Understanding emerging knowledge spillovers in team-group learning settings: Active team learning with limited friendships[i]

Nuria Hernandez Nanclares

Universidad de Oviedo, Oviedo, Spain, nhernan@uniovi.es

Bart Rienties

University of Surrey, Centre for Educational and Academic Development, Guildford, United Kingdom
b.rienties@surrey.ac.uk

Piet Van den Bossche

Universiteit Antwerpen, Instituut voor Onderwijs- en Informatiewetenschappen, Antwerpen, Belgium & Department for Educational Research & Development, Maastricht University, the Netherlands
Piet.VandenBossche@ua.ac.be

Abstract

In classroom teaching, teachers make increasingly use of collaborative learning formats such as team learning, and educational technology to enhance the learning experience of students. Most research on team-learning focuses on learning within teams. However, to what extent do learners also share knowledge between teams during a course? This study took place in a third-year course on International economics, whereby 57 students were divided into eleven teams and learned and collaborated in an innovative blended learning environment. For ascertaining whether inter- and intra-team learning and knowledge spillovers occurred during the course, we employed a method developed within the field of Social Network Analyses (SNA). We measured prior friendship relations during the first week, while possible knowledge spillovers between learners and teams were assessed during week 4, week 7 and week 14.

The results indicate that knowledge spillovers across teams do occur over time. All eleven teams developed outside links to other teams after 14 weeks. Already after seven weeks, the average number of external links tripled to 20.0, which implies that the number of external links is (almost) equal to the internal links with the teams, and the E-I index was -0.12. In other words, substantial knowledge spillovers occurred after seven weeks. Finally, after 14 weeks the average number of external links was 18.4 and the External-Internal (E-I) index is -0.17, implying that in comparison to the beginning of the course learning occurred both within teams as well as outside teams but relatively more within their team rather than outside their team. Friendship relations were positively correlated to the three learning networks. However, the size of these correlations was lower than the size of correlations between the three learning networks, indicating that new learning links (i.e. knowledge spillovers) were established over time, as confirmed by follow-up multiple regression quadratic assignment procedures. Our results indicate that pre-existing friendships play a part in knowledge spillovers, but dynamics between learners and teams over time seem more important.

Keywords

Dynamic social network analysis, knowledge spillovers, class-room learning, Wiki.

Introduction

Literature on regional economic development reveals that innovation is fostered when firms are in close proximity to and interact with one another —and this effect is especially pronounced for smaller firms (Capello, 1999; Capello & Faggian, 2005). In effect, this proximity of and interaction among firms creates a learning space for these firms and fosters processes that promote learning and innovation. Naturally, one wonders if this demonstrated phenomenon in regional economic development can provide a metaphor for helping to understand

ISBN 978-1-86220-283-2

the impact of proximity and interaction of learners in a classroom. In particular when learners are working and learning together in small teams as well as in classroom settings, we would like to explore whether proximity and ability to interact with learners and teams promotes learning.

There has been a rapid growth in the use of small groups in teaching to engage students in active learning (Decuyper, Dochy, & Van den Bossche, 2010; Lindblom-Ylänne, Pihlajamäki, & Kotkas, 2003; Michaelsen, Knight, & Fink, 2002). By implementing a learning structure based in teams, teachers aim to convert their classroom in a learning environment where students learn from and together with their fellow team members (Hurme, Palonen, & Järvelä, 2007; Katz, Lazer, Arrow, & Contractor, 2004; Lindblom-Ylänne, et al., 2003; Van den Bossche, Gijselaers, Segers, & Kirschner, 2006). However, the introduction of teams as basic learning units in the classroom questions the value of the classroom as learning space; a space in which the different agents in the learning process - teachers and students - are together. The above stated literature on regional economic development points to the potential value of having different learners and teams close in proximity (Capello, 1999; Capello & Faggian, 2005).

Research in organisational science has found that although people within an organisation or community share geographical or physical proximity, have opportunities to interact and share similar goals, not all members and teams are willing to actively share knowledge with others (Borgatti & Cross, 2003; Casciaro, 1998; Haythornthwaite & Wellman, 1998; Héliot & Riley, 2010; Krackhardt & Stern, 1988). As sharing knowledge and expertise with others is an implicit cost to an individual learner (e.g., spending time and energy to explain another learner/team, sharing a creative solution that other teams can "steal"), while the expected returns of receiving relevant new knowledge and expertise from others are unknown, some individuals are less willing to share knowledge than others (Bohle Carbonell, Rienties, & Van den Bossche, 2011; Borgatti & Cross, 2003; Héliot & Riley, 2010; Krackhardt & Stern, 1988). In research in Computer-Supported Collaborative learning, a similar trend has been found, whereby not only the willingness of learners to share knowledge within and across teams but also the actual behaviour of learners to share knowledge is substantially skewed and not a given artefact when courses are designed based upon collaborative learning (De Laat, Lally, Lipponen, & Simons, 2007b; Rienties, Tempelaar, Van den Bossche, Gijselaers, & Segers, 2009). Nonetheless, literature on teamwork has recently pointed out that in addition to engaging in internal learning activities, teams in organizations also must engage in external learning activities. That is, teams should also learn from external experienced others about the task (Bresman, 2010).

Within educational psychology, limited research has been conducted in order to assess whether teams also learn from the experiences of other teams in their class and what the underlying mechanisms for creating this learning space are (Hernandez Nanclares, Rienties, & Van den Bossche, 2012; Hommes et al., 2012). Therefore, in this paper we designed a specific learning environment whereby teams were working on authentic and complex team assignments and were dependent on the outcomes of other teams. Learners interacted in both a face-to-face context as well as in an educational technology context such as WIKIs or discussion forums. Small working teams constructed (shared) knowledge and tried to reach successful collaboration in their social learning space during 14 weeks.

The main goal of this research is explore whether and how knowledge spillovers across teams occurred over time and how researchers may capture these spillovers using social network analysis (Bohle Carbonell, et al., 2011; Borgatti & Cross, 2003; De Laat, et al., 2007b; Hernandez Nanclares, et al., 2012). In this study, we want to know if knowledge is really transferred among learners (individual students and small working teams), even if limited prior friendship relations have been established, and how this transfer occurs inside and between teams. Along the paper, by teams or small groups we are referring to an association of people who are working together in tasks and assignments. This study does so by applying a dynamic social network analysis in order to understand the dynamics of knowledge spillovers within and across teams at three consecutive time measurements (De Laat, Lally, Lipponen, & Simons, 2007a).

Method

Setting

This study took place in an elective third-year course of Business Administration in the Economics Faculty at University of Oviedo. The aim of this course was to introduce students to the ideas, concepts and theories in International Economic Relations. The students met twice a week during two-hour class session in a 14 weeks period. 57(26 males, 31 females) students were divided into eleven teams, which consisted of four to seven

ISBN 978-1-86220-283-2

members per team (5.4, sd = 0.84) who self-selected their members. The reason for the self-selection of team members rather than random formation of teams was that most students were not familiar with active learning methods such as team work. Research has highlighted when (novice) teams are formed, having a couple of members within a team that are familiar or even friends is beneficial for social interaction (Krackhardt & Stern, 1988).

Table 1 Teams' interaction opportunities and learning spaces

	Face-to-face learning space	Online Learning Space
Intra-team interaction	Teams work on their own materials Reading and summarizing Discussing and reflecting	Private team forum Wikis to develop specific written assignments Feedback and corrections through the forum
Inter-team interaction	Presentations of the resulting products each team get from different assignments Discussions Analysis and assessment of other teams' products	Task-specific forum to discuss about tasks and analyse and assess other teams' products Feedback and corrections through the forum

During the fourteen weeks, the eleven teams had to solve five authentic tasks related to international economics that were highly inter-related. These activities include the creation of a conceptual map of globalization, writing a comment from an economic blog by a famous economist or organisation, and preparing and participating in a final conference about globalization. The assignments were designed in such a way that they require a broad range of concepts, abilities and skills from teams. In this way, teams and students had to establish a profound understanding of the complex relationships between prior personal and team knowledge and international economic relations concepts. One important thing is that the instructional design offered the teams several opportunities to share knowledge both within and across teams. Furthermore, intra-and inter-team interaction tools were put into place both in the face-to-face and in the online environment, which is based upon successful designs of blended learning environments as described in Rienties et al. (2008) and Rehm (2009). In the former, 36 master students were divided in four teams in order to solve some economics problems, but at the same time both teams were able to share knowledge in the other teams, leading to more knowledge sharing than when students only communicated within their own team (Rienties, et al., 2008). In the latter design, 300 managers worked in small teams but at the same time worked in a community of learners of around 100 participants, (Rehm, 2009) thereby encouraging what we call knowledge spillovers across teams. Table 1 summarize the elements of the instructional design that promote the different types of teams' interactions.

Instruments

Measuring knowledge spillovers using SNA

For ascertaining whether intra-team learning and knowledge spillovers occurred during the course, we employed a method developed within the field of Social Network Analyses (SNA). That is, the evolution of knowledge exchange was analysed as follows. First, learning from team members and other members was measured by using Social Network Analysis techniques. The 57 students answered the Social Network question stem "I have learned a lot from..." in Spanish. A list with all 57 names of the students was provided as is commonly done in SNA (e.g. Bohle Carbonell, et al., 2011; Casciaro, 1998; Haythornthwaite & Wellman, 1998). In class, students had to mark on a Likert response scale of 1 (Totally disagree) – 5 (Totally agree) whether they learned a lot from each respective student or not. Second, the (possible) influence of pre-existing friendship relations was taken into consideration, as the knowledge spillovers between teams may solely be due to friendships rather than genuine learning from other insights and knowledge from other teams (Baldwin, Bedell, & Johnson, 1997; Casciaro, 1998; Eggens, van der Werf, & Bosker, 2008; Krackhardt & Stern, 1988). Therefore, the social network of friendships was measured at the first day of the course using a similar method as the learning network (using the question stem: 'I am a friend of ...). Afterwards, the friendship network was compared with the social learning network. Third, in line with De Laat et al. (2007b) we measured the social learning network at three phases (week 4, week 7 and week 14) during the course in order to analyse the dynamics of inter- and intra-team learning. For all three measurements a 100% response rate was established. Of the 589 learning relationships identified during these three measurements, 74 (2%) were negative (value 1 or 2) by students. 286 (9%) relationships were characterised as neutral (value 3), while 189 (6%) and 589 (19%) relationships were

ISBN 978-1-86220-283-2

characterised as positive (value 4) or very positive (value 5). As we focus on positive learning relations between students and teams, the valued social network matrixes that resulted from the learning questionnaires were dichotomised by recoding values 4 and 5 to 1 (indicating that student learned from a respective student), while values 1 – 3 were recoded as 0 (indicating that a student did not learn from a respective student).
Finally, to determine knowledge spillovers we calculated the position of each student within their team (intra) relative to other students (inter) in the (dichotomised) social learning network using the External – Internal index developed by Krackhardt and Stern (1988). Basically, the External – internal (E-I) index takes the number of ties of members of the team to students outside the team, subtracts the number of ties to members with the team, and divided by the total number of ties. The resulting index ranges from -1 (all ties are only with own team members) to +1 (all ties are to students outside the team).

Data analysis

First, a graphical analysis of the learning networks at week 4, week 7 and week 14 was conducted in order to identify the overall social network structure and identify patterns of sub-group development, as recommend by Newman (2003) and Wassermann and Faust (1994). Afterwards, a quantitative analysis was conducted in order to determine the dynamics of knowledge spillovers between teams as well as measuring knowledge spillovers at three time periods. Follow-up quadratic assignment procedure Pearson correlations (Hanneman & Riddle, 2005) were conducted in order to compare similarity measures between the friendship and learning networks, and assess the frequency of random measures as large as actually observed. Finally, multiple regression quadratic assignment procedures (MRQAP) were used to test whether friendships and learning networks developed in week 4 and week 7 predicted learning networkers after 14 weeks. MRQAP tests are permutation tests for multiple linear regression model coefficients for data organized in square matrices of relatedness of friendship and learning amongst our 57 students. Data were analysed on a network level using UCINET version 6.350.

Results

Development of learning networks using graphical analysis

To illustrate the power of SNA in understanding the knowledge spillovers within and between teams, the social networks of learning at week 4 (Figure 1) as well the social network of learning at week 7 (Figure 2) and week 14 (Figure 3) are presented. Four aspects can be distinguished from these figures. First of all, the social networks illustrate from whom students have learned a lot and what the direction of learning is. For example, in Figure 2 one student of team 3 (black, diamond) has indicated that (s)he learned a lot from one student of team 2 (blue, box), which is indicated by the direction of the arrow (Wassermann & Faust, 1994). Second, the respective student from team 2 has four so-called “reciprocal links” with the other four members of team 2. In other words, all five members of team 2 indicated to have learned a lot from each other’s contribution and the arrows go to each of the five members. However, no reciprocal link is indicated between the student from team 2 and team 3, indicating that knowledge spillovers were primarily from team 2 to team 3. In other words, SNA graphs can be used to determine how knowledge spillovers occur within teams as well as across teams.

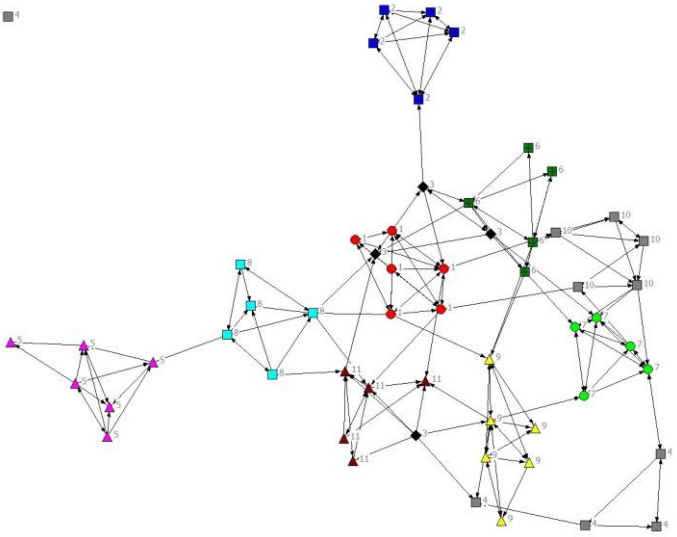
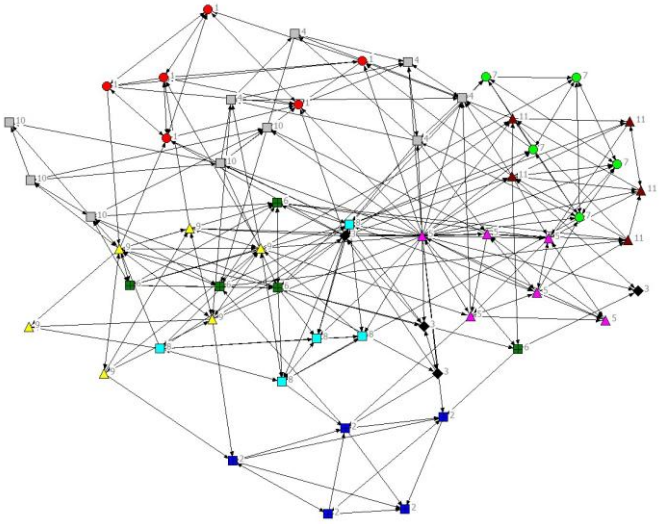


Figure 1 Social Learning Network after four weeks

ISBN 978-1-86220-283-2

Third, the social network graphs show the respective position of individual students as well as of teams. In Figure 1, some learners and teams are on the outer fringe of the network and are not well-connected to other members or teams. For example, only one member of team 2 and team 5 is connected to a student from another team. As a result, these teams are situated on the outer fringe of the network, while other teams have indicated to have learned more from other teams. Furthermore, some students and teams are more central in the learning network. Team 3 is an interesting exception to the other teams who mainly are situated closely with their own team members as members of team 3 are more in contact with other students than with their own team members.

Finally, when comparing Figure 1 with Figure 2, the number of learning links between students and teams alike has increased substantially. More importantly, after seven weeks the "natural borders" of teams become blurred as is illustrated in Figure 2. That is, while in Figure 1 students were primarily interacting within their team, in Figure 2 the position of the members of each teams are increasingly mixed and intertwined with other teams. More importantly, the number of connections between learners from different teams is substantially increased. In other words, after seven weeks members of teams not only indicated to have learned a lot from other members of the team but also from other students. Thus, more knowledge spillovers have occurred across teams after seven weeks. For example, team 2 who initially was only connected to one member of team 3 is now connected to eight students from five teams after seven weeks. That is, team 2 is connected to two members of team 9 (yellow, triangle), team 6 (green, square) and team 3 (black, diamond). At the same time, team 2 is connected to one member of team 5 (pink, triangle) and team 8 (light blue, square). Furthermore, after 14 weeks Team 5 has 17 connections to other students from nine teams, as is illustrated in Figure 3.



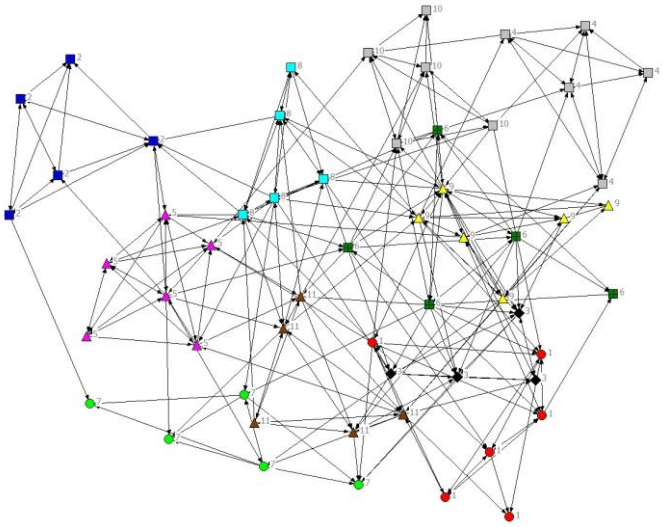


Figure 2 Social Learning Network after 7 weeks Figure 3 Social Learning Network after 14 weeks

Quantifying knowledge spillovers

Although the three social network graphs seem to indicate that teams over time develop more links and knowledge spillovers to other teams, distilling the actual number of intra- and inter-team learning relations per team is difficult to perform based upon visual inspection. Therefore, the E-I index of Krackhardt and Stern (1988) is used to measure the intra- and inter team learning network relations in Table 2. On average, students have 3 (sd = 1.2) friends within their team and 2.6 (sd = 2.2) friends outside their team, whereby standard deviations are in brackets. After four weeks, all teams except team 3 have more internal links to their team members than to students from other teams. On average, a team has 17.82 (sd = 7.0) ties within their team, while 6.5 (sd = 4.0) ties are made outside the team after four weeks. As a result, the E-I index for most teams is negative and the average E-I index for all eleven teams is -0.53, implying that most learning comes from inside the respective team. In other words, in the first month of the course students learned most from their team members rather than from students from other teams. This was already visually illustrated by Figure 2, whereby

ISBN 978-1-86220-283-2

most connections amongst learners were with other team members. Furthermore, with the exception of team 3 all other teams were visually distinctly positioned and clearly identifiable.

After seven weeks, the average number of external links triples to 20.0 (sd = 9.4), which implies that the number of external links is (almost) equal to the internal links with the teams, and the E-I index is -0.12. In other words, substantial knowledge spillovers have occurred after seven weeks. In addition to team 3, also team 5, team 6, team 8, team 9 and team 11 have more links to other students than to students within their own team, as is illustrated in Table 2. In Figure 3 this was visually illustrated by the fact that most members of team 5, 6, 8 and 9 occupy a central position in the social learning network. Finally, after 14 weeks the average number of external links is 18.4 (sd = 7.6) and the E-I index is -0.17, implying that in comparison to the beginning of the course learning occurs both within teams as well as outside teams but relatively more within their team rather than outside their team. In sum, while at the beginning of the course students were primarily interacting with their team members, over time substantial learning occurred within and across teams in line with Figure 2-4. At the same time, not all teams became externally focussed over time.

Table 2 Intra and inter team knowledge spillovers after 4, 7 and 14 weeks

	Measurement after four weeks			Measurement after seven weeks			Measurement after 14 weeks		
Team (members)	Internal	External	E-I	Internal	External	E-I	Internal	External	E-I
Team 1(7)	30	7	-0.62	28	13	-0.37	24	16	-0.20
Team 2(5)	20	1	-0.91	20	8	-0.43	20	7	-0.48
Team 3(4)	6	15	0.43	6	20	0.54	12	20	0.25
Team 4(6)	8	3	-0.46	20	14	-0.18	20	8	-0.43
Team 5(6)	24	1	-0.92	30	40	0.14	30	17	-0.28
Team 6(5)	16	7	-0.39	14	29	0.35	18	26	0.18
Team 7(5)	20	8	-0.43	18	13	-0.16	14	12	-0.08
Team 8(5)	18	5	-0.57	20	24	0.09	20	25	0.11
Team 9(6)	24	7	-0.55	24	27	0.06	28	30	0.03
Team 10(5)	16	8	-0.33	16	13	-0.10	18	16	-0.06
Team11(5)	14	10	-0.17	18	19	0.03	20	25	0.11
Average	17.82	6.55	-0.53	19.45	20.00	-0.12	20.36	18.36	-0.17

Learning ties and prior friendship relations over time

In Table 3, the friendship and learning ties during the fourteen weeks are illustrated, as well as the density scores for the entire classroom and the correlations between the four social networks using UCINET QAP correlation (Hanneman & Riddle, 2005). Density compares to centrality by looking at the number of ties an actor has divided by the number of pairs of actors. Centrality looks at the amount of direct ties an actor has. The overall density of learning increased from 5.98% after four weeks to 9.06% after fourteen weeks, which implies that only 9% of all possible network links are used for learning.

Table 3 Friendship and Learning Ties, density and correlations

	M	SD	Density (in %)	1	2	3
1. Friendship ties (M1)	11.00	3.89	3.83			
2. Learning ties after four weeks	4.70	1.68	5.98	.250**		
3. Learning ties after seven weeks	7.47	3.00	9.21	.259**	.532**	
4. Learning ties after 14 weeks	19.00	7.47	9.06	.235**	.514**	.534**

The dichotomised network measure of friendship is significantly correlated to the three measurements of learning networks as illustrated in Table 3. However, the size of these correlations is lower than the size of correlations between the three learning networks, indicating that new learning links were established over time. Finally, using multiple regression quadratic assignment procedures, learning ties after 14 weeks are significantly predicted by friendship ties ($\beta = .23$; $p < .01$), with an adjusted R-square of 0.055. Adding the learning ties after four and seven weeks significantly improves the fit of the model. That is, learning ties after 14 weeks are significantly predicted by friendship ties ($\beta = .11$; $p < .01$) and learning ties after four weeks ($\beta = .49$; $p < .01$),

ISBN 978-1-86220-283-2

with an adjusted R-square of 0.276. When including learning ties after seven weeks as well, the predictive power of friendship ties ($\beta = .07$; $p < .01$) is further reduced, in favour to learning ties after four weeks ($\beta = .31$; $p < .01$), and learning ties after seven weeks ($\beta = .35$; $p < .01$) with an adjusted R-square of 0.362.

Discussion

Using a dynamic analysis of social learning networks, we found that teams indeed develop more knowledge spillovers with other teams over time. That is, while in the beginning of the course most teams were primarily focussed on knowledge exchange within their own team (17.8 links internal, 6.5 links external), after fourteen weeks the number of knowledge spillovers to other teams almost tripled (20.4 links internal, 18.4 links external). The more detailed social network graph analyses indicate that teams in the beginning of course were primarily working and learning within their team. As a result, the structures and boundaries of the teams of knowledge spillovers after four weeks were clearly defined in the social network graph. However, over time the team structures and boundaries became more mixed or blurred with other teams, which illustrate that teams were actively learning from other teams' knowledge and experience. So, at the beginning of the course the students learned mainly from the members of its own team. But as time passed, most students learned beyond the borders of their own team and developed knowledge spillovers. The reasosn for this, in our opinion, could be that teams had a lot of possibilities to exchange knowledge and expertise with the other teams in the classroom learning space, as we explained in Table 1.

In contrast to paper 2, our setting demonstrated that teams over time developed more links to other teams. In our opinion, our setting resembled a community of learners (Rehm, 2009), who were dependent on each others' input to further develop and solve subsequent group tasks. Another main distinction with paper 2 and paper 3 (See also Hommes, et al., 2012) was that students were not randomised into teams but were able to select their team members. However, the impact of prior friendship declined over time, indicating that some of the knowledge spillovers between learners and teams are unrelated to pre-existing friendship relations. Follow-up multiple regression quadratic assignment procedures confirmed that the learning relationships developed over time between learners and teams were stronger predictors of learning networks at the end of the course than pre-existing friendships. Of particular interest in our context seems to be that learning networks between students and teams were continuously constructed, evolving, and broken down over time, and did not exclusively relate to initial learning networks developed after four weeks. In other words, our findings that both learning networks after four weeks and seven weeks significantly (and separately) predicted learning networks after fourteen weeks seemed to indicate that learners and teams over time developed different evolving learning relationships with different students and teams. Future research needs to address why certain teams preferred to work primarily within the team borders, while other teams developed strong knowledge spillovers to other teams. At the same time, further research is necessary in order to determine how teachers can design their module in order to stimulate teams to develop more knowledge spillovers over time, as the contradicting findings between paper 1 and paper 2 highlight that knowledge spillovers are not an automatic artefact of team learning.

References

Baldwin, T. T., Bedell, M. D., & Johnson, J. L. (1997). The Social Fabric of a Team-Based M.B.A. Program: Network Effects on Student Satisfaction and Performance. *The Academy of Management Journal, 40*(6), 1369-1397.

Bohle Carbonell, K., Rienties, B., & Van den Bossche, P. (2011). Transactive memory profiles and their influence on advice seeking. In P. Van den Bossche, W. H. Gijselaers & R. G. Milter (Eds.), *Building Learning Experiences in a Changing World* (Vol. 3, pp. 267-283): Springer Netherlands.

Borgatti, S. P., & Cross, R. (2003). A Relational View of Information Seeking and Learning in Social Networks. *Management Science, 49*(4), 432-445.

Bresman, H. (2010). External Learning Activities and Team Performance: A Multimethod Field Study. *Organization Science, 21*(1), 81-96.

Capello, R. (1999). Spatial transfer of knowledge in high technological milieu: learning vs. collective learning process. *Regional Studies, 33*(4), 353-365.

Capello, R., & Faggian, A. (2005). Collective Learning and Relational Capital in Local Innovation Processes. *Regional Studies, 39*(1), 75 - 87.

Casciaro, T. (1998). Seeing things clearly: social structure, personality, and accuracy in social network perception. *Social Networks, 20*(4), 331-351.

De Laat, M., Lally, V., Lipponen, L., & Simons, R.-J. (2007a). Investigating patterns of interaction in networked learning and computer-supported collaborative learing: A role for Social Network Analysis. *International Journal of Computer-Supported Collaborative Learning, 2*, 87-103.

De Laat, M., Lally, V., Lipponen, L., & Simons, R.-J. (2007b). Online teaching in networked learning communities: A multi-method approach to studying the role of the teacher. *Instructional Science, 35*(3), 257-286.

Decuyper, S., Dochy, F., & Van den Bossche, P. (2010). Grasping the dynamic complexity of team learning: An integrative model for effective team learning in organisations. *Educational Research Review, 5*(2), 111-133.

Eggens, L., van der Werf, M., & Bosker, R. (2008). The influence of personal networks and social support on study attainment of students in university education. *Higher Education, 55*(5), 553-573.

Hanneman, R. A., & Riddle, M. (2005). *Introduction to social network methods*. Riverside, CA: University of California.

Haythornthwaite, C., & Wellman, B. (1998). Work, friendship, and media use for information exchange in a networked organization. *Journal of the American Society for Information Science, 49*(12), 1101-1114.

Héliot, Y., & Riley, M. (2010). A study of indicators of willingness in the knowledge transfer process. *Journal of Management & Organization, 16*(3), 399-410.

Hernandez Nanclares, N., Rienties, B., & Van den Bossche, P. (2012). Longitudinal analysis of knowledge spillovers in the classroom. In P. Van den Bossche, W. H. Gijselaers & R. G. Milter (Eds.), *Learning at the Crossroads of Theory and Practice* (Vol. 4). Dordrecht: Springer.

Hommes, J., Rienties, B., de Grave, W., Bos, G., Schuwirth, L., & Scherpbier, A. (2012). Visualising the invisible: the impact of informal interaction on student learning. *Advances in Health Sciences Education*.

Hurme, T., Palonen, T., & Järvelä, S. (2007). Metacognition in joint discussions: an analysis of the patterns of interaction and the metacognitive content of the networked discussions in mathematics. *Metacognition and Learning, 1*(2), 181-200.

Katz, N., Lazer, D., Arrow, H., & Contractor, N. (2004). Network Theory and Small Groups. *Small Group Research, 35*(3), 307-332.

Krackhardt, D., & Stern, R. N. (1988). Informal networks and organizational crises: An experimental simulation. *Social Psychology Quarterly, 51*(2), 123-140.

Lindblom-Ylänne, S., Pihlajamäki, H., & Kotkas, T. (2003). What Makes a Student Group Successful? Student-Student and Student-Teacher Interaction in a Problem-Based Learning Environment. *Learning Environments Research, 6*(1), 59-76.

Michaelsen, L. K., Knight, A. B., & Fink, L. D. E. (Eds.). (2002). *Team-based learning. A transformative use of small groups in college teaching*. Sterling, USA: Stylus.

Newman, M. E. J. (2003). The Structure and Function of Complex Networks. *SIAM Review, 45*(2), 167-256.

Rehm, M. (2009). Unified in Learning – Separated by Space; Case Study on a Global Learning Programme. *Industry and Higher Education, 23*(4), 331-342.

Rienties, B., Tempelaar, D. T., Van den Bossche, P., Gijselaers, W. H., & Segers, M. (2009). The role of academic motivation in Computer-Supported Collaborative Learning. *Computers in Human Behavior, 25*(6), 1195-1206.

Rienties, B., Van Wesel, M., & Gijselaers, W. H. (2008). Integrating e-Learning and Classroom Learning; Four Years of Asynchronous Learning to Improve Academic Competences. *Journal of Systemics, Cybernetics and Informatics, 6*(3), 56-60.

Van den Bossche, P., Gijselaers, W. H., Segers, M., & Kirschner, P. A. (2006). Social and cognitive factors driving teamwork in collaborative learning environments. Team learning beliefs & behaviour. *Small Group Research, 37*, 490-521.

Wassermann, S., & Faust, K. (1994). *Social Network Analysis: methods and applications*. Cambridge: Cambrdige University Press.

[i] This chapter is in-part based work published elsewhere (Hernandez Nanclares, N., Rienties, B., & Van den Bossche, P. (2012). Longitudinal analysis of knowledge spillovers in the classroom. In P. Van den Bossche, W. H. Gijselaers & R. G. Milter (Eds.), Learning at the Crossroads of Theory and Practice (Vol. 4). Dordrecht: Springer). The correlation and multiple regression quadratic assignment procedures are new additions to our initial analyses.