Chapter 15
Visualising Social Network Structures in the Training of Professional Learning Communities of Educators in Informal and Formal Settings

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Introduction

In the 20th century, the main goal for science education in Austria was to deliver content knowledge which was often considered to be solid reproducible facts. Those able to accumulate and reproduce this knowledge were considered well prepared for a scientific carrier. Twenty-first century science education, however, is no longer valued only by those wishing to go into scientific or scientific related careers but by all members of an educated society. Supporting every child to become "*scientifically literate*" is now more than a slogan amongst science educators and curriculum planners and science education authorities (Hodson, 2008, p. 23).

Science education reform initiatives have been supported by the European Union's FP7 Funding Programme Science and Society aimed at implementing a "Renewed Pedagogy for the Future of Europe" (Rocard et al., 2007). Program designers put a strong emphasis on Inquiry Based Science Education (IBSE) as a kind of remedy for the problems traditional science teaching has caused such as young people's low interest in science topics (Sjøberg & Schreiner, 2010) and in choosing science related careers (OECD, 2006). Although IBSE is still a container concept which includes many different facets and approaches (Capps & Crawford, 2013; Minner, Levy, & Century, 2010), implementing any IBSE approach requires a more or less profound change in how science is taught.

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Science classes in Austria are still predominately characterised by teachers using questions in classroom discourse to scaffold student thinking and help students to construct scientific knowledge. Students very rarely experience opportunities to design and conduct experiments or investigations themselves. According to school heads questioned in the course of the 2006 PISA study, most 15 year-old students attend schools that provide Learning Outside the Classroom (LOtC) learning activities such as visits to museums, science centres or national parks (Grafendorfer & Neureiter, 2009).

A range of projects funded by the European Commission between 2007 and 2014 were developed and implemented in Austria and in many other EU member states. They tested different approaches to support the implementation of IBSE on a large scale by developing teaching material and teacher-training courses and teacher/school networks and partnerships amongst schools and LOtC institutions. The latter approach was founded in the programme design that called attention to LOtC organisations as very "significant actors in science education" (Rocard et al., 2007, p. 10).

However, research has shown that LOtC institutions are reluctant to engage in systemic educational reform efforts and in evaluating their educational programmes systematically (Phillips, Finkelstein, & Wever-Frerichs, 2007). Hence Tran and King (2011) argue:

> Without a shared knowledge base underpinning practice it may be argued that the pedagogical support provided by educators in the LOtC setting is inherently compromised. Furthermore a lack of an explicitly articulated body of knowledge raises concerns as whether the field can become a profession and further develop its practice (p. 282).

In addition professional development offers for LOtC educators are rare in Austria and in many other European countries.

It is a challenging exercise to benefit from the great potential LOtC science institutions have in K12 science education (Phillips et al., 2007). However, students benefit most if their teachers count on pre and post-processing of LOtC visits (Cox-Petersen, Marsh, Kisiel, & Melber, 2003). As the majority of students, not only in Austria, but in many OECD countries experience school visits to LOtC institutions (PISA, 2006) a promising way to improve science teaching and learning is to consolidate science teachers and LOtC educators to establish a shared understanding of inquiry based science teaching inside and outside the classroom.

This chapter will report on our experiences as a partner in the European FP7 Project INQUIRE: Inquiry Based Teacher Training for a Sustainable Future (2010–2013, www.inquirebotany.org). The main goal for this project was to support teachers and botanic garden and natural history museum educators to become reflective practitioners and to share their knowledge and experience via establishing social relations amongst each other. The Austrian INQUIRE professional development courses (IPDC) involved teachers and LOtC educators from different backgrounds. This study was designed to provide insight into how the social networks amongst course participants developed and to what extent the knowledge gained by monitoring and analysing this process via social network analysis could be used by the course management to improve participants learning experience.

Conceptual Framework

Traditional professional teacher development schemes have come under criticism for their inability to promote teacher learning in ways that impact on outcomes for the diversity of students in the classrooms (Hattie, 2009). Criticism is directed to in-service training that follows approaches based on an external view of what knowledge and skills teachers need to be equipped with a separation from the teacher's daily work or a setting that focuses on an individualistic development practices (Timperley, Wilson, Barrar, & Fung, 2007). Timperley and colleagues reviewed 97 individual studies and groups of studies that had substantive student outcomes associated with teacher professional learning and development. They found a set of criteria that distinguishes effective contexts for promoting professional learning. Besides other effective contexts "opportunities to participate in a professional community of practice were more important than place [school based or off-site with teachers from different schools]" (p. 25). The authors concluded that it is not enough to simply comply all these criteria but to reflect on the quality of each individual one when it comes to developing and running successful professional development courses.

Communities of Practice

In 1991, Jean Lave and Etienne Wenger published their book, 'Situated Learning: Legitimate Peripheral Participation' and introduced an epistemological principle of learning which was termed 'Situated Learning' which is often referred to a learning in a 'Community of Practice (CoP)'. The authors explained their theory of learning through an apprenticeship model by which newcomers to a community learn from other participants, during which time they are allowed to take over more and more tasks in the community and gradually progress to become 'masters' and enjoy full participation. This earlier perspective implied that "legitimate peripheral participation in a community inevitably leads to full socialisation, thus resembling earlier socialisation theories following Vygotsky" (Handley, Sturdy, Fincham, & Clark, 2006, p. 643). Members of a CoP are expected to develop a mode of belonging and an identity in practice. However, later both authors admitted that various forms of participation are both possible and fruitful and that becoming a full participant might not be aspired by all members of such a community. The concept of CoP has been similarly taken across social, educational and management science and is currently one of the most articulated and developed concepts within broad social theories of learning (Barton & Tusting, 2005).

However, hardly do know little about how these social networks develop in CoP-based professional development courses: who the experts, novices or the key players are; whether they change in course of time; or, whether a particular social network structure is more fruitful for the individual learner than another.

The Social Network Perspective

Social network theory assumes that each individual and its actions are embedded in social networks. Interactions between actors in a network draw them into this relationship (Herz, 2014). An actor's position in a network determines, in part, the constraints and opportunities this individual will encounter (Borgatti, Everett, & Johnson, 2013). The embeddedness argument emphasizes the importance of concrete personal relations in generating trust and cooperation (Granovetter, 1985). Network theory bears resemblance to Lave and Wenger's (1991) approach to learning as a deepening process of participating in a community of practice: "Over time this collective learning results in practices that reflect both the pursuit of our enterprise and the attendant social relations" (Wenger, 1998, p. 45).

So far the social network approach is popular in fields such as sociology, economics and anthropology. Research on teachers' social networks has received much attention in the last 10 years (Baker-Doyle & Yoon, 2011; Coburn, Mata, & Choi, 2013; Coburn & Russell, 2008; Penuel, Riel, Krause, & Frank, 2009) as "this vantage point offers interesting association for educational research when it comes to investigating social processes of learning, change and socialisation" (Herz, 2014, p. 242).

Network Analysis

Network analysis deals with the relationships between more than two actors: "A social network consists of a finite set or sets of actors and the relation or relations defined on them" (Wassermann & Faust, 1994, p. 20). Actors and their actions are incorporated in social networks. The central principles underlying the network perspective are:

- Structural relations are the key orienting principle;
- Linkages between actors are representing social resources;
- The structural relations should be viewed as dynamic processes; and,
- Changes in micro-level choices are also applied to the macro-level structural relations (Hennig, Brandes, Pfeffer & Mergel, 2012; Knoke & Yang, 2008; Wasserman & Faust, 1994).

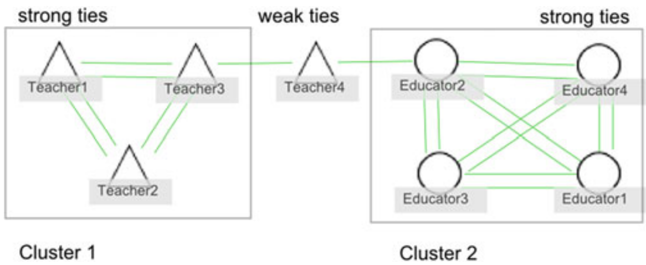

Fig. 15.1 The drawing shows the schematic representation of a cluster with teachers and a cluster with educators. The members of every cluster are highly connected. Weak ties connect the two clusters

Learning processes in network terms need the transfer through ties between actors in the social network. One classification involves the distinction between strong and weak ties (Granovetter, 1973). Granovetter defined tie-strength as a function of frequency of contact, reciprocity and friendship. Strong ties are frequent contacts, often friendly and include reciprocal favours but weak ties are distant and infrequent contacts and do not necessarily have affective content.

In the schematic representation (see Fig. 15.1) the members of every cluster are strongly connected based on the concept of homophile, which means that actors prefer having relationships with others of the same status (McPherson, Smith-Lovin, & Cook, 2001).

Weak links could be important for sharing new knowledge between, for example, teachers and LOtC educators. By bridging usually disconnected actors or subgroups weak ties enable the flow of new information (Granovetter, 1973). The transfer of knowledge through weak ties is efficient, if the knowledge is explicit, independent and the level of codification is low (Hansen, 1999). Furthermore Burt (2004) demonstrates the advantages of bridging structural holes with weak ties in the case of managers, who have more innovative ideas to solve upcoming problems.

If the knowledge is dependent with a high level of codification (that is, fully documented, complex knowledge) the knowledge transfer needs more assistance, because the recipient of knowledge needs some additional information of the larger system and the specific correlations. Here strong ties assume a greater supportive role with better access than weak ties (Granovetter, 1982).

Research Question

The Austrian INQUIRE Professional Development Courses (IPDC) involved teachers and botanic garden and natural history museum educators from different socio-cultural backgrounds. Therefore our research focus was on the following questions:

- How do ties between teachers and LOtC educators develop in course of a nine month training course?
- Does the knowledge about a particular network structures at a given time during the course has the potential to improve participants learning outcomes?

Methodology

The Austrian INQUIRE professional development course (IPDC) was offered by the University Botanic Gardens in Innsbruck. Our design tried to translate six out of seven criteria for efficient professional development published by Timperley and colleagues (2007) into practice. We put emphasis on an extended period of time to provide opportunities for individual and group learning. IPDCs comprised three face-to-face Modules, each lasting 16 h (see Fig. 15.2). In between, participants were invited to join the INQUIRE-Café (see Fig. 15.2) at the botanic garden and exchange and discuss their experiences and ideas in an informal setting. Science education researchers and scientists provided external expertise. Participants were asked to elaborate reflective case studies on student learning and explore how theoretical knowledge addressed in the course proved valuable in real-world situations. These case studies were presented and discussed in the third Module (see Fig. 15.2). We dedicated extensive time for a prevailing discourse. Extra meetings at the botanical garden and social group building activities during face-to-face Modules were offered to support CoP development. In addition, all resources, documents and tasks were accessible on the online File-Sharing-Platform Dropbox. Our approaches were consistent with current science and science education research findings and recommendations of professional bodies.

Course participants learned about the INQUIRE training courses via the official in-service teacher training programme (printed an online version) published twice a year by the Pedagogical College Tirol and via the Austrian LOtC network (Science Center Network Austria). In addition, private links to LOtC institutions and

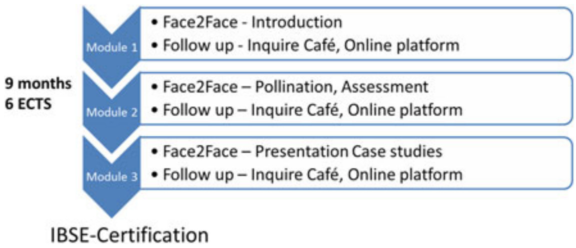

Fig. 15.2 Organizational structure of the INQUIRE Professional Development Courses (IPDC). The courses were designed to involve educators over a 9-month period of part-time study. Each course was worth 6 ECTS (European Credit Transfer System)

Table 15.1 The description of the INQUIRE professional development training course participating teachers and LOtC educators in Austria

Category	Name	Number
Number of participants	School teacher	8
Gender	Female	7
	Male	1
Institution	Primary school	7
	Secondary school	1
Experience	Years	0–35
Category	Name	Number
Number of participants	Informal educator	8
Gender	Female	6
	Male	2
Institution	Botanical garden	1
	Environmental education center	2
	Nature park	5
Experience	Years	0–12

teachers were used to inform prospects. The main goal was to end up with a heterogeneous group of teachers and botanic garden, museum and environmental educators sharing a wide range of experience and expertise.

Two INQUIRE training courses were run between 2011 and 2013. This study uses data from the second INQUIRE professional development course (IPDC2) and involves 16 participants (see Table 15.1).

Although the course evaluation included a mixed-methods design and additional data were gathered by means of pre- and post-test questionnaires, interviews and pre- and post-concept maps (Novak, 1990), this chapter reports on findings gathered via social network analysis (Carolan, 2013; Jansen, 2006; Rehrl & Gruber, 2007).

Social Network Analysis

Two essential parts of a social network are actors and the relations between them. Actors may be persons or groups. In this regard, training course participants are considered as social actors represented by nodes. The relationships between these actors are represented by linkages (ties). The logical data structure is based on a questionnaire completed by course participants before and after each course Module (see Fig. 15.2). Answers are given in relation to already existing relationships and teamwork and the desire to work together with certain participants. The first level of analysis is the egocentric network followed by the second level which is the socio-centric visualization of developments in the entire network and completed by a socio-centric analysis to depict different pattern of interactions.

The egocentric network. The egocentric graph is formed by targeting one actor (ego), including all other actors (alters) to which the ego is connected. Figure 15.3

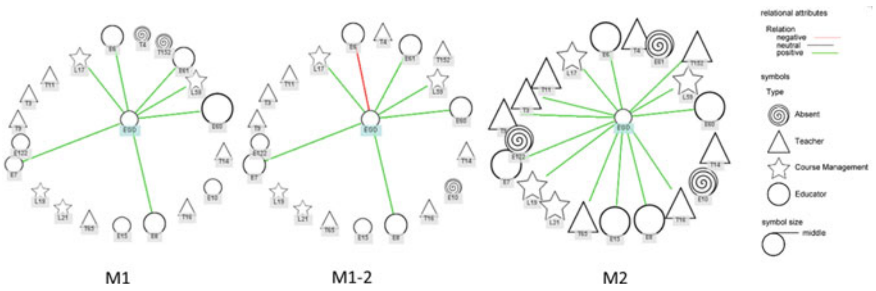

Fig. 15.3 Egocentric network of educator (E12) at the beginning of the Module 1 (M1-1), at the end of the Module 1 (M1-2) and at the beginning of Module 2 (M2)

gives an example of how such an egocentric network pattern of one LOtC educator (E12) developed from the beginning of Module 1 to the end of Module 2.

Socio centric visualisation. By using the information of all course participants' egocentric networks, the total network of the IPDC2 could be illustrated. In order to describe the number of linkages between the nodes in relation to the maximum number of possible linkages, the parameter density (D) was calculated. The parameter reciprocity (R) is an indicator for the mutuality of the relations in the egocentric network (i.e., if there is a linkage between two actors in both directions).

The socio-centric analysis. As a final step, a socio-centric analysis was applied to depict different patterns of interactions within the CoP network. This process enabled us to find out who the key players in the group are. The analysis of hubs and authorities was used to find out the position of the actor gained through relations. This calculation was based on the eigenvector-centrality. A high hub-factor means that this actor establishes multiple relations with actors who own a high authority-factor. Therefore a hub actor is very important, because other actors need this hub actor to get access to authorities. A high authority-factor means that this actor is being integrated from actors with high hub-factors (Borgatti, Everett, & Freeman, 2002). The software used for evaluation and visualisation of SNA was VENNMaker 1.3.2 and UCINET 6.461.

Results

Egocentric Networks of Individual Participants

Example of egocentric networks of IPDC2 participants (Table 15.2) are shown in Figs. 15.3 and 15.4. The relations between an ego and a set of alters is the focus of egocentric network analysis.

Table 15.2 shows that all participants who established two or more ties at the end of Module 2 (M2) handed in a case study while only two out of six participants who established less than two ties at the given time finished the course successfully. Participant (E12) is an educator and knows other LOtC educators and the course

Table 15.2 Egocentric network of participants at the beginning of the IPDC2 Module 1 (M1-1), at the end of the Module 1 (M1-2) and at the beginning of Module 2 (M2)

Nr.	Cat.	Ego-Code	Number Alteri M1	Alteri M1 categories	Number Alteri M1-2	Alteri M1-2 categories	Number Alteri M2	Alteri M2 categories	Case-study
1	E	E61	4	4x E	6	1x E, 3x T, 2x L	n.a.		No
2	E	E6	4	4x E	4	3x E, 1x T	0		No
3	E	E7	0		3	3x E	3	3x E	Yes
4	E	E8	6	6x E	6	5x E, 1x T	5	3x E, 2x T	Yes
5	E	E10	3	3x E	n.a.		n.a.		No
6	E	E12	7	5x E, 2x L	7	5x E, 2x L	13	5x E, 5x T, 3x L	Yes
7	E	E60	6	5x E, 1x L	0		5	4x E, 1x T	Yes
8	E	E15	0		3	3x E	4	3x E, 1x T	Yes
9	T	T65	1	1x T	2	1x T, 1x L	1	1x T	No
10	T	T3	0		6	3x E, 3x T	n.a.		Yes
11	T	T4	n.a.		5	1x E, 4x L	0		Yes
12	T	T9	0		3	2x E, 1x T	2	1x E, 1x T	Yes
13	T	T11	1	1x E	4	3x E, 1x T	3	2x E, 1x T	Yes
14	T	T14	1	1x T	1	1x T	n.a.		Yes
15	T	T16	0		0		0		Yes
16	T	T152	n.a.		0		7	2x E, 1x T, 4x L	Yes
17	L	L19							
18	L	L17							
19	L	L21							
20	L	L59							

Number of connections to alters, classification of the alters in the categories Educator (E), Teacher (T), Course Management (L) and Submission of the Case-Study

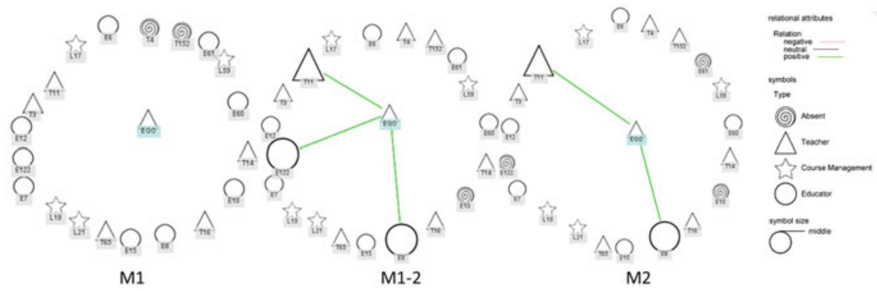

Fig. 15.4 Egocentric network of a teacher (T9) at the beginning of the Module1 (M1-1), at the end of the Module1 (M1-2) and at the beginning of Module 2 (M2)

management for personal and professional reasons at the beginning of the course already. The number of relations E12 (Fig. 15.3) increased considerably. In Module 1 and up to the end of Module 2, E12 established six new relations, five of which were with teachers. There was a negative relation at the end of Module 1 indicating a dissonance (marked in red).

Participant (T9) was a teacher and had no relation with any other course participant at the beginning of the course. T9 established ties with two educators and one teacher by the end of Module 1. At the end of Module 2, one relation to a teacher and one relation to an educator was established sustainably.

Socio-centric Visualization of Developments in the Total Network of the IPDC2 During the Training Course

(a) *Considering positive and negative linkages*

At the beginning of IPDC2, participants reported few relationships (linkages) between one another (Fig. 15.5). As some of the participating educators had already known each other before the beginning of the training course, relations between these educators dominated the social network. The parameter reciprocity (R) is an indicator for the mutuality of the relations in the network and shows that relationships are experienced as two-way roads. Of all relationships already established at the beginning of the course, 54% were reciprocal (R).

In order to describe the number of linkages between the nodes in relation to the maximum number of possible linkages, the parameter density (D) was calculated. By the end of Module 1 (Fig. 15.6) new relations were established and the density (D) increased from 10 to 13%. At the same time R decreased to 18%. R declines in a network, if newly-established relations are not reciprocal or some participants were absent. At the beginning of Module 2, D was 10% and R increased to 39% (see Table 15.3). R is growing, if the number of mutual relations has been increased throughout the entire network (Figs. 15.7, 15.8 and 15.9).

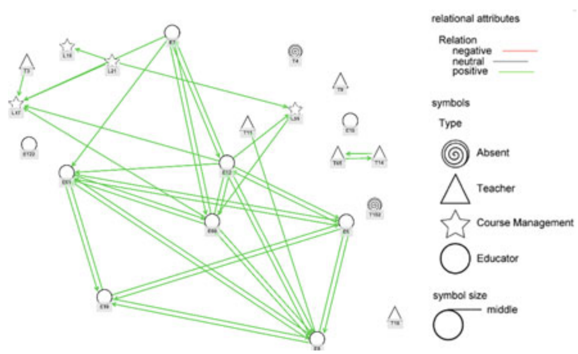

Fig. 15.5 Total social network of IPDC2 at the beginning of Module 1 including positive and negative linkages (M1-1)

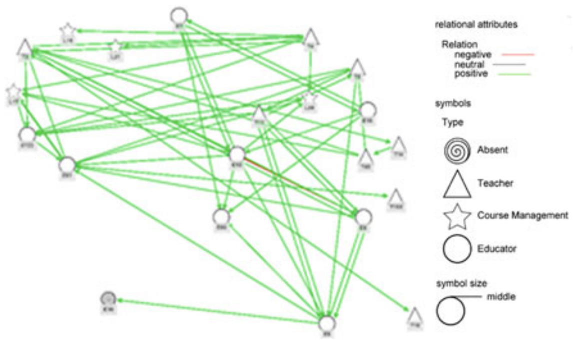

Fig. 15.6 Total social network of IPDC2 at the end of Module 1 including positive and negative linkages (M1-2(a))

Table 15.3 Analysis of the total social network of IPDC2 in respect to Density (D) and Reciprocity (R)

Parameter	Date						
	M1-1	M1-2(a)	M1-2(b)	M2(a)	M2(b)	M3-1	M3-2
D (%)	10	13	33	10	20	9	11
R (%)	54	18	27	39	25	9	7

M1-1: at the beginning of Module 1; M1-2(a): at the end of Module 1; M2(a): at the beginning of Module 2; M3-1: after presentation session 1; M3-2 after presentation session 2. Positive and negative linkages were evaluated. For M1-2(b) and M2(b) positive, negative and neutral linkages were evaluated

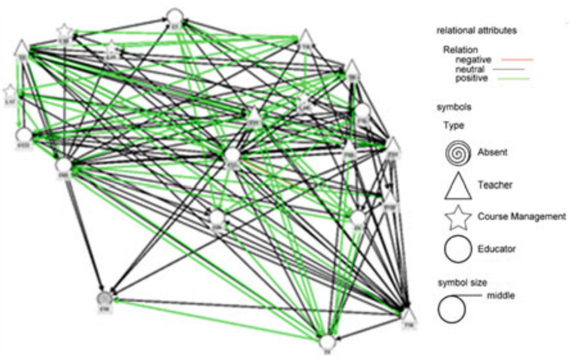

Fig. 15.7 Total social network of IPDC2 at the end of Module 1 including positive, negative and neutral linkages (M1-2(b))

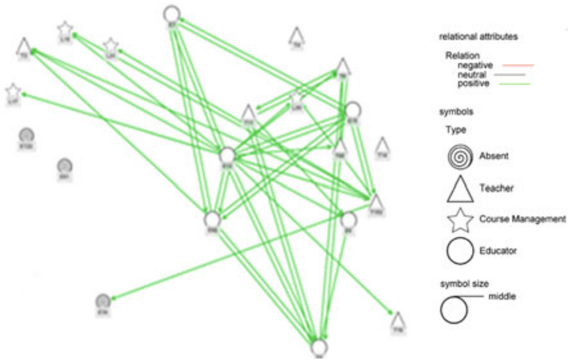

Fig. 15.8 Total social network of IPDC2 at the beginning of Module 2 including positive and negative linkages (M2(a))

At the very end of the course, Module 3 (M3) participants presented their case studies in two separate presentation sessions (Figs. 15.10 and 15.11). As there was no compulsory attendance for both of the sessions, some participants were absent from both events. Nonetheless, D reached similar values to Module 2 with 9 and 11%, respectively. R was below 10% (see Table 15.3).

At presentation session 1, the reciprocally-linked subgroup of the botanic garden educators (E6, E8, E10, E61) was absent (Fig. 15.10). Two members (E10, E61) of this subgroup were already absent from Module 2. At presentation session 2, the only member of this subgroup to present a case study was E8. E8 listed linkages to the absent educators E6, E10, E61 (Fig. 15.11). Although the subgroup was only represented by one member, the linkages to the absent members were still there. All participants who successfully completed the course were present at Module 2. Participants who missed Module 2 entirely or parts of it did not complete their case study successfully.

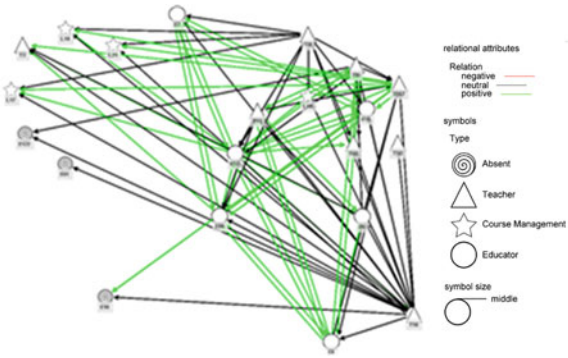

Fig. 15.9 Total social network of IPDC2 at the beginning of Module 2 including positive, negative and neutral linkages (M2(b))

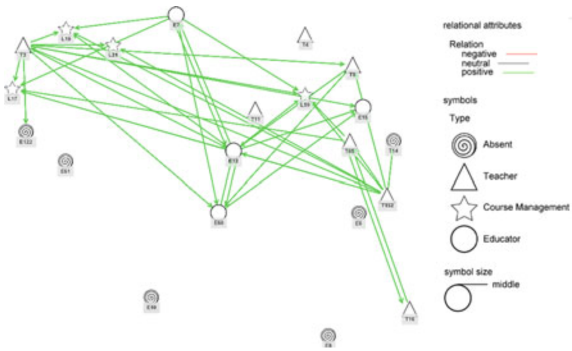

Fig. 15.10 Total social network of IPDC2 after presentation session 1, including positive and negative linkages (M3-1)

(b) *Considering positive, negative and neutral linkages*

For M1-2(b) and M2(b), positive, negative and neutral linkages were evaluated. A neutral relation means that working together with another person is desirable for a specific person but it is not being practiced actively at this point of time.

At the end of IPDC2 Module 1 (M1-2(b)), the number of relations increased considerably and the Density (D) increased from 10 to 33% (see Table 15.3). It should be noticed that this number includes positive, negative and neutral relations. The percentage of reciprocal relations (R) amongst persons decreased to 27%. At the beginning of Module 2 (M2(b)), the density of the network decreased to 20%. There are significantly fewer neutral relations. 25% of the relations are mutual (see Table 15.3).

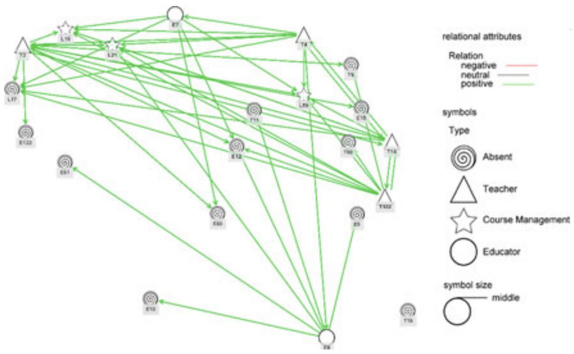

Fig. 15.11 Total social network of IPDC2 after presentation session 2, including positive and negative linkages (M3-2)

Depict the Process of Key Players' Development

Hubs—considering positive, negative and neutral linkages

Analysis of positive, negative and neutral linkages at the end of Module 1 (M1-2) showed that one educator and one teacher were representing hubs. In the beginning of Module 2 (M2) there was one educator representing a hub (see Table 15.4).

Authorities—considering positive, negative and neutral linkages

At the end of Module 1 (M1-2), two educators and one teacher were identified as authorities. At the beginning of Module 2 (M2), authorities were represented by five educators and two teachers (see Table 15.5). The development of the social network during the progression of the course revealed the risk of losing a subgroup of educators in Module 2 because they were absent in Module 2. The loss of the entire subgroup then had to be reported at presentation session 1 (M3-1). At presentation session 2 (M3-2), one member (E8) of this subgroup was present because this

Table 15.4 Hub-factor of specific actors in IPDC2

Number	Date				
	M1-1	M1-2	M2	M3-1	M3-2
1	E12	E12	E12	T3	T3
2	E60	T4		T152	T152
3	E8			E7	T4
4				E12	T14

Only actors are listed who reach at least 50% of the highest hub-factor in the course. M1-1: at the beginning of Module 1; M1-2: at the end of Module 1; M2: at the beginning of Module 2; M3-1: after presentation session 1; M3-2: after presentation session 2. Positive, negative and neutral linkages were evaluated

Table 15.5 Authority-factor of specific actors in IPDC2

Number	Date				
	M1-1	M1-2	M2	M3-1	M3-2
1	E61	E12	E15	L17	L19
2	E8	T11	E60	L59	L17
3	E60	E6	T3	L19	L59
4	L17		E8	T16	L21
5	E12		E7	E12	E12
6	E6		T9	E60	T14
7			E6		T3
8					

Only actors are listed who reach at least 50% of the highest hub-factor in the course. M1-1: at the beginning of Module 1; M1-2: at the end of Module 1; M2: at the beginning of Module 2; M3-1: after presentation session 1; M3-2: after presentation session 2. Positive, negative and neutral linkages were evaluated

educator (E8) had written a case study in collaboration with a teacher from outside the subgroup. E8, identified as hub and authority in Module 1, had an additional social relation outside the subgroup and could therefore produce the case study in a mixed team of one teacher and one educator.

Discussion

In 2007, the Rocard Report: 'Science Education now, a renewed pedagogy for the future of Europe', was published to support science education reform and forged a new direction by asking science and mathematics teachers, teacher trainers, LOtC institutions and formal educational systems across Europe to implement inquiry-based science education (IBSE) on a large scale. Inquiry-based science teaching (IBST) and learning is not necessarily a new, innovative approach and a remedy for all problems but an abstract concept. Capps and Crawford (2013) recently concluded that "today there is still no consensus as to what it [IBSE] actually is and what it looks like in the classroom" (p. 525).

Dillon (2012) argues that there is no such thing as the one and only scientific inquiry approach. Thus it is challenging for practitioners to make the abstract theory based concept of IBSE concrete and establish an individual content and context specific understanding of IBSE even if science education research and popular scientific literature and IBSE teaching material is provided on various online platforms free of charge. Practitioners are supposed to develop a in depth understanding of the science content and the specific knowledge gaining processes related to this content. In addition they need to develop a profound understanding of how to scaffold inquiry based learning efficiently when dealing with heterogeneous groups of students populating science classes and LOtC workshops. Thus it is unavoidable that practitioners establish a critical and reflective approach and look closely at whether their IBSE approach is successful in supporting student learning. However this is a complex and challenging task and our hypothesis was that mixed groups of teachers and LOtC educators have the potential to trigger social learning processes and will support practitioners to develop their understanding of IBSE. Tran and King (2011) argue that in terms of teaching science in a LOtC context a distinct body of knowledge and pedagogical practice has been established amongst educators working in the field. A few of these educators are aware of the various strategies they use or their relative efficacy, however, this body of knowledge is usually neither recognized nor shared by educators working across various institutions and settings. The INQUIRE professional development course provided a platform to share this knowledge not only across LOtC institutions but also with teachers from various backgrounds. Participants take these opportunities and establish ties with colleagues from the other "cluster" (see Fig. 15.3). E12, for example, had relations with colleagues at the beginning of the course already and focused on establishing new relations with teachers in particular.

Many training activities provide space for course participants, teachers and educators alike to adopt a positive attitude towards reflective practice as a tool for improving educational practice. Most teachers were already familiar with evaluating their practice at the beginning of the course while most LOtC educators did not have any experience in designing a case study or collecting data to reflect on. At the end of the course, three out of four participants who did not hand in a case study were educators. These educators did not establish ties with other participants who may have helped them to overcome the barrier of dealing with such a 'strange terrain'.

Shulman and Shulman (2004) noted that an on-going interaction between an individual professional and the community leads to a shared knowledge of the learning community which finally offers members the opportunity to confirm, interconnect and develop their professional knowledge. Our research focuses on how the relationships between teachers and LOtC educators develop over time. A better understanding of the social interactions is of central importance, because the individual actions can be explained with knowledge about the social network of the actor, but at the same time individual actions also change the social network (Granovetter, 1985). Analysing a social network in which participants have interest in getting in contact with others shows a dynamic web of relationships between actors to seek information, resources, support and beneficial opportunities (Borgatti & Foster, 2003; McPherson, Popielarz, & Drobnic, 1992). At the beginning of the course, the social network was dominated by the course management and additionally by LOtC educators who already knew each other for professional or personal reasons. Some participants were isolated or linked only to the network by a single relation. As early as the end of the first Module, all participants appeared to be integrated into the IPDC-network.

The strength of the ties between teachers and LOtC educators is one important dimension as a source of social capital. According to Hansen (1999) these ties facilitate problem-solving and the transfer of tacit, complex, or fine-grained information between these different professional domains. Granovetter (1982) argues that strong ties in the total network are supportive if dependent complex knowledge needs to be transferred. In addition the level of integration of all participants enables opportunities for knowledge transfer and access to resources across different professional domains. Direct contacts and more intensive interactions allow actors to get a better understanding to expand their professional knowledge. Participants with multiple relations, especially with strong ties to participants with a high authority factor, are central points by acting like a knowledge broker. A sub group connected via a hub or hubs to another subgroup or to the total network has a distinct advantage in the knowledge transferring process (Hansen, 1999; Kleinberg, 1999). In contrast participants with a high authority factor have multiple inbound relations and a tendency to behave passively; they react rather than act to transfer their knowledge (Hansen, 1999; Kleinberg, 1999).

The INQUIRE training course was asking participants to develop a complex understanding of IBSE and did not provide a simple copy and paste strategy. Thus strong ties amongst participants were assumed to be helpful. The dynamic of the INQUIRE course network shows the important role of the hubs connecting sub-groups and single participants. Participants acting as an authority are changing during the training course dependent to the course situation. Especially in the early stages of the training course, characterised by high reciprocity (R) and low density (D), the network dynamics remain uncertain in terms of which participants are really acting as an authority. However the integration of all teachers as well as LOtC educators into the social network during the first Module of the professional development course enables a range of opportunities.

All participants who successfully completed the IPDC were present for Module 2. Participants who missed Module 2 entirely, or parts of it, did not complete their case study successfully. This finding indicates that the social embeddedness of participants during the IPDC is a crucial factor for completing the course. Granovetter (1985) describes the importance of this so-called ‘embeddedness’. The more intensely educators, teachers and experts work together on the process of creation of new knowledge, the more knowledge is transferred amongst them (Huberman, 1993). The positions of the key-actors can be identified and supported. The development of the social network during the progression of the course revealed the risk of losing a subgroup of educators in Module 2. Personal support of the key-actor of this subgroup made it possible to avoid the loss of the whole subgroup. Booth and colleagues (2004) argue that CoP cannot be prescribed or installed to facilitate learning processes. They need to develop naturally and can be guided or supported by people interested in their development. By applying Social Network Analysis (SNA), the INQUIRE course management was able to identify and monitor important factors considered influential in CoP development:

- Hubs and authorities were identified in the initial stage;
- The reasons for absences of specific participants were gathered;
- Absent hubs and authorities were supervised intensively;

- Care was taken to achieve creative and innovative work in heterogeneous small groups;
- Topics for case studies were chosen by participants individually;
- The course management offered support/coaching during all stages of the course;
- In between Modules, participants were encouraged to exchange ideas and experience as well as to nurture their social network at the INQUIRE-Café;
- The training course lasted for an extended period of time to enable group members to establish social links.

Timperley and colleagues (2007) emphasised the importance of social learning in the context of Professional Learning Communities for effective in-service teacher training. We assume that SNA is an appropriate means to gain insight into the social dynamics of learning communities and thus a helpful tool to monitor their social development, to take notice of upcoming risks, and to act accordingly. More extensive research is necessary to provide sufficient evidence whether SNA will be an effective tool to improve CoP based course designs while work is in progress.

However, SNA does not tell us anything about what kind of knowledge is shared whether is helpful for the recipient or whether the knowledge content is understood accordingly in particular when it is shared amongst people with a different professional background. As learning processes are very complex and highly diverse endeavours they are difficult to observe and analyse. We experienced social network theory as a fruitful tool to interpret our observations. However, it will be important to gather more data about what is actually shared via these ties. This process will help us to understand better what makes some ties more fruitful than others and what reasons for teachers are to establish ties with educators and vice versa and whether and how mixed groups of professionals have the desired positive impact on individuals learning outcomes.

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