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Investigating patterns of interaction in networked learning and computer-supported collaborative learning: A role for Social Network Analysis

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Abstract The focus of this study is to explore the advances that Social Network Analysis (SNA) can bring, in combination with other methods, when studying Networked Learning/Computer-Supported Collaborative Learning (NL/CSCL). We present a general overview of how SNA is applied in NL/CSCL research; we then go on to illustrate how this research method can be integrated with existing studies on NL/CSCL, using an example from our own data, as a way to synthesize and extend our understanding of teaching and learning processes in NLCs. The example study reports empirical work using content analysis (CA), critical event recall (CER) and social network analysis (SNA). The aim is to use these methods to study the nature of the interaction patterns within a networked learning community (NLC), and the way its members share and construct knowledge. The paper also examines some of the current findings of SNA analysis work elsewhere in the literature, and discusses future prospects for SNA. This paper is part of a continuing international study that is investigating NL/CSCL among a community of learners engaged in a master's program in e-learning.

Keywords Social Network Analysis · Multi-method analysis · Learning · Teaching · Learning communities

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Introduction

Research studies in Networked Learning (NL)[1]/ Computer-Supported Collaborative Learning (CSCL) are often concerned with analysing the processes and practices of online learning and teaching (Banks, Goodyear, Hodgson, & McConnell, 2003, p.1). In order to study these NL/CSCL practices, many researchers have drawn upon methods such as content analysis, interviews, observations and questionnaires (Anderson, Rourke, Garrison, & Archer, 2001; Chi, 1997; Crook, 1994; Dillenbourg, 1999; Gunawardena, Lowe, & Anderson, 1997; Henri, 1992; P. Light & V. Light, 1999; McConnell, 1999; Newman, Johnson, Webb, & Cochrane, 1999; Pilkington & Walker, 2003; Strijbos, 2004; Veldhuis-Diermanse, 2002; Wegerif, Mercer, & Dawes, 1999). These methods are clearly useful to increase our understanding of the activities in which online learners and teachers are engaged. However, if we want to understand participation in NL/CSCL more fully, we need to ask important questions such as:

- Who is involved with the collaborative learning task?
- Who are the active participants?
- Who is participating peripherally?

Additionally, the dimension of understanding how these participatory patterns change over time is also important in the complex dynamics of NL/CSCL. The methods we have mentioned above do not help us to see the 'patterns' of interactions between the participants systematically. Nor do they help us to elicit the connections made among them. For this we need to draw on relational data, based on how the participants have used the computer network to interact.

One way of approaching this task is to start by thinking of a computer network (used to connect people), as a social network (Wellman, 2001). In NL/CSCL settings this analogy is particularly relevant because of the high level of interactions that occur between participants. It is then a small step from this to realizing that the computer system log files (containing information about the activity of the participants) can be used to study aspects of this social network and its interaction structure (Nurmela, Lehtinen, & Palonen, 1999).

As Barry Wellman indicated in the magazine *Science*, "human computer interaction has become socialized. Much of the discussion [...] is about how people use computers to relate to each other... [and] has slowly moved from the lone computer user to dealing with (1) how two people relate to each other online, (2) how small groups interact, and (3) how large unbounded systems operate." (Wellman, 2001, p. 2031).

We would like to propose that the technique of Social Network Analysis (SNA) may be able to assist in describing and understanding the patterns of participant interaction in NL/CSCL. SNA is a research methodology that seeks to identify underlying patterns of social relations based on the way actors are connected with each other (Scott, 1991; Wasserman & Faust, 1997). We propose that interactions among participants in NL/CSCL communities may be relatively easily mapped out and explored using SNA, and doing so provides us with additional useful analytical data about the activity and relationships of the NL/CSCL

[1] NL is a U.K. and European term that is used in place of CSCL. We think it is, for practical purposes, synonymous with CSCL and henceforth will refer to them both as NL/CSCL. By NL/CSCL we mean the use of internet-based information and communication technologies to promote collaborative and co-operative connections between one learner and other learners; between learners and tutors; and between a learning community and its learning resources, so that participants can extend and develop their understanding and capabilities in ways that are important to them and over which they have significant control (Banks, Goodyear, Hodgson, & McConnell, 2003, p.1)

members. SNA may help us to ask further questions about the nature of NL/CSCL because it provides a new way of viewing participants' activities. It may also help to confirm or contextualize conclusions and interpretations about participants' behaviour in NL/CSCL environments gathered using existing analytical techniques.

In the following sections of this paper, we will discuss (1) how SNA can be used, in general terms, when studying NL/CSCL, and (2) provide a brief account of the application of SNA to a small sample of our own case study data. This case study examines teaching and learning processes in a NL/CSCL community. This case study is provided as an illustration of the use of SNA in analysing NL/CSCL interactions. It is not intended as a full report of this case study in the present paper (see De Laat, 2006, for the full presentation of the case study). The sample size in this example study is based on a compromise arising from the need, in our view, for very detailed multi-method analysis, and the workload that this approach imposes upon researchers. Content analysis and social network analysis are very labor-intensive techniques. In assessing their value in helping us to understand the nature of NL/CSCL communities, this aspect of the analysis must be taken into account.

A general discussion of Social Network Analysis and NL/CSCL

Social Network Analysis (SNA) may help in identifying patterns of relationship between people who are part of a social network. It may assist us in the analysis of these patterns by illuminating the 'flow' of information and/or other resources that are exchanged among participants. In this paper, we claim that SNA produces results that may be used to further investigate aspects of the effects that these relationships have on the people that are part of the network. Using SNA, the social environment can be mapped as patterns of relationships among interacting members (Wasserman & Faust, 1997). SNA offers a method to focus on relational data, as distinct from data or attributions where the focus is on the characteristics of the individual. The network patterns generated by SNA may thus form the basis of many further investigations. The unit of analysis in SNA is not the individual, but the interaction that occurs between members of the network. The exchange of messages in a discussion forum is our primary focus in this paper. The attributes of these messages-the author, the message content, or the roles of participants, for example-are secondary to SNA itself, but they are very central to the interpretation of the 'nature' of the relationships that are revealed by SNA.

A Networked Learning Community, such as we might encounter in a Higher Education Masters Program, may show many connections between participants and have clear boundaries with respect to who is a member and who is not. Membership is based on participation in a university course, fixed for a finite period of time, and moderated by a teacher or tutor. It will employ a range of collaborative learning and problem solving techniques, which make NL/CSCL distinctive. Based on these criteria, such a community can be studied as a 'whole' social network. SNA allows us to visualize the network based on the presence and absence of connections between its members.

This whole network perspective may be complemented by studying the content of the exchanges between the participants. In NL/CSCL, this content will be related to the kind of collaborative task that members have set out to achieve. The use of content analysis (Gunawardena et al., 1997; Hara, Bonk, & Angeli, 2000; Henri, 1992) can provide insight into the nature of the content of communication among the participants. This can then augment the perspective gained by using SNA to focus on network connections. These may vary in content, in direction of information flow, and in strength (network connections can be weak or strong, depending on the number of exchanges between participants).

When applying a whole network perspective, SNA can be used to provide an indication of the cohesion of a network. The two key indicators of SNA are "density" and "centrality." Density provides a measure of the overall 'connections' between the participants. The density of a network is defined as the number of communicative links observed in a network divided by the maximum number of possible links (Scott, 1991). This varies between 0 and 100%. The more participants connected to one another (by, for example, their message exchanges), the higher will be the density value of the network (Borgatti, Everett, & Freeman, 2000; Scott, 1991). Centrality is a measure that provides us with information about the behavior of individual participants within a network. Centrality indicates the extent to which an individual interacts with other members in the network (Wasserman & Faust, 1997). Using this measure, we can uncover who, for instance, is a central participant of a particular social network. This can be done for each participant by measuring the number of connections with the other members and generating "in-degree" and "out-degree values." In-degree centrality is a form of centrality that counts only those relations with a focal individual reported by other group members. Therefore, it is not based on self-reports (as is the case with out-degree centrality) (Borgatti, Everett, & Freeman, 2000). In this study, in-degree measures provide information about the number of people who respond to a message from a certain participant. Out-degree gives an indication of the number of messages a person has sent to other individual members of network (see below for further details). SNA can also be used to visualize the network connections by creating a graphical representation called a sociogram. A sociogram is a representation of all participant connections in a social network. The participants are represented as "nodes" and the connections are visualized with lines between the nodes. In this way, one can examine the nature of interactions within the network and how individuals are positioned within the network to play more central or more peripheral roles in the interactions of the group. Visualizations of social networks can show whether interactions are occurring between all members of a group or whether some group members are communicating more (or less) with other specific individuals (Haythornthwaite, 2002).

The SNA approach offers a method for mapping group interactions, visualizing 'connectedness' and quantifying some characteristics of these processes within a community. This technique is used commonly in sociology and organizational studies, but there is a growing interest among researchers in NL/CSCL to apply SNA to study group interaction, communication and dynamics (see Haythornthwaite, 2001). We will now briefly summarize some recent studies in NL/CSCL that have made use of SNA. Haythornthwaite, for example, showed that during class communication in a NL/CSCL environment there was a tendency to interact more as teams within the network. Martinez, Dimitriadis, Rubia, Gomez, and de la Fuente (2003) found that the density of a network was affected by the teacher's presence. Reffay & Chanier (2003) illustrated that SNA can help study the cohesion of small groups engaged in collaborative distance learning as a way to locate isolated participants, active subgroups, and various roles of the participants in the interaction structure. Reuven, Zippy, Gilad, and Aviva (2003) found that in a structured, asynchronous learning network (as opposed to an unstructured open discussion forum) the knowledge construction process reached a high level of critical thinking and the participants developed cohesive cliques. Nurmela et al. (1999) used SNA to study participation in collaborative learning activities such as knowledge building and acquisition. Cho, Stefano, and Gay (2002) used SNA techniques in an educational context to identify central, influential actors in a class. They found, similarly to Beck, Fitzgerald, and Pauksztat (2003), that participants using a discussion board were more likely to follow recommendations made by highly 'central' actors than those made by peripheral actors. Daradoumis, Martinez-Mones, and Xhafa (2004) used SNA to assess participatory aspects, identify the most effective groups and most prominent actors to monitor and assess the performance of virtual learning groups.

An example of SNA as part of a multi-method case study

In the second part of this paper we will present a brief summary of one of our own case studies as an example of how SNA may be used to explore group cohesion and interaction patterns within a networked learning community. This is part of a larger study, but it serves to illustrate how these patterns evolve over time, and attempts to combine these outcomes with the development of teaching and learning processes that were also investigated as part of the study. To our knowledge this is the first time that SNA has been used in this way and, as a consequence, there is little comparative data available with which to compare our findings. However, the notion of following interaction patterns over time within Networked Learning Communities has been implemented in several studies. Hara et al. (2000) provide a study in which they conduct a timeline analysis of computer-mediated communication. Howell-Richardson & Mellar (1996) made weekly visual representations of conference activity, based on direct or indirect connections made by the students in their messages. Their analysis was focused on describing interaction patterns when students are assigned to particular roles, and exploring these patterns as they changed over time. Daradoumis et al. (2004) implemented a similar time-line analysis in their research design to track the changes in student participation and group cohesion over time. However, they did not relate these findings with their analysis of student productivity and qualitative coding of collaborative learning processes. Haythornthwaite (2001) and Martinez et al. (2003) also concluded that network patterns change and that it is important to study these changes over time.

The study presented in this paper is part of an ongoing academic collaboration in which we are studying a networked learning community pursuing a Higher Education course for an M.Ed. at Sheffield University (UK). In our previous studies within this project, our focus was on describing teaching and learning processes through content analysis and interviews (De Laat & Lally, 2003, 2004). As such, we were investigating this community by trying to give an account of the teaching and learning behaviour of participants. This provided us with detailed analytical data about the content of the interactions and about participants' thinking, but we lacked data about the dynamics of participants' interactions in this community and how they were connected to each other. This makes it difficult to assess or make claims about the overall performance of the NLC. Questions about how activities are distributed over the community (levels of participation), the progress made over time in interacting as a balanced community, and the growth and decay of relationships between the members were largely unexamined by these earlier methods. During our previous studies we had developed some expectations and knowledge about the nature of participation of some of the participants. With SNA, we hoped to be able to illuminate these issues more systematically and extend our analysis by synthesizing these findings with the other studies that are part of our research project. In this study, we focused on the interaction patterns between the members of the community and studied its dynamics over time.

To summarize, in this study we focus on the following questions:

1. How dense is participation within the network and how does this change over time?
2. To what extent are members participating in the discourse and how does this change over time?

The participants featured in this study were undertaking a Master's Program in E-Learning. This M.Ed. program is based on the establishment of a 'research learning community' among the participants and the university teacher. It is fully online; there is no scheduled face-to-face contact in the 2 years of the part-time program. In this community, activities are undertaken around five 'workshops' over a two-year period. The program is hosted in the virtual learning environment called WebCT. The students are mainly mid-career professionals, many of whom have post-graduate experience of higher education, are themselves professionally engaged with teaching responsibilities, and are often charged with developing e-learning within their own organization. Our analysis is based on collaborative project work conducted by seven students and one tutor in the first workshop of this program (approximately 10 week's duration). In order to make the analysis manageable we sampled the message data from the workshop (approximately 1,000 messages were posted during the task). We divided the 10-week period into three sections: beginning, middle and end. From each period, we took a 10-day message sample to form our data set. In each sample we analysed messages in selected threads rather than sampling across threads. This was important to enable us to follow and code the development of learning and tutoring within an ongoing discussion rather than across unrelated messages. This resulted in a selection of 160 messages. Content analysis is a powerful technique, but it is also a labor intensive endeavor and generates very detailed analytical data. For this reason, we sampled the raw data rather than subjecting all of the message threads to content analysis.

The central purpose of content analysis (CA) is to generalize and abstract from the complexity of the original messages in order to look, in our case, for evidence of learning and tutoring activities. In order to probe collaborative NL/CSCL learning and tutoring we 'coded' the contributions using two schemas. The first coding schema, developed by Veldhuis-Diermanse (2002), was used to code units of meaning that were regarded as "on the task." These focused on the learning processes used to carry out the task. This schema includes four main categories: cognitive activities used to process the learning content and to attain learning goals; metacognitive knowledge and metacognitive skills used to regulate the cognitive activities; affective activities used to cope with feelings occurring during learning; and, finally, miscellaneous activities. We decided to exclude the miscellaneous category in our analysis since we were interested in the evidence of learning activities. The second schema is used to code units of meaning that are "around the task," where the focus is on tutoring (Anderson et al., 2001). This schema includes three main sub-categories: design and organization, facilitation of discourse, and direct instruction. Our intention here was to attempt to reveal the ways in which the participants were facilitating and regulating each other's learning while undertaking the workshop project task.

Codes were assigned to parts of messages based on semantic features. For example, expressions of ideas, argument chains, and topics of discussion were coded using the smallest unit that made sense to the reader (Chi, 1997). This is known as a unit of meaning. Therefore, our unit of analysis was the unit of meaning. Capturing these activities using strict syntactic rules was not possible because of the elaborate nature of a discussion. We chose to use NVivo software to help us to partially automate this process-to highlight segments of the text with coding that we claim represent a particular learning or tutoring activity. In effect, these coded segments were our units of meaning. NVivo was also used to conduct searches of the coded data in order to produce summary tables (see tables, below). To determine our inter-coder reliability, for each coded message we first checked to see if the codes assigned by the two coders referred to the same parts of the message (i.e., the same units of meaning). Second, we checked to see if the two coders had assigned the same codes to each unit. Based on a 10% sample of all the messages coded by the two researchers, a Cohen's Kappa of 0.86 was established, indicating an acceptable level of agreement between the coders.

Content analysis has provided us with evidence of learning and tutoring process patterns that were occurring in this group during the workshop task. To understand these patterns further, we used the summary results of the content analysis as a stimulus for "critical event recall" (CER) interviews with the participants. This was done to gain feedback from them about their own understandings of the patterns that emerged, and to help us to understand the context in which these patterns were emerging. The CER interviews enabled the articulation of many previously unexpressed aspects of learning and helped to contextualize and elucidate individual behavior, based on personal motives and perceptions in relation to the task and the other participants. Therefore, we pursued those situational and contextual aspects of NL/CSCL that were identified by participants during these recall interviews. The interview layout contains two parts. The first part is based on stimulated recall of the learning event (CER). During the second half of the session the opportunity for post-hoc reflections is provided, with additional follow-up questions to help probe and understand the group processes.

A shortened version of the summary table is included in this paper (Table 1). For a full description of the coding and CER process and outcomes, see De Laat and Lally (2003, 2004). The present brief example seeks to demonstrate how these studies are enriched by using SNA as a third method to analyze and contextualize our findings on learning and tutoring processes in an NLC. This 'triangulation' is a process through which more than one approach is used in the investigation of a research question in order to enhance confidence in the ensuing findings (Bryman, 2004). Triangulation in this research project is done in several ways. First, it is done by integrating the outcomes of one (or more) method into the next method. In the example study presented here, we used notions of student participation and teaching and learning activities to opportunistically select the participants for the CER interviews. In this way we tried to cover what seemed to us to be interesting emergent patterns, like participants who showed increasing versus decreasing activity over time. Second, we used the summary tables produced during the CA (for example) as a stimulus during the CER interviews and asked the participants to reflect on these patterns as a way to focus the interview. Third, we used the outcomes of one method to interpret and contextualize the outcomes of another method. For example, we related participants' positions on the sociograms with the outcomes of the CA table. It is expected that central participants will also have engaged more frequently in learning and teaching activities (the

Table 1 Units of meaning coded for learning and tutoring processes in the three phase samples for workshop one

	Bill	Katie	Brian*	Pauline	Andrea	Felicity	Charles	Margaret	Total
Beginning phase sample (57 messages)									
Learning processes	0	5	6	2	25	9	18	7	72
Tutoring processes	3	4	18	7	9	3	13	3	60
Middle phase sample (70 messages)									
Learning processes	7	1	0	8	9	11	19	21	76
Tutoring processes	5	4	5	6	31	5	7	9	72
End phase sample (33 messages)									
Learning processes	6	0	3	1	9	4	4	5	59
Tutoring processes	7	0	18	2	10	4	3	1	45

*Brian was the designated university tutor in this group forms of triangulation we are using are referred to as data triangulation (gathering data at different times) and methodological triangulation (using more than one method to gather data) (Denzin & Lincoln, 2000).

Using WebCT as a source of raw data for SNA

WebCT generates log-files that may be used to analyze activity of the participants of a learning community. The information retrieved from WebCT logs can be treated as relational data and stored in a case-by-case matrix (based on writing and responding activities) in order to analyze interaction patterns. UCINET is an SNA software package and may be used to analyze the data derived from WebCT log files in order to help visualize the social structure of the community. For this purpose, we focused on the cohesion of the network (Scott, 1991; Wasserman & Faust, 1997). We conducted density and centrality measures, and created sociograms based on the same data set. We use these measures to interpret the nature of the discourse by relating these findings to our previous content analysis.

Sample results of SNA analysis

This research is of a qualitative nature. It is important to note that no inferential statistical tests were carried out on the data. SNA and CA results are used to describe the teaching and learning processes as they took place within the NLC. We use the quantitative nature of the data to make comparisons, in relative terms, but not for inferential purposes. The density values show that the overall connection between the participants, especially in the beginning and the middle phase, is reasonably high (Table 2), which suggests that the members of this community are closely collaborating on their group task. In the beginning phase, the density is 48%, and for the middle phase the value is 46%. In the last phase of the collaboration the value drops somewhat, to 36%. One has to keep in mind that density values tend to be higher in smaller networks; it is, of course, much easier to maintain many connections with a few participants than with very many participants.

To find out how balanced the participation is within this community, we have to look at the out-degree centralization measures. A high out-degree centralization value indicates that the communication is dominated by some central participants; a low value means that communication is distributed more equally among all the participants. It is interesting to see that while the density drops slightly in the middle, the out-degree centralization goes up. This means that some participants have become more centrally involved compared to the beginning phase. The same holds for the ending phase where both values dropped, but still the out-degree centralization is leaning towards a domination of the interaction by a few participants. In general, this imbalance does not necessarily mean that some participants control the communication by excluding others. It may mean that some participants choose to make fewer contributions to the community during this phase.

Table 2 Density and out-degree centralization for each phase of this network

	Beginning	Middle	End
Density %	48	46	36
Out-degree centralization %	88	109	52

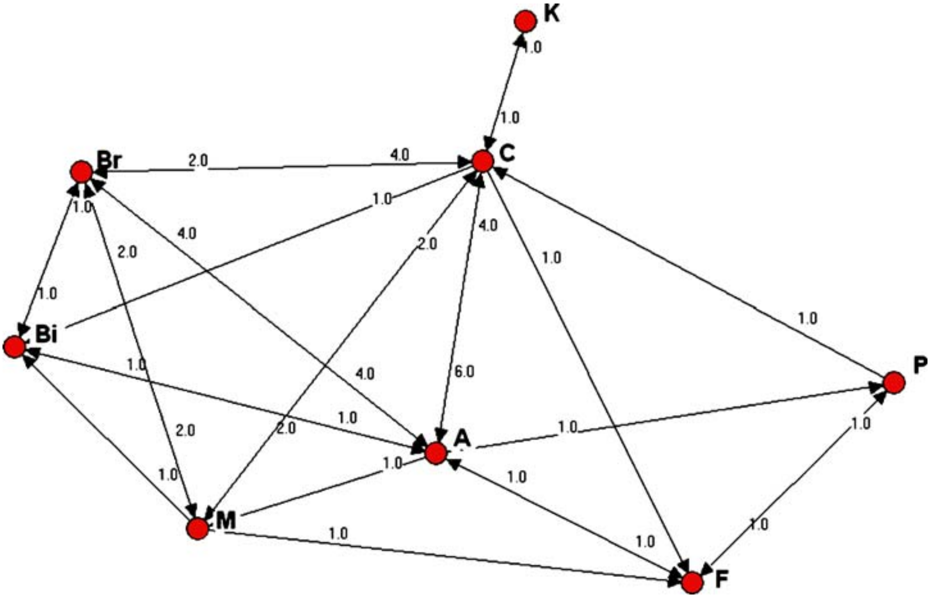

Fig. 1 Interaction patterns between eight participants in the beginning phase of a learning task

To explore some answers to the second question, (To what extent are members participating in the discourse and how does this change over time?), we start by presenting the findings of the in- and out-degree values for each participant (Table 2). We also present the visual representation of the interaction patterns (Fig. 1) for each phase of this NLC as they emerged from the discussion threads in WebCT. The high values (in bold) in Table 1 clearly show who are the more active participants during this collaborative work project. Overall, one may say that there seems to be a difference between active and more passive members. In the beginning phase, Brian (the university teacher), Andrea and Charles are responsible for almost 75% (36 messages) of all the written messages. They also receive about 65% of all the responses. This suggests that this sub-group may be communicating among themselves. Using SNA alone, however, does not provide us with a full picture. It is also useful to combine these findings with the outcomes of content analysis to interpret whether central participants, as determined by SNA, are also central to the learning and teaching activity within this group. If they are not, they are probably chatting about issues that are not central to their learning task. Therefore, we need to compare these SNA findings with the learning and teaching analysis undertaken during our previous studies.

When relating the SNA results to the CA (Table 3) we see that Andrea and Charles are responsible for 60% of the learning messages, and that the others (except Bill) are also making a learning input. With respect to tutoring, it seems that Brian and Charles (50%) are responsible for most of this, but all the participants were involved to some extent as well. This leads to the conclusion that although Brian, Andrea and Charles appear to be active participants, they are not entirely dominating the teaching and learning activities of the NLC during this phase. In the middle phase, where the network out-degree centralization went up, we see a shift in participation. Andrea, Charles and Margaret are the strongest contributors (70%) and receivers (65%) in this phase. Charles and Margaret are mainly focused on learning contributions (50%), while Andrea has taken a strong interest in trying to tutor the activities of this community (43%). Brian, besides a modest tutoring input, has

Table 3 Out- and in-degree of the participants and initiated threads in the three phase samples for workshop one

	Bill	Katie	Brian*	Pauline	Andrea	Felicity	Charles	Margaret	Total
Beginning phase sample (57 messages)									
Out-degree	2	1	9	2	14	2	13	6	49
In-degree	4	1	11	2	10	4	12	5	49
Initiated Threads	0	1	1	1	1	1	1	2	8
Middle phase sample (70 messages)									
Out-degree	5	3	2	6	21	2	11	11	61
In-degree	8	5	2	6	17	0	11	12	61
Initiated Threads	1	1	0	1	3	0	2	1	9
End Phase Sample (33 messages)									
Out-degree	5	0	6	1	8	4	2	2	28
In-degree	11	0	3	0	4	5	2	3	28
Initiated Threads	2	0	0	0	2	0	0	1	5

*Brian was the designated university tutor in this group

made little contribution during this phase. His in- and out-degree dropped to 2. During the ending phase, where the density of the network dropped, we see that general participation went down and that there is a difference between the in- and out-going degrees. In fact, there is one participant (Bill) who receives 40% of all the comments made. The relatively active contributors here are Bill, Brian and Andrea (67%), while Charles and Margaret have dropped considerably. Table 3 shows that both Charles and Margaret are still making a learning contribution to the community, whereas Brian, Andrea and Bill, provide the tutoring input to the last phase of their collaborative project.

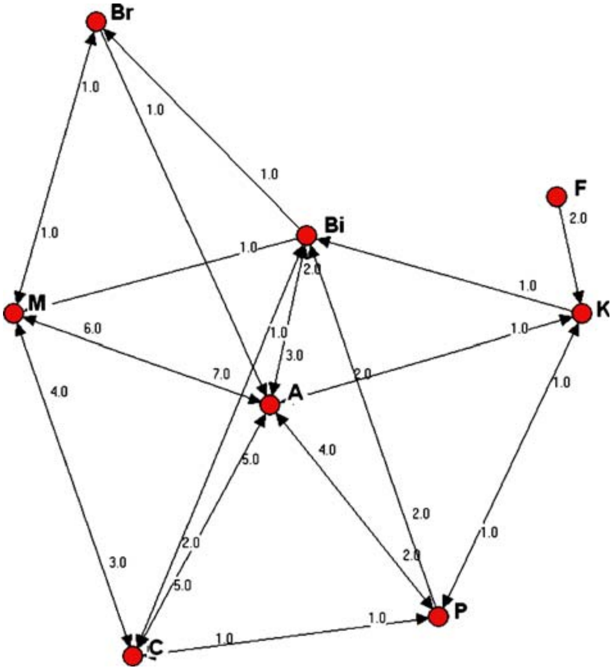

Fig. 2 Interaction patterns between eight participants in the middle phase of a learning task

These general network properties can also be studied more closely using the sociograms. In this way we can visualize all the connections each participant has made with the other members of this NLC. Figures 1, 2 and 3 also show how the communication between the participants evolves over time as they work collaboratively on the learning task. Each phase (beginning [B], middle [M] and end [E]) has its own focus and dynamic in the community. In these figures, the numbers associated with the network ties represents the volume of communication between participants.

In the beginning phase, the presence of Charles (C) is evident in the community. He is the only one who is connected to all the other members of this community. This position was to some extent already evident from his relatively high in- and out-degree scores as shown in Table 2, but we had no information about the nature of his connections with the other participants. At the beginning of the learning task Charles acts as a central member in this community by actively taking the lead in discussing where this project should be heading. Andrea (A) also is a very central member in the community. But she has a different way of contributing. Our previous research showed that she took a more 'learning' interest in the project at this stage (L-25/T-9; see Table 3) whereas Charles (L-18/T-13) was active as a learner and a tutor, trying to get things going. Andrea indicated previously (during the CER when she was asked to reflect on her behaviour in this NLC) that she was surprised to see the analysis of the way she contributed to the group. For her, this way of working was natural. However, she was conscious that she made a large contribution to the

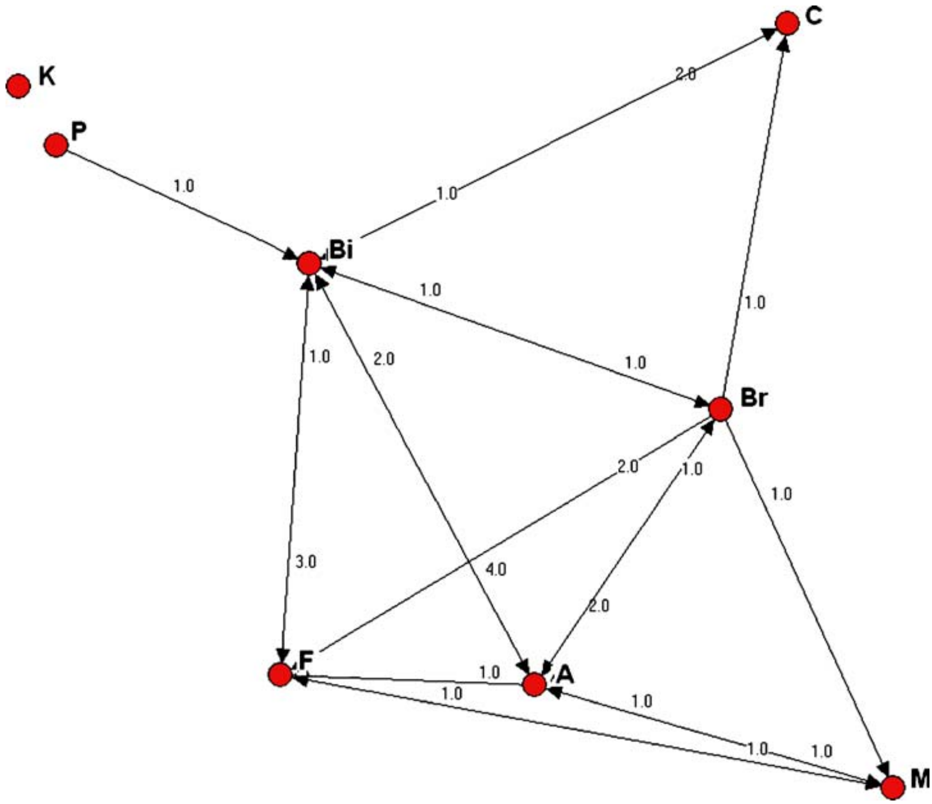

Fig. 3 Interaction patterns between eight participants in the end phase of a learning task

groups' discussion, while Charles thought it was important for the NLC to keep task-focused. He saw his role as contributing ideas to the group. He was not surprised by his central position during this phase of the collaboration. In this phase Brian (Br) (the university teacher) is also a participant; his concerns were mostly with moderating this community (T-18; see Table 3), making sure everybody was participating and getting on with the project.

Another interesting feature we can see in this graph is how tightly knit this community is; no one is left out completely. Although there are different levels of contribution, everybody is engaged in writing messages and one can see that the participants get responses from almost all the members. This finding is consistent with the relatively high density of this network as reported earlier. This is also reflected by the in-degree values of Felicity (4) and Bill (4), who only made minor contributions to the discussion in this phase but are still connected to four other members of this community. Only Katie (K) and Charles seem to have been writing (exclusively) to each other.

In the middle phase (Fig. 2) the interaction pattern seems to have changed. One might say that the starting phase, where everybody gets to know each other, is now passed and the discussion has become more exclusively focused on working on the project. There is an increase in learning and tutoring activities, yet the network density remained mostly the same. The more active participants in this phase are again Andrea (A), Margaret (M), and Charles (C). On the other hand, the contributions made by Bill, Pauline and Katie to the discussion have also gone up a little. However, the shape of the interaction pattern has taken roughly the form of a square (between M, Bi, P and C, with A in the middle). Where, in the previous phase, messages were sent out to almost every member in the community (as was indicated by its circular shape), here the connections between all the participants are less strong and have become more centralized. Felicity seems to have left the discussion during this phase and Pauline and Bill were making contributions more peripherally. However, based on how the arrows are pointing, it seems that the community has not split up into different subgroups that are ignoring each other. If we compare these interactions with our previous findings (Table 3), we can see that Andrea's active interest is mostly towards tutoring (L-9/T-31) instead of making learning contributions as she did in the previous phase (L-25/T-9). When asked to reflect on group participation, Andrea was thought of by some of the other members as a group facilitator and "people-focused." This explains her position in the middle phase. She indicated she was constantly checking and watching the group process. According to the teacher (Brian), she was very facilitative in all her communications. Where Andrea developed a more tutoring role, Charles did the opposite. He continued to stay focused on the task. The teacher labelled him as a 'do-er' and was very active putting in ideas and experience. But apart from dialogue about how to get things done he did not want to talk or think about it. Margaret's active participation during this phase shows an increase in learning activities (L-7 in the beginning/L-21in the middle phase).

The final phase shows a very strong shift in the interaction pattern (Fig. 3). This finding is supported by the earlier reported decrease in density and the drop in in- and out-degree values. Bill, however, has now become a full member in this community-reflected by his relatively high in- and out-degree values-and is actively moving the discussion forward, acting as both a learner and tutor in the community (L-6/T-7; see Table 2), and Felicity has made a 'come back.' According to the teacher, Bill was motivated throughout the entire workshop. But he was new to this way of working and used the beginning and middle period to familiarize himself with it and at the end he was ready to make an active contribution. When asked to reflect on the way he participated in this NLC, Bill said of himself that he had to go through a huge learning curve, but as he became more confident he started to see his fellow participants as peers and felt comfortable enough to engage. He sees himself as a finisher and felt, in part, responsible for bringing this collaborative project to a good end. Brian (the teacher) has moved more towards the center again, sending out messages to most of the other participants and seemed mainly concerned with moderating the community (L-3/T-18). Pauline and Katie have made no contribution to the community at this stage and Charles has moved away from the center completely. Margaret's learning interest, as she showed in the middle phase, has dropped, but she remains an active member along with Andrea, while Bill is still actively regulating the community discussion.

Conclusion and discussion

In this paper, we have argued that if we want to understand participation in NL/CSCL more fully, we need to ask important questions, such as:

- Who is involved with the collaborative learning task?
- Who are the active participants?
- Who is participating peripherally?

Additionally, we argue that participatory patterns change over time. It is therefore also important, in understanding the complex dynamics of NL/CSCL, to use methods that help us to see the 'patterns' of interactions between the participants and their temporal dynamics. For this we need to draw on relational data, based on how the participants have used the computer network to interact. We argue that SNA provides us with a suitable analytical tool for this work, one that helps us probe these dynamics and reveal the interaction patterns in the social networks that develop in collaborative group work. SNA seems to hold promise as a method that may enable researchers to quickly analyze group properties of networked learning communities. In order to develop this argument, the paper is divided into two sections. First, we provided a general account of SNA and how it may be used to analyze data made available through WebCT log files. Second, we provide a brief example, from our own work, of how SNA analysis may be undertaken in combination with other analytical techniques, and an indication of the kinds of understandings that may be derived from such analysis.

In our example analysis we found that the group density was quite stable, and only dropped at the end of the collaborative project. This means that the levels of connectivity and engagement in this community are relatively equally spread. These are positive findings in terms of group cohesion. They are very promising for NL/CSCL research because they indicate that NLC members in this course are able to sustain productive collaborative relationships over time without showing large drop out effects, or without individual participants being pushed to the side by more dominant participants.

Figures 1, 2 and 3 represent the interaction patterns for this learning community over three phases of a learning task of ten weeks' duration and show how these patterns evolve. When combining these findings with the outcomes of the content analysis, it became clear that although the position of the participants in the network remained the same, the nature or focus of their contributions changed over time. This suggests that participants develop different roles or interests during their collaborative work (Reuven et al., 2003) or take different interests as their project develops. We think, therefore, that it is important when studying NL/CSCL to not only focus on overall patterns of participation, collaboration and knowledge construction during NL/CSCL, but to take into account the evolution of these processes over time. Group behaviour is not stable, and as researchers in NL/CSCL we are interested in studying how participants learn and develop their competencies as networked learners in the first place, and how to design pedagogical support for them as they go along. The fact that participants gain or lose interest during their collaborative project is made visible using SNA. The interaction patterns clearly showed transformation of membership; some participants were gradually moving more towards the center of the network, while others were moving away from the core activity to become more peripherally engaged. We also found that it is not necessarily the case that the most active members always regulate and dominate the discussion (Tables 2 and 3) (Reuven et al., 2003). Some participants simply take a strong interest in debating and putting in new ideas to the project, while others are more concerned with managing the overall group activity. The group seems to make use of the different qualities participants bring to their collaborative project as a way to get things done collectively. Hara et al. (2000) found similar participation characteristics in their study; they noted that some participants were more socially engaged while others displayed extensive metacognitive skill.

At the present time, the number of studies available that adopt a research agenda similar to the one outlined here is relatively small. Based on existing studies that implement some kind of timeline analysis we would like to offer the following observations. Hara et al. (2000) established that group interaction patterns change over time and that pre-assigned student roles (a starter and a wrapper role were distributed over the group) have an impact on the interaction patterns at various stages in the collaborative project. In the patterns that emerged, they could identify the starter and wrapper role by the way the messages were pointing (directly or indirectly), and they also indicated that the interaction patterns were scattered when one of these roles was not executed. Another finding of theirs was that halfway through the course all the messages were connected either directly or indirectly, resulting in a synergistic pattern, and some students started to act as a wrapper spontaneously. However, from this pattern they also concluded that most messages still pointed towards the starter, suggesting a strong influence of the starter throughout discussion. Later in their study, the interaction pattern became more explicit and there were fewer indirect connections between the messages. In the study conducted by Martinez et al. (2003), the density of the networks decreased over time but went up in the last period when the participants needed to develop a collaborative product. Daradoumis et al. (2004) described a study in which the density values remained stable over time, with only a slight drop in the last period. The prominent participants showed a regular participation throughout the course. The teachers, in spite of their high level of activity, were never in a top position, which means that the students were actively involved in the classroom activities. Daradoumis et al. used SNA in combination with other qualitative and quantitative techniques to evaluate student performance in virtual learning groups. Although they did not relate their changes in density over time with their other findings, one can assume that where density is higher the group is collaborating more closely, suggesting that they also found that groups working on collaborative tasks are able to develop a relatively stable group structure in order to see their collaboration through to the end.

Our research suggests that these patterns may change dramatically over time, providing opportunities for every member of the community to become a full or peripheral member. Full participation during one phase may involve active learning as well as regulating or coordinating the discourse. It is therefore crucial to use a combination of content analysis, interviews and social network analysis to understand the teaching and learning processes that are present during NL/CSCL. This approach also enables researchers to track the changing relationships between the group members, the nature of their contributions and the participants' experiences. We suggest that research into NL/CSCL would benefit from a multi-method approach in which analysis of data in complementary ways is used to draw a more complete picture and deepen our understanding of NLCs.

In summary, what do these social network analysis diagrams and network properties add to what we already know, from previous research (De Laat & Lally, 2003, 2004), about this community? The overall patterns of communication are illustrated in a way that shows the social nature of group learning and tutoring. This dimension was not revealed in content analysis of messages (Table 3) and CER. The diagrams show how people connect to the members in the group, the patterns of collaboration are revealed (one-to-one or many-to-many), and the involvement of individuals in each phase. The findings may be used to seek further explanation for this behavior or can be used to contextualize previous findings about the NL/CSCL activities. However, only by combining SNA with CER and CA can we understand the process and intentions of the participants at the level of individual agency-what they claim they are doing, why they are doing it and how it occurs through posted messages. By using a time line analysis when studying learning and teaching processes we can also see how certain participants become gradually more active and central figures in their community.

We conclude that SNA is a valuable complementary analytical tool in our search for richer understandings of the processes occurring in Networked Learning Communities. SNA can provide a useful window for teachers and students to see how they act as a group. Information can then be used by them to reflect strategically on their collective performance and to make decisions on how to move forward.

SNA provides added value within a multi-method approach and meets the need for triangulation of data. First, SNA provides a quick way to build up a clear understanding of group activities and its cohesion. A Networked Learning Community (NLC), such as we see in Higher Education, is of a kind that is potentially heavily connected and has clear boundaries with respect to who is a member and who is not. For researchers (but also for both teachers and students), it is valuable to know more about the engagement of participants in particular NLC activities. SNA can be used as a selection method, and as such will assist in selecting the appropriate groups to study. For instance, if one is interested in studying teacher-student interaction one will need to know if there was any teacher-student interaction in the first place. But SNA will also provide teachers with the information on how the students are engaged in the project. In this way the teacher is able to target isolated participants and offer some kind of support.

SNA may be used to interpret outcomes of other methods-it provides information about the overall group's functioning and the strength and direction of their interactions. CA and CER outcomes will be viewed differently when it is known if the group was heavily connected with equally distributed in- and out-degrees, or (for example) if there was a relatively low level of connection between the whole group, with only two participants being responsible for most of the interaction that took place. Furthermore, CA coding results can be mapped against position in the group as identified by SNA. We have demonstrated that it is important to assess the relationship between CA scores and position in the group. Statements made by the participants about their own and others' engagement in group activity can then be contextualized from their own position in the network. Our work with SNA also increases our confidence that CSCL/NL participants, interviewed during CER sessions, have a good understanding of how the community interacts. They seem to have built up a mental picture of the interaction patterns and have an impression of who is active and who is not and also who is related to whom. They also show awareness of who acts as a central figure, trying to move the learning or teaching activities of the community forward. According to Daradoumis et al. (2004) evaluating a real collaborative learning situation is a very complex task. One has to consider a variety of aspects, and integrate several analysis techniques, data and tools into a mixed evaluation method. They used a mixture of methods to complement their findings to "unfold the group's internal workings and achieve a more objective interpretation." Our work supports this conclusion.

We think it is important to systematically create an evidence base of NL/CSCL processes and procedures that can be used to develop hypotheses to study particular aspects of NL/CSCL in more detail. We have argued elsewhere that researching NL/CSCL is complex and not easy, and that a multi-method approach is needed to study the complexities of NL/CSCL practices. In this paper, we discussed SNA techniques that can be used to visualize and describe patterns of relationships present in social networks. This may have value for NL/CSCL research when complemented with other research methods. NL/CSCL is a complex reality where multiple variables interact and influence each other in rich empirical and 'ecological' settings. We suggest that multi-method research can contribute to our understandings of this complexity and create an evidence base of networked learning practices based on user experiences and interpretations of participation (Hakkinen, Jarvela, & Makitalo, 2003; Strijbos, 2004). However, this research is based on one NLC and systematic descriptive research in other NLCs is needed to contextualize these findings. Research in NL/CSCL is often based on small-scale studies and is, as a consequence, in need of meta-analysis and synthesis. Research in NL/CSCL will benefit from a synthesis of findings drawn from a wider range of studies, as a way to relate results and generate a more coherent body of work. It is our hope that the present paper, and the series of which it is part, makes a helpful contribution to that endeavor.

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