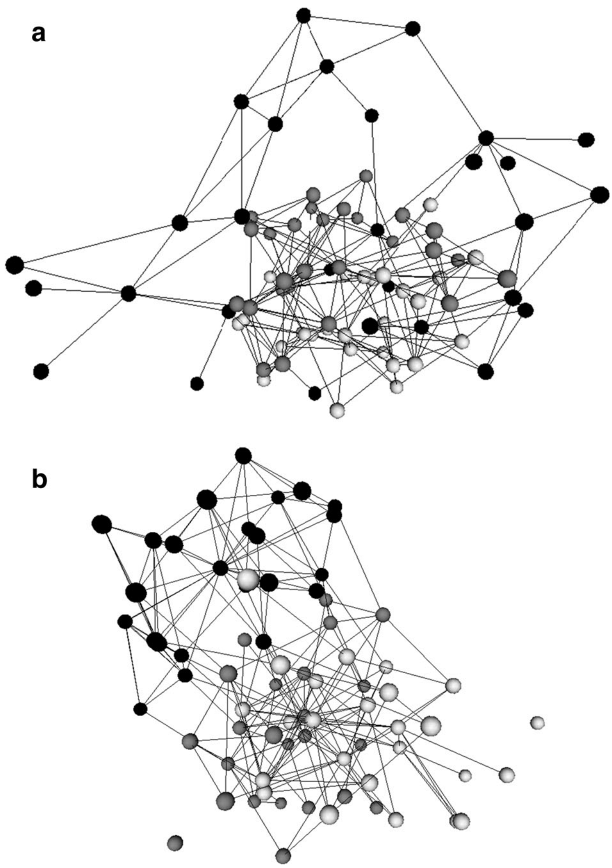

Fig. 1 **a** Overall network in the beginning of the training. **b** Overall network at the end of the training. The network graphs based on multidimensional scaling (MDS) and visualized using Spindel tools reveal how the course participants interacted with each other during advice-seeking and collaboration regarding energy efficiency issues. The colour code in the graphs represent the university that the person comes from: *grey* University A; *white* University B; *black* University C

Social networks at the small group level

The networking structure of the small groups was analysed by examining how the density of the small groups changed during the training. The density of small group networking reported in Table 3 indicates that the density for both the advice-seeking and collaboration ties increased mainly among participants of University C, with some emerging new networking relations. In cases of Universities A and B, the number of networking connections increased only in two small groups, while it remained the same or decreased in all remaining cases. Nevertheless, it should be noted that in many small groups in Universities A and B, the density of advice-seeking ties was rather high even in the beginning of the training. In Universities B and C, a small group was found without any reported collaboration at the end of the training. The densities may have appeared to be lower because of missing responses (e.g. in group 3).

Table 2 Regression analysis of advice-seeking and collaboration networks at the end of the training (standardized coefficients)

	Advice-seeking network II[a]	Collaboration network II[a]
1. Education	.008	.006
2. Public or private sector	.010	.053**
3. Gender	.072**	.044*
4. University	.035	−.005
5. Small group	.309***	.102**
6. Collaboration network I	.140***	.429***
7. Advice-seeking network I	.209***	.002
R^2 adjusted	.35	.24

[a] represents dichotomized

***, **, and * represent $p < 0.001$, $p < 0.01$ and $p < 0.05$, respectively

I: in the beginning of the training

II: at the end of the training

A visualization based on hierarchical cluster analysis characterizes the group formation in the beginning (Fig. 2a) and at the end of the training (Fig. 2b). Each participant is characterized by university code, personal number, and small group membership. The contour lines mark the groupings that evolved during the training; participants who are within several contour lines can be said to be in denser interaction together than with other actors (i.e., together at the same 'mountain'). Figures 2a, b indicate that networking relations among the participants were almost entirely based on the small groups both in the beginning and at the end of the training. However, the majority of the participants did not belong to any groups, thereby indicating that they had very little interaction with other course participants. In the beginning of the training, there were 13 groups that were all based on the small group organization. Interaction was lowest regarding groups of University C. At the end of the training, two groups of University A and three groups of University B had disappeared, thereby indicating that networking interaction among their participants had reduced. In turn, interaction among University C's participants increased both within the small groups and among them. One can see that one separate group of four actors and one bigger cluster comprising two groupings and one separate actor coming from three different small groups evolved in University C. Moreover, groups of three actors from University A and two actors from University B created networks with each other. This is the only cluster connecting actors from different universities. The results of the hierarchical cluster analysis are in line with the density measures, thereby revealing that interaction strengthened among small groups of University C and diminished among some small groups of Universities A and B.

Moreover, the interviews of the organizers revealed differences in the activity of the small groups. The organizers stated that some small groups worked spontaneously, actively, and purposefully whereas some others appeared to stop working completely. The course participants were divided into small groups according to their place of residence rather than similarity of profile, expertise or the nature of working assignments. Consequently, the members of the small groups did not necessarily have a common professional interest, thereby making it difficult to create a favorable atmosphere for group work. Overall, the organizers emphasized that the course participants were highly heterogeneous in terms of experience and competence in energy efficiency issues. It appeared that the

Table 3 Density measures (%) of small groups pre- and post-measurement

	Advice-seeking network I[a]		Advice-seeking network II[a]	Collaboration network I[a]		Collaboration network II[a]
University A						
Group 1	60	−	42	25	0	25
Group 2	58	+	92	33	+	58
Group 3	50	−	20	30	−	20
Group 4	80	0	75	30	0	25
Group 5	48	−	29	43	−	19
University B						
Group 6	65	+	75	40	0	33
Group 7	77	0	75	33	−	20
Group 8	50	−	35	40	−	20
Group 9	53	−	37	13	0	10
Group 10	40	−	17	25	−	0
University C						
Group 11	43	+	80	0	+	35
Group 12	20	0	27	0	0	0
Group 13	57	+	80	33	0	40
Group 14	30	+	75	13	+	45
Group 15	20	+	50	3	+	17

Measures are presented as percentage values, that is perceived values divided by all possible connections, multiplied by 100

[a] Represents dichotomized

I: in the beginning of the training

II: at the end of the training

+ 10 or greater increase in percentage points

−10 or greater decrease in percentage points

0 or less than 10 change in percentage points

excessive heterogeneity of the participants did not support the creation of interdisciplinary networks or establish a basis for common thinking.

> I was just thinking that it would be useful to have different, that the group is heterogeneous so that there would be different viewpoints. But could we somehow advance such kind of unified thinking, so how could we progress towards that kind of goal. (OC)

Organizers OA, OB, and OC considered it challenging to motivate people coming from different contexts and having different kinds of expertise to work in groups. Overall, small group work was conducted mainly within the framework of the contact days. Otherwise, it was assumed that small group activity was conducted through virtual working and informal meetings among the group members themselves. However, only some of the small groups actually functioned beyond the contact days. OA highlighted that even though the heterogeneity of the participants was an obstacle for networking, it appeared that small group work enabled some participants to find each other and establish a collaboration network. It was important and helpful to find even one participant with whom a professional tie could be established.

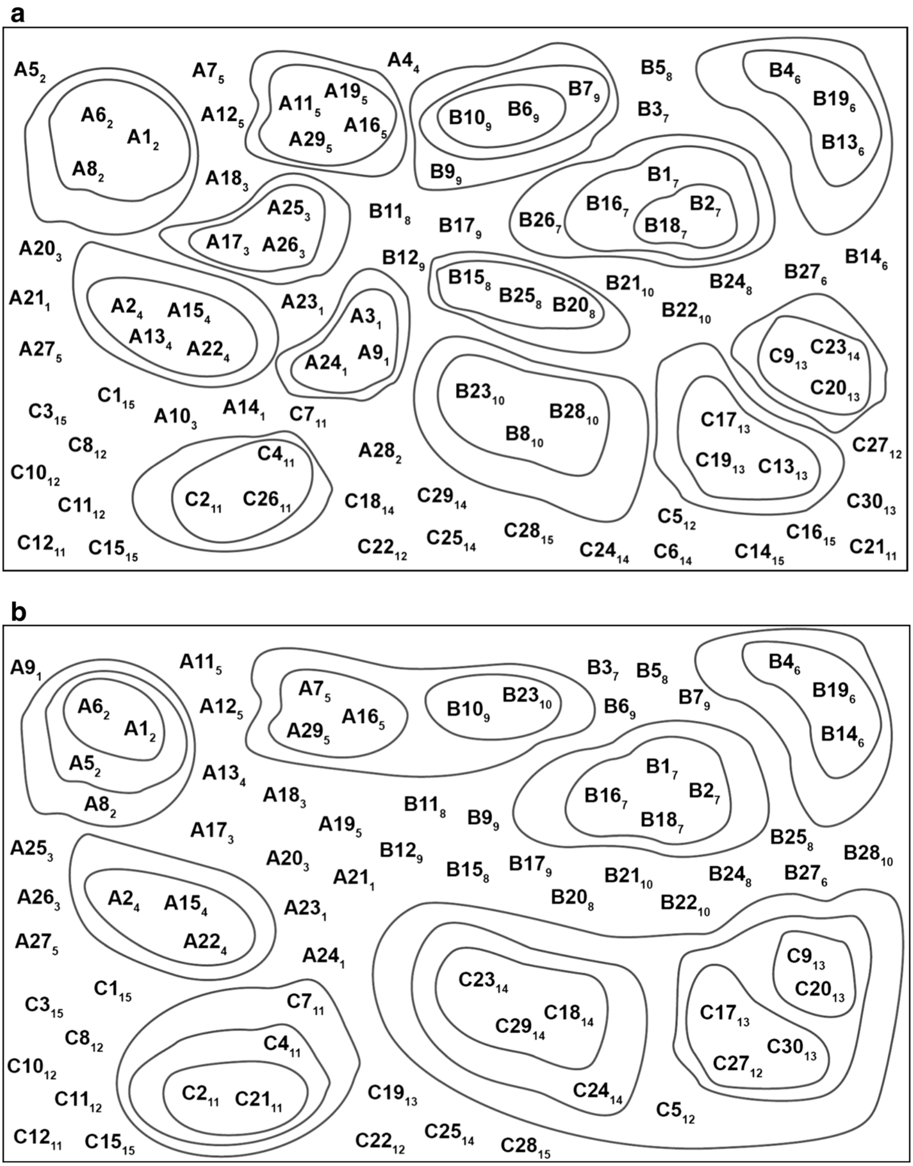

Fig. 2 **a** Group formation in the beginning of the training. **b** Group formation at the end of the training. The visualizations based on hierarchical cluster analysis reveal the structure of group formation in the beginning (**a**) and at the end (**b**) of the training. Each actor is provided a code identifying the university (e.g. *A*), personal number (e.g. 1) and the small group (e.g. $_1$). The map is generated with contour lines at multiple levels

> Some groups were very actively engaged in organizing meetings and got, in a sense, support from one another, and I know one group that learned to know one another in this way, it was a group of three, they even continued to collaborate even after the project ended. (OA)

OC stated that passive members of small groups who neglected their group assignments had a negative impact on group dynamics and impeded the intended collaborative activity. In University B, small groups worked during the initial contact days, but because of a high dropout rate in certain groups, this practice was gradually discontinued.

Social networks at the individual level

At the individual level, we examined course participants' networking activity by analysing the number of networking ties as well as the change in the number of ties from the beginning to the end of the training. This network centrality was assessed by peer evaluation based on Freeman's In Degree (a column sum in the advice-seeking matrix), which revealed how many course participants selected the actor in question as an information source in advice-seeking or partner in a collaboration network. Table 4 presents the means (*M*) and standard deviations (*SD*) of centrality values in advice-seeking and collaboration networks across all course participants. Table 4 reveals that the average number of individual-level advice-seeking ties increased from 3.2 to 3.7 ($SD = 2.0$) and the number of individual-level collaboration ties increased from 1.8 to 2.1 ($SD = 1.6$). However, the average level of personal networking connections that evolved during the training was rather low for both types of networks.

A repeated measures ANOVA was performed to examine whether the rise of networking ties at the individual level was significant and whether there were differences between public and private sector actors, or according to gender or age group of the participants. Table 5 presents the means and standard deviations for each cell. The analysis revealed that during the training, the number of partners in advice-seeking network increased statistically significantly for both private and public sector actors ($F(1, 72) = 13.10$, $p = .001$, $\eta^2 = .154$) and there was no statistically significant difference in the number of ties between the two sectors. There was a greater increase in the number of advice-seeking ties established during the training among private sector actors than among public sector actors ($F(1, 72) = 7.93$. $p = .006$, $\eta^2 = .099$). Further, during the training, the number of advice-seeking partners in both genders increased statistically significantly ($F(1, 72) = 9.20$, $p = .003$, $\eta^2 = .113$); there was also a statistically significant difference between males and females—females established more ties ($F(1, 72) = 9.24$, $p = .003$, $\eta^2 = .114$). The interaction effect was not statistically significant. During the training, the number of collaboration partners did not increase statistically significantly for both genders and the number of collaboration partners of males and females did not differ. However, the effect of a change was greater for males ($F(1, 72) = 4.10$, $p = .047$, $\eta^2 = .054$). Moreover, the number of collaboration partners for public and private sector actors increased in statistically significantly ($F(1, 72) = 7.61$, $p = .007$, $\eta^2 = .096$), but there was no

Table 4 Individual level in degree measures across pre- and post-measurements

	Advice-seeking network I[a]	Advice-seeking network II[a]	Collaboration network I[a]	Collaboration network II[a]
M	3.2	3.7	1.8	2.1
SD	1.6	2.0	1.5	1.6

[a] Represents dichotomized

I: in the beginning of the training

II: at the end of the training

Table 5 Change in the number of advice-seeking and collaboration partners

	Advice-seeking partners I				Advice-seeking partners II				Collaboration partners I				Collaboration partners II			
	Public		Private		Public		Private		Public		Private		Public		Private	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
M	5.1	4.2	4.2	3.0	5.6	4.2	6.9	4.9	3.2	2.9	2.1	1.4	2.7	2.5	3.6	3.1
SD	1.9	1.1	1.3	1.4	3.4	2.8	3.4	2.2	2.3	1.4	1.3	1.3	2.4	1.9	3.4	2.0
N	19	19	5	31	19	19	5	31	19	19	5	31	19	19	5	31

F female

M male

I: in the beginning of the training

II: at the end of the training

difference in the number of collaboration partners for public and private sector actors. However, the effect of change was greater for private sector actors ($F(1, 72) = 24.49$ $p = .000$, $\eta^2 = .254$). There were no statistically significant age-related differences in the changes related to advice-seeking or collaboration ties.

Discussion

Traditionally, the apprenticeship type of learning has been used in vocational education to describe vocational formation of new entrants; however, recently the concept has been stretched to higher education and knowledge-intensive fields as well as knowledge workers, such as contract researchers and software engineers (Fuller and Unwin 2010, 2011). In addition, it is used to describe the reformation of career switchers', like aircraft engineers, professional practice (Guile 2011). The Academic Apprenticeship Education model established in Finland in 2009 has been particularly profiled as an educational path in emerging knowledge-intensive professional fields that typically develop on the interface of traditional areas of expertise and, therefore, do not yet provide a common knowledge base, shared professional standards and common methods of framing professional tasks; in these fields expertise and competence can be very divergent and learning takes place often through practice. In this study, we examined whether the Academic Apprenticeship Education model in the energy efficiency field promoted the creation of expert networks among participants from both the public and private sectors to support their daily work with energy efficiency issues. For this purpose, we analysed the network structure and the changes it underwent during the training among all course participants and small groups, and also examined the networking activity of individuals.

The apprenticeship type of learning aims to provide a supportive framework for facilitating the development of expertise and becoming a member of an occupational community (Lave and Wenger 1991; Fuller and Unwin 2010). The results of the present study revealed that at the overall network level there was little change in the establishment of networking ties during the energy efficiency training. This indicates that the training did not effectively support comprehensive networking among the training participants and creation of the occupational knowledge exchange forum for energy efficiency professionals. It appears to us that one reason for a low intensity of networking may have been that the operational practices and mechanisms of the training were too weak to provide sufficient time or opportunities for networking. Since the participants belonged to different parts of Finland, their physical dispersion was likely to make the sharing of knowledge and expertise difficult (Cross et al. 2003).

However, when we examined the small group and individual levels, we found evidence of efforts for networking, sharing of energy efficiency knowledge and initiated collaboration. The best predictor for the emergence of professional network connections appeared to be an efficient small group work process; when the members of the small group did not establish networking connections with each other, their networking during the overall training process remained low. The organizers of the training perceived that some course participants were able to found relevant others with whom to collaborate even outside the training program; the quality of interpersonal interaction appears to be a key driver of emergent collective socio-cognitive structures that are required in new collaboration networks (Curseu et al. 2012). At the individual level of analysis, energy efficiency professionals appeared to establish ties with actors from the same gender more often. As such, males and females did not differ from each other, but the effect of change in the ties was higher among males than among females. In addition, the results revealed differences between the public and private sectors at all three levels of networking. While the private sector actors were slightly isolated from the public sector actors, their networking connections increased during the course. Further, the fact that some course participants did not respond the networking questionnaire may have affected the results. In particular, the analysis at the small-group level was sensitive in this respect. However, as the number of respondents who submitted their answers at least once was over 80 % and as there was no doubt that the remaining answers would have been biased, we interpreted that the response rate was sufficiently high for our study.

The participants of the energy efficiency training appeared to have very heterogeneous energy efficiency expertise and associated professional experiences. Earlier studies indicate that on one hand, the high diversity of participants may impede understanding, hamper collaboration, and decrease the density of networks (Akkerman et al. 2006; Brass et al. 2004; Cross et al. 2003); however, on the other hand, it may be considered as a potential resource for creating and enriching knowledge (Akkerman et al. 2006) and critical for transmitting novel knowledge and ideas. Even though one aim of the training was to create interdisciplinary ties among actors in the energy efficiency field, the interviews of the organizers revealed that the excessive heterogeneity of the participants may have hindered the identification of common interests and grounds for collaboration and, thus, creation of professional collaboration network. The energy efficiency training did not appear to support participants in utilizing each other's complementary expertise and know-how and, thus, enabling participants to transfer their knowledge to those beyond their own immediate area of expertise. Novel complex knowledge is not easily transmitted without relatively strong reciprocal networking ties—ones that the training, apparently, did not elicit (Palonen, Hakkarainen, Talvitie and Lehtinen 2004).

In conclusion, the energy efficiency training could be considered, in this context, as a particular type of boundary-crossing project (see Akkerman and Bakker 2011; Akkerman et al. 2006) in which heterogeneous experts from different backgrounds and with different levels of energy efficiency expertise came together to learn. In addition, to learn simplified routines and homogeneous knowledge base there is a need to elaborate expertise in multidiscipline context or journeymen networks. However, according to our results, successful collaboration, construction of a networked community and crossing the boundaries between different epistemic cultures is not possible without planning and deliberate and sustained efforts (Akkerman et al. 2006). Overall, the results of this investigation suggest that ad hoc networks may not provide sufficient support for coordinating knowledge exchange among participants. Consequently, it appears that networking and knowledge sharing must be actively worked on, supported by effective activities and well-developed operating models (Vesalainen and Strömmer 1999), as well as by making the differences among participants as a focus of their concern.

It appears to us that even though professional networking did not emerge during the energy efficiency training, it might have led to the establishment of some latent social connections for participants, which have not been actively utilized and maintained but exist when needed in future. The present investigation did not permit us to analyze whether the evolved networking connections were maintained after the training. In the future, it is essential to examine whether the Academic Apprenticeship Education model has long-term networking impacts (Muijs et al. 2010).

Further, there might also be some problems in using the concept of apprenticeship in the context of academic education as it emphasizes informal learning instead of formal modes. In the case of the energy efficiency training, all course participants do not necessarily have other energy efficiency experts in their workplaces to provide professional supervision; in many cases they themselves carry the leading expertise. In addition, in emerging fields, there is often unclear and diffuse understanding of the best practices and operational models, and these are not learned simply through hands-on methods. On the other hand, recent studies have indicated that apprenticeship can be extended to professions in which expertise and knowledge have to be reformed and re-contextualised (Guile 2011). This might be a situation with the energy efficiency training where the participants already were experts in some other field.

Even though networking is often foreseen and expected to have a positive effect akin to professional training, its actual influence has only seldom been studied or reported. The current investigation indicated that shared standards and guidelines need to be created for the Academic Apprenticeship Education model. If this training would provide better opportunities for actually networking and collaborating with peers (and there would be more systematic formal training and professional standards in the field), the quality of education would improve and knowledge-sharing among experts would not rely only on ad hoc networks. Therefore, the Academic Apprenticeship Education model might help to fill the gaps in the educational system, for example, to provide education for professionals that have not yet established educational programs for developing expertise; moreover, it could also be used to educate experts in domains where multiple skills or specific know-how are needed. Citing an earlier paper published in this journal (Zitter et al. 2011), we ask the following question: How can we characterize learning environments in innovative higher professional education programs from a design perspective? In other words, how can we better integrate the forums of learning institutions with learning at work? These questions present sufficient challenges to be addressed in future studies.

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