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## Research paper

# The development of university teachers' collaboration networks during a departmental professional development project



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## HIGHLIGHTS

- Collaboration networks became denser during the professional development project.
- Collaboration patterns were positively related to propinquity.
- Experienced teachers (more than 5 years) were more likely to collaborate.
- Informal interaction outside work was positively related to a collaboration tendency.
- Teachers were more likely to observe a colleague with whom they already collaborate.

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## ABSTRACT

Professional interaction in the workplace is an indispensable part of professional development. We examined how teachers' teaching collaboration networks within a university department changed throughout an eight-month professional development project and how these networks influenced teachers' observation choices in formative peer observations. Stochastic actor-oriented modeling (SAOM) shows that it was more likely that teachers started to collaborate when they were working on the same floor (propinquity), were more active in attending project meetings, and had more teaching experience. The multiple regression quadratic assignment procedure (MR-QAP) indicates that teachers were more likely to observe colleagues with whom they already collaborated.

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## 1. Introduction

In the last two decades, improving teaching and learning practices is an increasingly recognized priority in many higher education institutions in Europe (Gaebel et al., 2018; Van Waes et al., 2018). Professional development in higher education has mainly focused on increasing individual teachers' teaching and learning skills, knowledge, and expertise (Leslie et al., 2013; Steinert et al., 2016; Stes et al., 2010), which is consistent with the typical teaching practices in university education where teachers design and teach their courses independently (Hadar & Brody, 2010; Spalter-

Roth et al., 2010). The social component in the development process is mostly neglected (Hadar & Brody, 2010). This is surprising since interaction between colleagues in the workplace has been considered as an integral aspect of professional development for decades (e.g., Lave & Wenger, 1991; Little, 1993). Recently, there has been a renewed appeal in higher education policy and research for a shift from traditional - individual-focused - practices to professional development as a socially interactive and contextual process (e.g., Benbow & Lee, 2019; Gaebel et al., 2018; Hadar & Brody, 2010; Hinojosa-Pareja & García-Cano, 2020). Correspondingly, this paradigm shift aims to break with the notion of teaching as an isolated practice and instead emphasizes shared responsibility to respond to changing societal demands and educational innovations (Gaebel et al., 2018; Gast et al., 2017; Saroyan & Trigwell, 2015; Taylor & Znajda, 2015).

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We adhere to the shared responsibility paradigm, which we illustrate by the example of a departmental professional development project. The project's main goal was to strengthen professional interaction between teachers within the department. To realize this goal, teachers were asked to collaboratively redesign the curriculum. Collaboratively designing a curriculum can be seen as a form of professional development; activities and processes that teachers engage in to improve their teaching, and consequently students' learning (Saroyan & Trigwell, 2015). As teachers collaboratively develop a curriculum, they share knowledge, exchange perspectives, and solve challenges. This is further facilitated by the fact that the activity is connected to their everyday practice (Steinert et al., 2016). Collaboration has various beneficial effects. It can strengthen the connection between the formal and the enacted curriculum through enhancing teachers' collective ownership of the curriculum (Penuel et al., 2009; Voogt et al., 2016) as well as increases the acceptance, implementation, and sustainability of the educational reform (Bolander Laksov et al., 2020; Daly, Moolenaar, Bolivar, & Burke, 2010). Further, it can improve teacher well-being – through increased job motivation, self-efficacy beliefs, collegiality, and reduced feelings of isolation (Moolenaar et al., 2012; Vangrieken et al., 2015)–, and teachers' teaching practices, beliefs, and attitudes (Voogt et al., 2016).

In higher education, the department level is a uniquely suitable context for teacher collaboration due to its relative autonomy in designing courses and the fact that staff members are already grouped in an organizational unit, allowing for potentially more frequent social interactions (Quardokus & Henderson, 2015). Furthermore, departmental structures have considerable influence on members' acceptance of change initiatives, such as curriculum reform (Quinlan & Åkerlind, 2000; Wieman, 2010). While researchers are increasingly focusing on team-based professional development activities in higher education (e.g., Bolander Laksov et al., 2020; Gast et al., 2017; Hinojosa-Pareja & García-Cano, 2020; Quardokus & Henderson, 2015), collaboration on the department level as a focus of professional learning is largely missing in the higher education literature (Katajuvuori et al., 2019; Vangrieken et al., 2015).

In this study, we examine university teachers' collaboration networks in a professional development project from a longitudinal social network perspective. Social network analysis (SNA) can provide information on the structure of teachers' professional networks and on how the relationships can be influenced (Penuel et al., 2009). To measure network change, we surveyed teachers at the start and at the end of an eight-month professional development project that focused on community building through curriculum design activities. Longitudinal social network analysis can provide insights in how the interaction patterns change over time within the network (Kadushin, 2012; Wasserman & Faust, 1994). Furthermore, we investigate how the collaboration among teachers contribute to the choice of peers in formative observations of teaching at the end of the project. The context of our study is a language teaching department at a Dutch research-oriented university.

Our study positions itself in the literature in various ways. First, we are unaware of any research that examines the development of teaching collaboration networks in a professional development project over time while taking into account cross-network effects and selection mechanisms. Second, although authors have highlighted the importance of professional development activities in teams (e.g., Gast et al., 2017), only a few studies have focused on the department level (e.g., Quardokus & Henderson, 2015). Third, most studies examining professional networks have relied on self-reported ego-centric social network measures (Van Waes et al., 2018). In this study, we combine survey responses with

observational data about participants' engagement in the professional development project, such as peer observations and participation in project meetings. Finally, the outcomes of our study can contribute to the design of professional development activities as strengthening relationships and community building is considered an important goal of professional development (Van den Bossche & Segers, 2013; Van Waes et al., 2018).

### 1.1. The importance of social capital building for professional development

The importance of collaboration among teachers is rooted in social capital theory. Although various definitions of social capital exist (e.g., Bourdieu, 1986; Coleman, 1990; Lin, 2001; Loury, 1987), in general, social capital refers to the ability of actors to access resources as a result of their membership in a social network (Portes, 1998). Whereas all definitions (Bourdieu, 1986; Coleman, 1990; Lin, 2001; Loury, 1987) recognize the access of resources, authors differ in their emphasis of the other elements of social capital. Bourdieu (1986) considers the amount and quality of the resources accessed in his definition of social capital. Coleman (1990) states that social capital is defined by its function; the structure facilitates the action of the members within it and individuals can obtain certain goals that could not be obtained otherwise. Finally, Lin (2001) highlights, in addition to the access of social capital, the actions of the individuals in mobilizing the resources within their network. In this study, we regard social capital as an individual's access to and mobilization of resources that exist within the social relations in their social networks. Resources are defined as the potential for information, knowledge, ideas and support that are derived from social relationships (Coleman, 1990; Lin, 2001).

Researchers in higher education are increasingly turning to social network analysis (SNA) to study university teachers' social networks – and the social capital that resides within these networks (e.g., Benbow et al., 2020; Benbow & Lee, 2019; Rienties & Kinchin, 2014; Van Waes et al., 2015). Whether or not social capital is mobilized, depends, among other things, on teachers' actions. Therefore, teachers' social networks are not their effective social capital, but a reflection of the potential of it.

### 1.2. Social network theory

SNA represents actors as nodes in a web of connections (or ties) and explores the patterns within these connections, allowing for the identification of members' social positions and their behaviour (Wasserman & Faust, 1994). Each actor – in our study a teacher – has a certain position in the network based on the connection with other actors. Actors are connected for different reasons, such as friendship, informational transfer, and formal relations. SNA measures are used to study the relational structure among these actors (Snijders, 2001, 2011; Wasserman & Faust, 1994). There are two main SNA perspectives; structuralism and connectionism. The structuralist perspective focuses on how the social network structure impacts the actors, whereas the connectionist perspective provides understanding on the flow of information between the actors and how this affects their behaviour (Borgatti & Foster, 2003; Jaspersen & Stein, 2019). In this study, we adopt the structuralist perspective with a main focus on the social network structures of a university department.

Several measures describe the network at different levels. First there is the individual (node) level. A well-established descriptive measure at the node level is degree centrality (Borgatti et al., 2009). Degree centrality means the total number of connections of an actor and can be distinguished in incoming connections (indegree centrality) and outgoing connections (outdegree centrality; see

Gest & Kindermann, 2012). For example, teacher A asks teacher B for teaching advice. In this case, the directionality of the connection is from A to B. In SNA terms, this is indicated as an outdegree measure for teacher A and an indegree measure for teacher B. Whether or not teacher B will also consult teacher A, depends, for example, on whether or not teacher B also values teacher A's teaching expertise. Teachers who are more central in a department's network have more opportunities to access the social resources within the network (Moolenaar, 2012; Quardokus & Henderson, 2015). Besides the node level, the smallest possible group within a network is a dyad. A dyad represents two actors who are connected. At the dyadic level, the measure reciprocity expresses the proportion of mutual connections between two actors in a network (Borgatti et al., 2013). Transitivity, or transitive triplets, is a triad (i.e., three actors) where two actors are intended to connect to a common connection (Wasserman & Faust, 1994). This is often expressed as a friend of a friend becomes a friend (Davis, 1970; Holland & Leinhardt, 1971; Prell, 2012). For example, teacher A has a connection with teacher B, teacher B with teacher C, then it is likely that teacher A also connects to teacher C. Another key metric at the network level about social cohesion is density. This refers to the proportion of the possible connections in a network (Borgatti et al., 2013). A network with a higher density indicates that teachers are more connected to each other. In addition to the network structures, different personal attributes (such as teaching experience) and other networks (such as friendship) are conditions for initiating connections among actors.

### 1.3. Social selection mechanisms: why teachers initiate collaboration with each other

Developing relationships (social networks) as well as mobilizing the resources that resides within them (social capital) are a result of actors' intended or unintended decisions, which are in turn determined by various factors. This means that networks are not static as individuals form and dissolve relationships, resulting in an altered network structure. These mechanisms of tie formation and deactivation can either be a result of intentional decisions of the actors to achieve a certain goal (Kossinets & Watts, 2006; Schreurs et al., 2019) or they are unintentionally influenced by their individual and the organization's characteristics (Van Waes et al., 2015).

Two well-established mechanisms that influence social selection are homophily and propinquity. Homophily refers to the perception of social similarity: "birds of a feather flock together" (McPherson et al., 2001, p. 417). Transferred to teachers, it is more likely that they interact more with colleagues who are similar to them. For example, secondary school teachers who teach the same subject are more likely to interact with each other (Van Gasse et al., 2020) as well as academics who perform similar work tasks (Pataria et al., 2014). Propinquity means being in close proximity to someone else. Besides spatial propinquity, two related spatial mechanisms are in play when examining the formation of social ties: spatial composition and spatial configuration. Spatial composition refers to the presence or absence of functional zones that allow for social interaction, such as teacher lounges. Spatial configuration refers to how the workplaces and functional zones are placed in the building (Small & Adler, 2019). The importance of physical proximity of workplaces for professional interaction between teachers has been well-established in primary and secondary education research. For example, Spillane, Shirrell, & Sweet (2017) examined help-seeking behaviour of elementary school teachers. They found that teachers whose walking paths to functional zones – such as restrooms and the photocopy machine – overlapped more frequently were more likely to interact with each other about work. Furthermore, Thomas et al. (2020) found that

beginning primary teachers interact more with colleagues whose classrooms are located in close proximity to their own. Similar to in the study of Van Gasse et al. (2020), teachers also indicated that relationship building was supported by an inviting staffroom. While Thomas et al. (2020) focused on beginning teachers, Lohman and Woolf (2001) interviewed experienced teachers. They found a propinquity effect for teachers' tendency to self-initiate learning activities, such as knowledge exchange and collaboration. In conclusion, propinquity has found to be especially important for teachers to serendipitously interact with other colleagues (Schreurs et al., 2019).

The importance of frequent interaction possibilities to increase the likelihood of establishing a relationship also comes forward in the higher education literature (Kossinets & Watts, 2006; Pataria et al., 2014; Van Waes et al., 2015). For example, the close proximity of university teachers' offices facilitates interaction compared to teachers whose office location is more isolated (Fleming et al., 2016).

### 1.4. Choosing a colleague to observe: an indication of mobilizing social capital

A widespread professional development activity that is increasingly receiving attention in the higher education literature is peer observations of teaching (POT) (e.g., Chamberlain et al., 2011; O'Leary & Savage, 2020; Torres et al., 2017). POT is rooted in social cognition theory which, in essence, assumes behaviour is learned observationally through modeling (Bandura, 1997; Hendry et al., 2014). The premise of formative POT is that by participating in it teachers identify new teaching and learning strategies and change their own practice. The activity is also associated with various indirect benefits for teaching and learning. For example, broadening collegiality and collaboration (Bell, 2001; Sandr, 2012; Tezcan-Unal, 2018), encouraging reflection on teaching, and developing conceptions of teaching (Bell & Mladenovic, 2015).

There is consensus in the literature that POT is best implemented for developmental and collaborative purposes in which academic staff engage as equals in a partnership to observe and provide feedback to each other on their teaching practices (Bell & Mladenovic, 2015). The importance of a trusting, collegial relationship without power dynamics has been stressed by various authors as a key element for successful implementation of the activity (e.g., Hammersley-Fletcher & Orsmond, 2005; Huxham et al., 2017; O'Leary & Savage, 2020, Thomas et al., 2014). To make sure teachers perceive observations as a formative instead of an evaluative activity, it has been suggested to provide them with a choice of the observer (McMahon et al., 2007). While Bell (2001) suggests that teachers might prefer to have a "friendly face" observe them in order to increase the chance of receiving positive feedback, not much is known about how teachers select peers to observe.

### 1.5. The current study

Although the body of literature that studies teachers' social networks in higher education is growing (e.g., Benbow & Lee, 2019; Benbow et al., 2020; Ma et al., 2019; Pataria et al., 2014, 2015; Rienties & Kinchin, 2014; Roxå & Mårtensson, 2009; Van Waes et al., 2015, 2016, 2018), to our knowledge, we are the first who tested selection mechanisms in university teachers' networks with the advanced statistical tool of stochastic actor-oriented modeling (SAOM). Contrary to conventional statistical techniques, SAOM does not violate the assumption of independent observations and is equipped to account for this interdependency in the network changes over time (Snijders, 2005; Snijders et al., 2010). The method has advanced insights in related fields. Van Gasse et al. (2017), for



instance, looked at interaction networks in teacher teams in secondary education. Over time teachers were more likely to invest in reciprocated relationships. Purwitasari et al. (2020), investigating researchers' collaborations through co-authorship, concluded that academics demonstrated the tendency to collaborate with the co-authors of their co-authors. Brouwer et al. (2020), examining communication networks of pre-service teachers, reported a decrease in the networks' cohesion and found a cross-networks effect for friendship and support from peers. We will investigate structural changes in teachers' collaboration networks, and, specifically, two selection mechanisms in the networks: homophily and propinquity, while controlling for cross-network effects. Furthermore, we will investigate whether teacher's collaboration networks contribute to peer observations as part of a professional development programme. By doing so, we address the following research questions: (1) To what extent do collaboration patterns of university language teachers change throughout a professional development project? (2) To what extent do selection mechanisms relate to collaboration between university language teachers? (3) To what extent are collaboration patterns related to peer observations?

Regarding the collaboration patterns, we expect that when teachers collaborate and attend project meetings, that social cohesion will increase over time, i.e., increasing percentage of reciprocity, transitivity, and density. This means also that more connections will emerge over time, but this may vary among teachers. Regarding the selection mechanisms, we expect that it is more likely that teachers collaborate with each other when they are more similar to each other (homophily) and when they have more opportunities to frequently interact with each other due to physical proximity. In the collaboration networks, we take teacher attributes and cross-network effects into account. We include relevant teacher characteristics such as teaching time, employment history at the department, contract type (i.e., tenure or not), and course coordinator role. Course coordinators have been found to demonstrate influence on instruction through informal leadership in departmental teaching networks (Apkarian & Rasmussen, 2020). Further, we take into account teachers' teaching experience as it has been found to be both positively and negatively associated with network strength, size, and diversity (Benbow & Lee, 2019; Van Waes et al., 2015, 2016). Finally, we consider cross-network effects; i.e., do connections in one network influence those in another. More specifically, does having either an established informal relationship outside of work (informal contact network) or having an office on the same floor (propinquity network) make it more likely that a professional collaborative relationship will develop between colleagues. Informal interactions have been found to be key to establish work-related interactions (Rienties & Kinchin, 2014; Van Gasse et al., 2020; Van Waes et al., 2015) and can be considered as a proxy for trust (Liou et al., 2017). Regarding the link between collaboration and peer observation, we expect that it is more likely that a teacher chose a peer to observe when they also collaborated. It has been suggested that the existence of an interpersonal relationship between the observer and the observed teacher is essential for teachers to engage in formative peer observations (Hammersley-Fletcher & Orsmond, 2005; Thomas et al., 2014).

## 2. Methods

### 2.1. Professional development project

At a research-oriented university in the Netherlands 35 European language teachers, clustered in eight language groups within a department, participated in an eight-month professional

development project that focused on strengthening professional interaction. To realize the project's goal, teachers were asked to collaboratively redesign their curriculum to reduce teacher workload and benefit student learning. The project was inspired by research on knowledge sharing. In order for teachers to efficiently collaborate, they need to be aware of their colleagues' expertise, value the expertise, and have access to it (Borgatti & Cross, 2003). Furthermore, teachers should feel supported in a safe environment and be committed to the collaboration (Cross et al., 2001).

To support teachers' information seeking behaviour, recommendations from the literature were included in the project's design. First, the project kicked-off with a two-day conference in November 2018. The conference strongly focused on involvement of all participants by, for example, hosting discussions of what entails good language teaching and learning and smaller participatory sessions in which teachers could showcase practices in their courses. In a similar way, the project was wrapped-up at a conference in June 2019. Second, monthly project meetings were organized for all involved teachers. These meetings served as a format in which colleagues could highlight course adaptations and research findings, raise questions, and discuss their practice. Department administrators were instructed to exempt all teachers involved from teaching tasks during the time of these meetings. This allowed teachers to disconnect from their daily work and provided time to reflect on their practices (Tynjälä, 2008). Furthermore, it allowed teachers to get to know each other's expertise as well as it provided opportunities to interact with each other; i.e., gaining access to their colleagues (Borgatti & Cross, 2003). Third, several smaller working groups, consisting of members from different language groups, were created to work on specific output, such as the redesigning of a course module and reviewing the programme learning outcomes. Each language group was further represented by a language coordinator in a core project group (Kossinets & Watts, 2006; Rienties & Kinchin, 2014). Fourth, participants were asked to engage in formative peer observations of at least three colleagues throughout the project (Benbow & Lee, 2019; Chester et al., 2019). During the conference in November an observation training was held in which attention was paid to the observation instrument, the formative goal of the observations, and how to provide feedback. Fifth, organizational support was strongly present in the project (Newell & Bain, 2020). For example, the head of the language learning cluster was often present at the project meetings (Benbow & Lee, 2019; Taylor & Znajda, 2015; Voogt et al., 2016) and additional finances were acquired from the university to provide teachers with additional time and resources (Taylor & Znajda, 2015). Lastly, an educational advisor from the central educational support department was assigned to the project (Quinlan & Åkerlind, 2000; Voogt et al., 2016).

### 2.2. Data collection

Before starting the data collection, approval for the study was obtained from the Ethics Committee of the university in question. Next, participants were informed about the aim of study, the duration, participation on a voluntary basis, and ethical concerns (such as data storage and withdrawal from the study). Participants completed twice the same questionnaire on paper: at the start of the project in November 2018 and at the end in June 2019. The questionnaire started with asking the participants for their informed consent. It further inquired about participants' characteristics (years of teaching experience, percentage teaching time, coordinator role, contract type, employment history, and location of their office). The main part of the questionnaire focused on network questions. The teachers were presented with a complete roster of names of their colleagues in the department. The question

probing the collaboration networks asked about whom the participants consulted regarding teaching the last two months. Consultation of colleagues is a form of collaboration that mostly involves discussing and planning teaching and learning content, ideas, materials, and assessment practices (Vangrieken et al., 2015). To control for personal relationships, participants nominated with whom they already informally interacted with outside of work during the last two months (for example to meet for a coffee, social activities, or activities that are connected to their children).

Participants engaged in various activities throughout the project. The information regarding teachers' participation in these activities served as input for the network data. A project assistant tracked project meeting attendance. Teachers' participation in peer observations was recorded through an online application. To prevent missing data, teachers could also inform the first author about observations carried out via email or during a project meeting.

### 2.3. Participants

Our sample was comprised of 19 European language teachers, out of the 35 employees of the department, as they completed both surveys (i.e., response rate 54%). This resulted in 342 possible ties within the network for each measurement. All eight language groups are represented in the sample. Table 1 summarized the characteristics of the teachers in the collaboration networks. More than half of the teachers were working for at least 3 years at the department and had at least five years of language teaching experience. Almost three quarter of the teachers had a tenured contract at the end of the second semester. Only 20% indicated to have at most 80% of their time assigned to teaching tasks, and 40% acted as a coordinator for their language group. Out of nine project meetings, teachers attended on average between seven to eight meetings and 11 (58%) participated in all meetings. Due to the underrepresentation of male teachers in the department, gender specificities are not provided to safeguard anonymity of the participants in this study.

### 2.4. Data analyses

We examined changes in teachers' collaboration networks with SAOM (Brouwer & Froehlich, 2020; Snijders, 2001, 2005; Snijders et al., 2010), using the data-analysis package Simulation investigation for empirical network analysis (SIENA) within the programming language R. Advantages compared to conventional methods are that RSiena simultaneously takes into account the relationship between teachers in the network (the network

structure), various characteristics that determine why members collaborate with each other, and cross-network effects (informal contact outside of work and propinquity) (Ragan, Osgood, Ramirez, Moody, & Gest, 2019; Ripley et al., 2020). Since social network data are interdependent it is not allowed to make use of conventional statistical techniques, such as repeated measures ANOVA, as they violate the statistical assumption of independent observations (Snijders, 2005; Snijders et al., 2010; Veenstra & Steglich, 2012).

The estimation of the parameters is performed with an iterative continuous-time Markov chain Monte Carlo procedure where the simulated network is compared to the observed network as specified by the model parameters (Schweinberger & Snijders, 2007; Snijders, 2001). The parameter estimates are interpreted as log odds ratios referring to the likelihood that relationships are established. A positive estimate means that it is more likely that a relationship will be formed, whereas a negative estimate means that it is less likely that a relationship will be formed given the parameters in the model. Parameters are commonly tested with t-ratios (parameters/standard errors) and the corresponding significance level. Modeling in RSiena requires dichotomized social network data in which a dyad of two actors is represented with either a 1 (presence of a tie) or a 0 (absence of a tie) (Ripley et al., 2020; Snijders, 2005; Snijders et al., 2010). To be informed about selection and non-selection processes - i.e., in which a teacher initiates collaboration with another teacher - we need to make use of whole networks measured longitudinally (Veenstra & Steglich, 2012). The whole network refers to a set of actors within a certain finite boundary (Wasserman & Faust, 1994). The network boundary is determined based on a nominalist approach (Laumann et al., 1983), meaning it is based on researchers' argumentation. In this study, the network boundary is the complete university language teaching and learning department where all teachers could nominate each other.

To address our research questions, we modelled general structural effects, cross-network effects, and the effect of actor-level attributes on the formation of relationships at the beginning of the first semester and at the end of the second semester (Ripley et al., 2020; Wasserman & Faust, 1994). See Table 2 for an overview and explanation of the effects that we included in the RSiena model (cf., Gregg et al., 2019; Ripley et al., 2020; Snijders, 2001). We tested selection processes with our variables of interest as follows. The dependent network variable was a teacher's collaboration network measured in the first semester and at the end of the academic year (second semester). In the selection model, the covariates (i.e., the two cross-networks: informal contact outside of work and propinquity) are measured at the first time point (i.e., at the beginning of the first semester) and are fixed. We include three parameters related to actor-characteristics (i.e., individual attributes). The first parameter, the alter, indicates whether the attribute (such as teaching experience) is associated with the extent to which teachers receive collaboration nominations. The second parameter, the ego, specifies whether the attribute is associated with the extent to nominating colleagues. Finally, the similarity parameter indicates the tendency whether teachers name colleagues who are similar to themselves on the attribute. Specifically, we relate the parameters to three actor-characteristics: frequency of the attendance to the project meetings (ordinal attribute), teacher's experience with language instruction (at least five years) (categorical attribute), and teaching time (at most 80%) (categorical attribute). To have the most optimal and parsimonious model, we excluded the non-significant attributes in our final models, i.e.,

**Table 1**  
Demographics of the teachers in the collaboration networks.

Teacher's network characteristics	Percentage
Experience	
≥3 years working at the department	53%
≥5 years language teaching experience	53%
Fixed-term contract	
First semester	68%
Second semester	74%
Teaching time (≤80%)	21%
Language group coordinator	42%
	Mean (SD)
Attendance of project meetings	7.79 (2.04)

**Table 2**  
Overview of the effects included in the RSiena-model.

Explanation		Significance
<i>General structural network effects</i>		
Density	The proportion of existing ties relative to all possible ties in the network	Indication of the departments' cohesiveness
Degree centrality	Number of directed ties of an actor	Indication of teacher visibility within the department
Indegree centrality	Number of ties an actor receives from others	Indication of perceived importance or popularity of a teacher within the department
Outdegree centrality	Number of ties an actor sends to others	Indication of exposure to other teaching practices
Reciprocity	The tendency to which ties are bidirectional	Indication of equality within the relationship between two teachers
Transitive triplets	The tendency to which actors form a triad in a transitive structure.	Indication of access to potential collaboration relationships via colleagues (a colleague of a colleague)
Transitive reciprocated triplets	Interaction effect of transitive triplets and reciprocity	Indication to form a reciprocated collaborative relationship with a colleague of a colleague
Rate function	The rate at which changes can occur in actors' outgoing ties	Indication of teachers' opportunities to change their collaborative outgoing connections with colleagues
<i>Cross-network effects</i>		
Office on the same floor		Indication of propinquity
Informal contact outside of work		Proxy for friendship and trust
<i>Attributes</i>		
Attendance of project meetings	–	Indication of propinquity
Teaching experience	–	Indication of homophily
Teaching time	–	Indication of homophily
Language coordinator	–	Indication of homophily
Contract type	–	Indication of homophily
Employment history at the department	–	Indication of homophily

whether or not being a language coordinator, contract type, and employment history (at least three years' work experience at the department). Our decision about the most optimal model was based on the convergence of the parameters and convergence of the complete model (see Ripley et al., 2020).

Additionally, to determine whether collaboration patterns are a predictor of selecting a colleague to observe, we used the Multiple Regression Quadratic Assignment Procedure (MR-QAP) in R (Borgatti et al., 2013). With this procedure, we regressed the peer observations, measured at one point in time at the end of the project, on the collaboration networks at the beginning of the first semester, the independent matrices.

### 3. Results

#### 3.1. RQ1. To what extent do collaboration patterns of university language teachers change throughout a professional development project?

Table 3 shows the descriptive statistics for the collaboration network in the first and the second semester. The mean degree centrality indicates that teachers connected on average with five to six of their colleagues during the first semester and 9 to 10 of their colleagues in the second semester (towards the end of the project). The standard deviation was larger for the outdegree than for the indegree, which means that more variance exists for teachers who are active in their networks (outgoing ties) than for popularity or status (incoming ties). The density, which means the proportion of actual ties divided by all possible ties in a network, increased from 32% to 54% over the course of eight months. The same holds for reciprocity, which increased from 46% to 56% and for transitivity, which increased from 49% to 70%. Across the two semesters, the network changed with 25 connections dissolved, 100 ties emerged, and 86 ties maintained.

**Table 3**  
Descriptive network statistics of teachers' collaboration networks.

	Contact	
	Sem. 1	Sem. 2
<i>Network indicators</i>		
Average degree	5.8	9.8
SD Indegree	2.3	2.1
SD Outdegree	3.5	5.1
Density	32%	54%
Reciprocity	46%	56%
Transitivity	49%	70%
<i>Change</i>		
	Sem. 1 – Sem. 2	
Number of ties dissolved	25	
Number of ties emerged	100	
Number of ties maintained	86	
Jaccard index	41%	
Hamming distance	125	

Note. Collaboration networks refer to the extent teachers consulted each other for teaching related questions during the last two months. Semester 1: September and October 2018; Semester 2: April and May 2019.

#### 3.2. RQ2. To what extent do selection mechanisms relate to collaboration between university language teachers?

The Jaccard Index is 41%, which means that the stability in the networks is sufficient for estimating the parameters in RSiena (Ripley et al., 2020; Snijders et al., 2010). Table 4 shows the RSiena results for teachers' teaching collaboration networks. The structural network effects revealed that teachers were more likely to reciprocate the professional relationship (Est. = 1.90, SE = 0.79) and to form transitive triplets (Est. = 0.27, SE = 0.11). Within the transitive triplet, the tendency to reciprocate the relationship appears to be lower than outside of it (Est. = -0.28, SE = 0.16). Teachers who worked on the same floor were 1.58 times more likely to

**Table 4**

RSiena results on the effects of propinquity, attendance of project meetings, and teaching experience on collaboration among teachers.

	Teachers' collaboration networks		
	Estimate (Est. = $x$ )	$e^x$	SE
Rate parameter	16.14*		4.19
<i>Structural network effects</i>			
Outdegree	-1.63*	0.20	0.50
Reciprocity	1.90*	6.69	0.79
Transitive triplets	0.27*	1.31	0.11
Transitive reciprocal triplets	-0.28*	0.76	0.16
<i>Cross-network effects</i>			
Office on the same floor (propinquity)	0.46*	1.58	0.22
Informal contact outside of work	0.61*	1.84	0.26
<i>Attributes</i>			
Attendance of meetings alter	0.05	1.05	0.07
Attendance of meetings ego	0.16*	1.17	0.06
Attendance of meetings ego $\times$ alter	-0.09	0.91	0.05
Teaching experience alter	-0.22	0.80	0.19
Teaching experience ego	0.48*	1.62	0.19
Same teaching experience	0.16	1.17	0.17
Teaching time alter	-0.09	0.91	0.32
Teaching time ego	0.51	1.67	0.32
Same teaching time	0.07	1.07	0.33

Note. \* $p < 0.05$  (based on non-rounded estimates). Overall maximum convergence ratio 0.15 (<0.25). Convergence t-ratios all <0.05.

collaborate than teachers who worked on different floors (Est. = 0.46,  $e^{0.46} = 1.58$  SE = 0.22). The odds for collaborating were even larger when teachers meet each other outside of work (Est. = 0.61,  $e^{0.61} = 1.84$ , SE = 0.26). When teachers attended more often the monthly project meetings, they were 1.17 times more likely to collaborate compared to their colleagues who less often attended the project meetings (Est. = 0.16,  $e^{0.16} = 1.17$ , SE = 0.06). Teachers with at least five years of language teaching experience were also 1.62 times more likely to collaborate with their colleagues to teachers with less than 5 years experience (Est. = 0.48,  $e^{0.48} = 1.62$ , SE = 0.19). Other attributes, such as the period of working at the department, having a tenured contract, and being a language group coordinator appeared not to be significant and were excluded from the model.

### 3.3. RQ3. To what extent are collaboration patterns related to peer observations?

In addition, we tested whether collaboration in the beginning of the project was related to the likelihood that teachers observed each other's teaching practices (i.e., formative peer observations of teaching). The MR-QAP showed that when teachers collaborated during the first semester with each other (T1), it was more likely that they observed each other's teaching (Est. = 0.09;  $p = 0.04$ ).

## 4. Discussion

Professional development in higher education is increasingly being recognized as a socially interactive and contextual process. This is evidenced by the growing body of literature that adopts SNA to examine teachers' interactions in professional development programmes (e.g., Rienties & Kinchin, 2014; Van Waes et al., 2018). However, to our knowledge, no previous research has considered the development of teachers' networks in a professional development project while simultaneously taking into account teachers' characteristics and cross-network effects. We used SAOM to examine structural changes in teachers' collaboration networks over time using the data-analysis package RSiena. Besides the structural network effects, we specifically focused on two selection mechanisms: homophily and propinquity.

First, we examined the development of the collaboration patterns over the course of the professional development project. In our model, we found several structural network effects related to tie formation. Overall, the number of ties and the network's degree centrality, density, reciprocity, and transitivity were higher towards the end of the project compared to the beginning. The increased degree centrality and density indicate that the teachers in the department became more directly, and more cohesively, connected to each other. We further observed an increase in reciprocity. This is expected as collaboration implies a joint interaction (Vangrieken et al., 2015). We also found an increase in transitive triplets in which teachers were less likely to reciprocate the relationship within, compared to outside of the triad. This structural tendency against reciprocated ties can be considered as a local informal hierarchy within the network (Block, 2015; Ripley et al., 2020; Snijders et al., 2010).

Next, we explored the tendency to which selection mechanism – propinquity and homophily – relate to teachers' collaboration networks by examining cross-network effects and teacher's attributes. We found an effect of the location of teachers' offices (propinquity network) on their collaboration patterns. Teachers whose offices were located on the same floor were more likely to collaborate with each other. The close proximity to each other as well as sharing the same functional zones on the floor, such as the coffee corner, photocopying machine, and lavatories, created opportunities for (serendipitous) interaction. Our results correspond to studies that researched professional interactions of teachers in primary and secondary education. They found that both experienced (Lohman & Woolf, 2001) and beginning (Thomas et al., 2020) teachers self-initiate more knowledge exchange, resource sharing, and collaboration with colleagues whose classrooms were closer in proximity. Teachers whose walking paths to functional zones crossed more frequently were also more likely to start a professional relationship (Spillane et al., 2017; Van Gasse et al., 2020). The importance of propinquity was further stressed in the existence of a centrally-located staff room (Lohman & Woolf, 2001; Spillane et al., 2017; Van Gasse et al., 2020).

Further, teachers in our study who more frequently attended the project meetings were also more likely to collaborate. Similar to Bjorklund and Daly (2021), we postulate that the project meetings allowed teachers time to form professional relationships and therefore this is also a propinquity effect. Corresponding to previous research (Rienties & Kinchin, 2014; Van Gasse et al., 2020; Van Waes et al., 2015), teachers who informally interacted outside of work (informal contact network) were also more likely to collaborate, which is not surprising since we perceived this relationship as a proxy for trust. The odds of collaborating when teachers have informal contact outside of work are slightly greater than those of collaborating when their offices are on the same floor, which may indicate that the former is of greater importance for collaborative interactions.

Turning to teacher's attributes, we did not find a homophily effect in teachers' collaboration patterns. Compared to Van Gasse et al. (2020), who found that teachers who teach the same subject are more likely to interact with each other, the participants in our study are more similar to each other as they all teach a European language and belong to the same department. In addition, Rienties and Kinchin (2014) have argued that when teachers collaborate for a substantial period of time – in our study the participants were involved in a professional development project of eight months – they develop relationships across characteristics.

Teachers who had more than five years of teaching experience were more likely to collaborate. The difference between novice and experienced teachers in collaborating may be explained by their knowledge systems. Compared to novices, more experienced



teachers generally have well-developed and hierarchically organized cognitive schemata about teaching that allows them to determine what resources are relevant and adopt an overarching curriculum perspective, resulting in more efficiently lesson planning (Borko & Livingston, 1989; Ropo, 2004). Consequently, the less experienced teachers in our study may have had less time for collaboration.

Lastly, we examined whether collaborating with colleagues was a predictor for selecting them as a peer to observe in classroom observations. The results of the MR-QAP show that the choice of a peer to observe was related to an existing collaboration relationship at the beginning of the academic year. Chester et al. (2019) suggested that peer observations of teaching can support social capital development amongst teachers in higher education. However, our results indicate that teachers observed colleagues with whom they already collaborated regarding teaching. This is not surprising since the existence of a collegial – trusting – relationship is considered paramount for successful formative peer observations in the literature (e.g., Hammersley-Fletcher & Orsmond, 2005; Thomas et al., 2014). Further, expanding professional networks does not automatically lead to social capital development since mobilizing capital largely depends on teachers' decisions; in this case: the choice of a peer to observe. Although not surprising, this result may be undesirable for departmental teaching and learning practices since observing various colleagues implies more diversity which is associated with innovation and change (Burt, 2004).

This study is subject to a few limitations. Our study offers a unique data set that presents the development of departmental collaboration networks in higher education. Research reporting longitudinal SNA results is scarce as the data is time-consuming and costly to collect (Stadtfeld, Snijders, Steglich, & van Duijn, 2020). Although we succeeded in collecting such data and our models converged well, our response rate was 54%. From our observational data we know that attendance of the monthly project meetings was not a 100%. Non-respondents might have not attended – or showed up late to – the first or last project meeting in which the survey was distributed. Possible reasons for non-attendance of these meetings are conflicting work schedules if they were also employed at another organization than the university, personal circumstances such as being out sick or taking care of a child, or running into a student or colleague in the hall. To reach teachers who did not attend – or showed up late – to the aforementioned meetings, we distributed the survey electronically and on paper via the university postal office. Other reasons for non-response may be reluctance to share personal data, such as contact outside of work. While we have no reasons to believe our sample differs distinctively from the non-respondents, we acknowledge that there might still have been a selection bias and therefore we need to be cautious with firm conclusions. Moreover, we focused on one department in higher education; i.e., European language teachers. The generalisability of our results may be limited due to the particular characteristics of this department within a research-oriented university. Considering these limitations, we recommend replication of the current study in other settings and in university departments from different disciplines.

Compared to the beginning of the first semester, the collaboration networks became denser towards the end of the second semester. While more cohesive teams tend to report more collective learning (Palonen et al., 2004), for example developing a shared teaching repertoire, our structuralist SNA perspective does not provide insights in the focus of the collaboration. Different forms of collaboration can be distinguished and placed on a continuum characterised by increasing levels of interdependence: in which sharing ideas can be placed on one end and high levels of teamwork on the other (Vangrieken et al., 2015). For further

research, it is recommended to combine a structuralist with a connectionist perspective by collecting qualitative data to analyse what resources (social capital) flow through the network (Jaspersen & Stein, 2019). For example, the following topics can be considered: the contribution of collaborative relationships to curriculum redesign and student learning, the perception of teachers regarding the overall success of a departmental professional development project on establishing a community, and the reasons for choosing a colleague to observe.

Finally, we collected our data before the Covid-19 pandemic. Although the pandemic has resulted in an increase in remote working, we believe our results can contribute to designing future workspaces that support the kind of interactions that cannot happen remotely (Boland et al., 2020). The results of this study indicate that physical proximity and informal social connections have an extensive impact on collaboration patterns and the development of social capital at work. When colleagues largely work from home, they will encounter less serendipitous interactions, such as running into each other at the coffee machine, resulting in less opportunities to establish social connections. This endangers the upcoming paradigm that views teaching and learning as a shared responsibility and risks perceiving teaching, once again, as an isolated practice. As a consequence, this may result in teachers reinventing the wheel on their own, in which an example of the proverbial wheel in the online teaching and learning context is how to create educational videos, instead of collaborating. Educational developers and department heads play an important role in purposefully creating (online) collaboration opportunities, bringing teachers together, and nurturing communities.

## 5. Conclusions and implications

Our results suggest that the professional development project has been successful in fostering professional interaction by creating more collaborative relationships. The project design was inspired by research on knowledge sharing (Cross et al., 2001). Following this reasoning, the development of collaborative relationships is subject to four relational conditions: teachers 1) are aware of their colleagues' expertise, 2) have timely access to their colleagues, 3) interact in a safe environment, and 4) are committed to the interaction. Our study provides empirical evidence that supports the claims of Cross et al. (2001). First, teachers with more than five years of teaching experience (indication of expertise) were more likely to collaborate with colleagues. Second, we found a propinquity effect of teachers' office location as well as a cross-network effect of informal contact outside of work. The close proximity of teachers' offices can shape interaction by creating timely access to colleagues as well as create serendipitous encounters. Third, by interacting outside of work, teachers simultaneously gain access to their colleagues' expertise and establish a relationship of trust, which supports a safe collaboration environment at work. Fourth, although we did not explicitly examine participants' commitment to the project, teachers who more frequently attended the project meetings were also more likely to collaborate. Our study further revealed that teachers' choice of a colleague to participate in formative peer observations of teaching was related to an existing collaboration relationship before the project.

The findings of this study have implications for practice. The massification of higher education has as a result that universities are pressed for space. As a consequence, teachers who belong to the same department are sometimes scattered across a building, like the participants in our study. Similar to studies in primary and secondary education (e.g., Lohman & Woolf, 2001; Spillane et al., 2017; Van Gasse et al., 2020) – who underscored that school

building design should take into account the importance of proximity for collaborative interaction and informal professional development – we argue that universities should pay attention to office allocation of teachers, by minimizing walking distance between the offices and considering functional zones (such as coffee corners) overlap to increase interaction opportunities. We further advocate for the creation of designated spaces where teachers can meet each other, similar to teacher lounges in secondary education. As building design measures take time, we agree with Thomas et al. (2020) that department heads play a mitigating role in relationship building by allocating designated time for knowledge exchange and resource sharing by, for example, regularly organizing activities in which teachers can (in)formally meet each other, such as lunch meetings and curriculum discussion sessions, as exemplified by the project described in this study.

Past research has posited that formative peer observations of teaching supports the development of a shared teaching repertoire and improve teaching practices, of which a beneficial effect is noted for both the observer as the observe, as the method can serve “as a springboard for sharing ideas and stimulating reflective dialogue” (O’Leary & Price, 2016, p. 115). However, our findings indicate that when teachers are free to choose a colleague to observe, they intend to select someone with whom they already collaborate. To maximize the benefits of peer observations of teaching, educational developers and managers should consider regulating formative observations, for example by requesting monthly observations of a different colleague. This will result in more diverse observations, which in turn contributes to building a more cohesive departmental network.

#### Author credits statement

**Ine Noben:** Conceptualization, Methodology, Investigation, Data Curation, Writing – Original draft, Writing - Review & Editing, Project administration. **Jasperina Brouwer:** Conceptualization, Methodology, Software, Formal analysis, Writing – Original draft, Writing - Review & Editing. **Jan Folkert Deinum:** Supervision. **W.H. Adriaan Hofman:** Supervision.

#### Declaration of competing interest

None.

#### References

- Apkarian, N., & Rasmussen, C. (2020). Instructional leadership structures across five university departments. *Higher Education*, 81, 1–23. <https://doi.org/10.1007/s10734-020-00583-6>
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.
- Bell, M. (2001). Supported reflective practice: A programme of peer observation and feedback for academic teaching development. *International Journal for Academic Development*, 6(1), 29–39. <https://doi.org/10.1080/13601440110033643>
- Bell, A., & Mladenovic, R. (2015). Situated learning, reflective practice and conceptual expansion: Effective peer observation for tutor development. *Teaching in Higher Education*, 20(1), 24–36. <https://doi.org/10.1080/13562517.2014.945163>
- Benbow, R. J., & Lee, C. (2019). Teaching-focused social networks among college faculty: Exploring conditions for the development of social capital. *Higher Education*, 78(1), 67–89. <https://doi.org/10.1007/s10734-018-0331-5>
- Benbow, R. J., Lee, C., & Hora, M. T. (2020). Exploring college faculty development in 21st-century skill instruction: An analysis of teaching-focused personal networks. *Journal of Further and Higher Education*, 1–18. <https://doi.org/10.1080/0309877X.2020.1826032>
- Bjorklund, P., & Daly, A. J. (2021). The ties that belong: Tie formation in preservice teacher identification networks. *Teaching and Teacher Education*, 97, 1–12. <https://doi.org/10.1016/j.tate.2020.103223>
- Block, P. (2015). Reciprocity, transitivity, and the mysterious three-cycle. *Social Networks*, 40, 163–173. <https://doi.org/10.1016/j.socnet.2014.10.005>
- Boland, B., De Smet, A., Palter, R., & Sanghvi, A. (2020). *Reimagining the office and work life after COVID-19*. McKinsey & Company.
- Bolander Laksov, K., Elmlberger, A., Liljedahl, M., & Björck, E. (2020). *Shifting to team-based faculty development: A programme designed to facilitate change in medical education*. Higher Education Research & Development. <https://doi.org/10.1080/07294360.2020.1841122>
- Borgatti, S. P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science*, 49(4), 432–445. <https://doi.org/10.1287/mnsc.49.4.432.14428>
- Borgatti, S. P., Everett, M. G., & Johnson, J. C. (2013). *Analyzing social networks*. SAGE Publications. <https://doi.org/10.5565/rev/ledes.637>
- Borgatti, S. P., & Foster, P. C. (2003). The network paradigm in organizational research: A review and typology. *Journal of Management*, 29(6), 991–1013. [https://doi.org/10.1016/S0149-2063\\_03\\_00087-4](https://doi.org/10.1016/S0149-2063_03_00087-4)
- Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network analysis in the social sciences. *Science*, 323, 892–895. <https://doi.org/10.1126/science.1165821>
- Borko, H., & Livingston, C. (1989). Cognition and improvisation: Differences in mathematics instruction by expert and novice teachers. *American Educational Research Journal*, 26(4), 473–498. <https://doi.org/10.3102/00028312026004473>
- Bourdieu, P. (1986). The forms of social capital. In J. G. Richardson (Ed.), *Handbook of theory and research for the Sociology of education* (pp. 241–258). Greenwood.
- Brouwer, J., Downey, C., & Bokhove, C. (2020). The development of communication networks of pre-service teachers on a school-led and university-led programme of initial teacher education in England. *International Journal of Educational Research*, 100. <https://doi.org/10.1016/j.ijer.2020.101542>
- Brouwer, J., & Froehlich, D. E. (2020). Co-evolution models of longitudinally measured interactions. In M. Huber, & D. E. Froehlich (Eds.), *Analyzing group interactions: A researcher's guidebook* (pp. 107–115). <https://doi.org/10.4324/9780367321116-12>. Routledge.
- Burt, R. S. (2004). Structural holes and good ideas. *American Journal of Sociology*, 110(2), 349–399. <https://doi.org/10.1086/421787>
- Chamberlain, J. M., D’Artry, M., & Rowe, D. A. (2011). Peer observation of teaching: A decoupled process. *Active Learning in Higher Education*, 12(3), 189–201. <https://doi.org/10.1177/1469787411415083>
- Chester, A., Johnston, A., & Clarke, A. (2019). Partnerships for learning and belonging in tertiary education: A social capital analysis. In B. Tynan, T. McLaughlin, A. Chester, C. Hall-van den Elsen, & B. Kennedy (Eds.), *Transformations in Tertiary education* (pp. 11–26). [https://doi.org/10.1007/978-981-13-9957-2\\_2](https://doi.org/10.1007/978-981-13-9957-2_2). Springer.
- Coleman, J. S. (1990). *Foundations of social theory*. Harvard University Press.
- Cross, R., Parker, A., Prusak, L., & Borgatti, S. P. (2001). Knowing what we know: Supporting knowledge creation and sharing in social networks. *Organizational Dynamics*, 30(2), 100–120. [https://doi.org/10.1016/S0090-2616\(01\)00046-8](https://doi.org/10.1016/S0090-2616(01)00046-8)
- Daly, A. J., Moolenaar, N. M., Bolivar, J. M., & Burke, P. (2010). Relationships in reform: The role of teachers’ social networks. *Journal of Educational Administration*, 48(3), 359–391. <https://doi.org/10.1108/09578231011041062>
- Davis, J. A. (1970). Clustering and hierarchy in interpersonal relations: Testing two graph theoretical models on 742 sociomatrices. *American Sociological Review*, 35, 843–851. <https://doi.org/10.2307/2093295>
- Fleming, S. S., Goldman, A. W., Correlli, S. J., & Taylor, C. J. (2016). Settling in: The role of individual and departmental tactics in the development of new faculty networks. *The Journal of Higher Education*, 87(4), 544–572. <https://doi.org/10.1080/00221546.2016.11777413>
- Gaebel, M., Zhang, T., Bunescu, L., & Stoeberer, H. (2018). *Learning and teaching in the European higher education area*. European University Association.
- Gast, I., Schildkamp, K., & Van der Veen, J. T. (2017). Team-based professional development interventions in higher education: A systematic review. *Review of Educational Research*, 87(4), 736–767. <https://doi.org/10.3102/0034654317704306>
- Gest, S. D., & Kindermann, T. A. (2012). Analysis of static social networks and their developmental effects. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 577–597). The Guilford Press.
- Glegg, S. M. N., Jenkins, E., & Kothari, A. (2019). How the study of networks informs knowledge translation and implementation: A scoping review. *Implementation Science*, 14(34), 1–27. <https://doi.org/10.1186/s13012-019-0879-1>
- Hadar, L., & Brody, D. (2010). From isolation to symphonic harmony: Building a professional development community among teacher educators. *Teaching and Teacher Education*, 26(8), 1641–1651. <https://doi.org/10.1016/j.tate.2010.06.015>
- Hammersley-Fletcher, L., & Orsmond, P. (2005). Reflecting on reflective practices within peer observation. *Studies in Higher Education*, 30(2), 213–224. <https://doi.org/10.1080/03075070500043358>
- Hendry, G. D., Bell, A., & Thomson, K. (2014). Learning by observing a peer's teaching situation. *International Journal for Academic Development*, 19(4), 318–329. <https://doi.org/10.1080/1360144X.2013.848806>
- Hinojosa-Pareja, E. F., & García-Cano, M. (2020). *Excellence is not an island: Team-based professional development in higher education* (pp. 1–19). Professional Development in Education. <https://doi.org/10.1080/19415257.2020.1814382>
- Holland, P. W., & Leinhardt, M. (1971). Transitivity in structural models of small groups. *Comparative Group Studies*, 2(2), 107–124. <https://doi.org/10.1177/104649647100200201>
- Huxham, M., Scoles, J., Green, U., Purves, S., Welsh, Z., & Gray, A. (2017). ‘Observation has set in’: Comparing students and peers as reviewers of teaching. *Assessment & Evaluation in Higher Education*, 42(6), 887–899. <https://doi.org/10.1080/02602938.2016.1204594>
- Jaspersen, L. J., & Stein, C. (2019). Beyond the Matrix: Visual methods for qualitative network research. *British Journal of Management*, 30(3), 748–763. <https://doi.org/10.1111/1467-8551.12339>
- Kadushin, C. (2012). *Understanding social networks: Theories, concepts and findings*. Oxford University Press.
- Katajuvuori, N., Virtanen, V., Ruohoniemi, M., Muukkonen, H., & Toom, A. (2019).

- The value of academics' formal and informal interaction in developing life science education. *Higher Education Research and Development*, 38(4), 793–806. <https://doi.org/10.1080/07294360.2019.1576595>
- Kossinets, G., & Watts, D. J. (2006). Empirical analysis of an evolving social network. *Science*, 311(5757), 88–90. <https://doi.org/10.1126/science.1116869>
- Laumann, E. O., Marsden, P. V., & Prensky, D. (1983). The boundary specification problem in network analysis. In L. C. Freeman, D. R. White, & R. A. K. (Eds.), *Research methods in social network analysis* (pp. 61–79). Transaction Publishers. <https://doi.org/10.4324/9781315128511>
- Lave, J., & Wenger, E. (1991). *Learning in doing: Social, cognitive, and computational perspectives. Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- Lin, N. (2001). *Social capital: A theory of social structure and action* (Vol. 19). New York, NY: Cambridge university press.
- Liou, Y., Daly, A. J., Canrinus, E. T., Forbes, C. A., Moolenaar, N. M., Cornelissen, F., & Hsiao, J. (2017). Mapping the social side of pre-service teachers: Connecting closeness, trust, and efficacy with performance. *Teachers and Teaching*, 23(6), 635–657. <https://doi.org/10.1080/13540602.2016.1218329>
- Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, 15(2), 129–151. <https://doi.org/10.3102/01623737015002129>
- Lohman, M., & Woolf, N. H. (2001). Self-initiated learning activities of experienced public school teachers: Methods, sources, and relevant organizational influences. *Teachers and Teaching*, 7(1), 59–74. <https://doi.org/10.1080/13540600123835>
- Loury, G. (1987). Why should we care about group inequality? *Social Philosophy and Policy*, 5(1), 249–271. <https://doi.org/10.1017/S0265052500001345>
- Ma, S., Herman, G. L., West, M., Tomkin, J., & Mestre, J. (2019). Studying STEM faculty communities of practice through social network analysis. *The Journal of Higher Education*, 90(5), 773–799. <https://doi.org/10.1080/00221546.2018.1557100>
- McMahon, T., Barrett, T., & O'Neill, G. (2007). Using observation of teaching to improve quality: Finding your way through the muddle of competing conceptions, confusion of practice and mutually exclusive intentions. *Teaching in Higher Education*, 12(4), 499–511. <https://doi.org/10.1080/10108010701415607>
- McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, 27(1), 415–444. <https://doi.org/10.1146/annurev.soc.27.1.415>
- Moolenaar, N. M. (2012). A social network perspective on teacher collaboration in schools: Theory, methodology, and applications. *American Journal of Education*, 119, 7–39. <https://doi.org/10.1086/667715>
- Moolenaar, N. M., Slegers, P. J., Karsten, S., & Daly, A. J. (2012). The social fabric of elementary schools: A network typology of social interaction among teachers. *Educational Studies*, 38(4), 355–371. <https://doi.org/10.1080/03055698.2011.643101>
- Newell, C., & Bain, A. (2020). Academics' perceptions of collaboration in higher education course design. *Higher Education Research and Development*, 39(4), 748–763. <https://doi.org/10.1080/07294360.2019.1690431>
- O'Leary, M., & Savage, S. (2020). Breathing new life into the observation of teaching and learning in higher education: Moving from the performative to the informative. *Professional Development in Education*, 46(1), 145–159. <https://doi.org/10.1080/19415257.2019.1633386>
- Palonen, T., Hakkarainen, K., Talvitie, J., & Lehtinen, E. (2004). Network ties, cognitive centrality, and team interaction within a telecommunication company. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: Gaps and transitions on the way from novice to expert* (pp. 271–291). Kluwer Academic Publishers. [https://doi.org/10.1007/1-4020-2094-5\\_14](https://doi.org/10.1007/1-4020-2094-5_14)
- Pataraiia, N., Margaryan, A., Falconer, I., & Littlejohn, A. (2015). How and what do academics learn through their personal networks. *Journal of Further and Higher Education*, 39(3), 336–357. <https://doi.org/10.1080/0309877X.2013.831041>
- Pataraiia, N., Margaryan, A., Falconer, I., Littlejohn, A., & Falconer, J. (2014). Discovering academics' key learning connections. *Journal of Workplace Learning*, 26(1), 56–72. <https://doi.org/10.1108/JWL-03-2013-0012>
- Penuel, W., Riel, M., Krause, A., & Frank, K. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record*, 111(1), 124–163.
- Portes, A. (1998). Social capital: Its origins and applications in modern sociology. *Annual Review of Sociology*, 24, 1–24. <https://doi.org/10.1146/annurev.soc.24.1.1>
- Prell, C. (2012). *Social network analysis: History, theory and methodology*. SAGE.
- Purwitasari, D., Fatchah, C., Sumpeno, S., Steglich, C., & Purnomo, M. H. (2020). Identifying collaboration dynamics of bipartite author-topic networks with the influences of interest changes. *Scientometrics*, 122(3), 1407–1443. <https://doi.org/10.1007/s11192-019-03342-2>
- Quardokus, K., & Henderson, C. (2015). Promoting instructional change: Using social network analysis to understand the informal structure of academic departments. *Higher Education*, 70(3), 315–335. <https://doi.org/10.1007/s10734-014-9831-0>
- Quinlan, K. M., & Åkerlind, G. S. (2000). Factors affecting departmental peer collaboration for faculty development: Two cases in context. *Higher Education*, 40, 23–52. <https://doi.org/10.1023/A:1004096306094>
- Ragan, D. T., Osgood, D. W., Ramirez, N. G., Moody, J., & Gest, S. D. (2019). A comparison of peer influence estimates from SIENA stochastic actor-based models and from conventional regression approaches. *Sociological Methods & Research*, 1–39. <https://doi.org/10.1177/0049124119852369>
- Rienties, B., & Kinchin, I. (2014). Understanding (in) formal learning in an academic development programme: A social network perspective. *Teaching and Teacher Education*, 39, 123–135. <https://doi.org/10.1016/j.tate.2014.01.004>
- Ripley, R. M., Snijders, T. A. B., Boda, Z., Vörös, A., & Preciado, P. (2020). *Manual for RSiENA*. Nuffield College: University of Oxford, Department of Statistics.
- Ropo, E. (2004). Teaching expertise. In H. P. A. Boshuizen, R. Bromme, & H. Gruber (Eds.), *Professional learning: Gaps and transitions on the way from novice to expert* (pp. 159–180). Kluwer Academic Publishers. [https://doi.org/10.1007/1-4020-2094-5\\_9](https://doi.org/10.1007/1-4020-2094-5_9)
- Roxå, T., & Mårtensson, K. (2009). Significant conversations and significant networks – exploring the backstage of the teaching arena. *Studies in Higher Education*, 34(5), 547–559. <https://doi.org/10.1080/03075070802597200>
- Sandr, F. O. (2012). Peer observation action research project. *School Leadership & Management*, 32(4), 355–373. <https://doi.org/10.1080/13632434.2012.712511>
- Saroyan, A., & Trigwell, K. (2015). Higher education teachers' professional learning: Process and outcome. *Studies in Educational Evaluation*, 46, 92–101. <https://doi.org/10.1016/j.stueduc.2015.03.008>
- Schreurs, B., Van den Beemt, A., & De Laat, M. (2019). Networked individualism and learning in organizations: An ego-network perspective on informal learning ties. *Journal of Workplace Learning*, 31(2), 95–115. <https://doi.org/10.1108/JWL-05-2018-0070>
- Schweinberger, M., & Snijders, T. A. B. (2007). Markov models for digraph panel data: Monte Carlo-based derivative estimation. *Computational Statistics & Data Analysis*, 51(9), 4465–4483.
- Small, M., & Adler, L. (2019). The role of space in the formation of social ties. *Annual Review of Sociology*, 45, 111–132. <https://doi.org/10.1146/annurev-soc-073018-022707>
- Snijders, T. A. B. (2001). The statistical evaluation of social network dynamics. *Sociological Methodology*, 31, 361–395.
- Snijders, T. A. B. (2005). Models for longitudinal data. In P. J. Carrington, J. Scott, & S. Wasserman (Eds.), *Models and methods in social network analysis* (pp. 215–247). New York, NY: Cambridge University Press.
- Snijders, T. A. B. (2011). Statistical models for social networks. *Annual Review of Sociology*, 37(1), 131–153. <https://doi.org/10.1146/annurev.soc.012809.102709>
- Snijders, T. A. B., Van der Bunt, G. G., & Steglich, C. E. G. (2010). Introduction to stochastic actor-based models for network dynamics. *Social Networks*, 32, 44–60.
- Spalter-Roth, R., Mayorova, O., Scelza, J., & Van Vooren, N. (2010). *Teaching alone? Sociology faculty and the availability of social networks*. American Sociological Association.
- Spillane, J. P., Shirrell, M., & Sweet, T. M. (2017). The elephant in the schoolhouse: The role of propinquity in school staff interactions about teaching. *Sociology of Education*, 90(2), 149–171. <https://doi.org/10.1177/0038040717696151>
- Stadtfeld, C., Snijders, T. A. B., Steglich, C., & van Duijn, M. (2020). Statistical power in longitudinal network studies. *Sociological Methods & Research*, 49(4), 1103–1132. <https://doi.org/10.1177/0049124118769113>
- Steinert, Y., Mann, K., Anderson, B., Barnett, B. M., Centeno, A., Nasmith, L., Prideaux, D., Spencer, J., Tullo, E., Viggiano, T., Ward, H., & Dolmans, D. (2016). A systematic review of faculty development initiatives designed to enhance teaching effectiveness: A 10-year update: BEME guide No. 40. *Medical Teacher*, 38(8), 769–786. <https://doi.org/10.1080/0142159X.2016.1181851>
- Stes, A., Min-Leliveld, M., Gijbels, D., & Van Petegem, P. (2010). The impact of instructional development in higher education: The state-of-the-art of the research. *Educational Research Review*, 5, 25–49. <https://doi.org/10.1016/j.edurev.2009.07.001>
- Taylor, K. L., & Znajda, S. K. (2015). Demonstrating the impact of educational development: The case of a course design collaborative. *Studies in Educational Evaluation*, 46, 39–46. <https://doi.org/10.1016/j.stueduc.2014.11.003>
- Tezcan-Unal, B. (2018). Action research on a collegial model of peer observations. *Educational Action Research*, 26(4), 641–654. <https://doi.org/10.1080/09650792.2017.1358199>
- Thomas, L., Rienties, B., Tuytens, M., Devos, G., Kelchtermans, G., & Vanderlinde, R. (2020). *Unpacking the dynamics of collegial networks in relation to beginning teachers' job attitudes*. *Research Papers in Education*. <https://doi.org/10.1080/02671522.2020.1736614>
- Torres, A. C., Lopes, A., Valente, J. M. S., & Mouraz, A. (2017). What catches the eye in class observation? Observers' perspectives in a multidisciplinary peer observation of teaching program. *Teaching in Higher Education*, 22(7), 822–838. <https://doi.org/10.1080/13562517.2017.1301907>
- Tynjälä, P. (2008). Perspective into learning in the workplace. *Educational Research Review*, 3(2), 130–154. <https://doi.org/10.1016/j.edurev.2007.12.001>
- Van Gasse, R., Goffin, E., Vanhoof, J., & Van Petegem, P. (2020). *For squad-members only! Why some teachers are more popular to interact with than others in data use*. *Studies in Educational Evaluation*, Article 100881. <https://doi.org/10.1016/j.stueduc.2020.100881>
- Van Gasse, R., Vanlommel, K., Vanhoof, J., & Van Petegem, P. (2017). Unravelling data use in teacher teams: How network patterns and interactive learning activities change across different data use phases. *Teaching and Teacher Education*, 67, 550–560. <https://doi.org/10.1016/j.tate.2017.08.002>
- Van Waes, S., De Maeyer, S., Moolenaar, N. M., Van Petegem, P., & Van den Bossche, P. (2018). Strengthening networks: A social network intervention among higher education teachers. *Learning and Instruction*, 53, 34–49. <https://doi.org/10.1016/j.learninstruc.2017.07.005>
- Van Waes, S., Moolenaar, N. M., Daly, A. J., Heldens, H. H. P. F., Donche, V., Van Petegem, P., & Van den Bossche, P. (2016). The networked instructor: The quality of networks in different stages of professional development. *Teaching and Teacher Education*, 59, 295–308. <https://doi.org/10.1016/j.tate.2016.05.022>



- Van Waes, S., Van den Bossche, P., Moolenaar, N. M., De Maeyer, S., & Van Petegem, P. (2015). Know-who? Linking faculty's networks to stages of instructional development. *Higher Education*, 70(5), 807–826. <https://doi.org/10.1007/s10734-015-9868-8>
- Van den Bossche, P., & Segers, M. (2013). Transfer of training: Adding insight through social network analysis. *Educational Research Review*, 8, 37–47. <https://doi.org/10.1016/j.edurev.2012.08.002>
- Vangrieken, K., Dochy, F., Raes, E., & Kyndt, E. (2015). Teacher collaboration: A systematic review. *Educational Research Review*, 15, 17–40. <https://doi.org/10.1016/j.edurev.2015.04.002>
- Veenstra, R., & Steglich, C. (2012). Actor-based model for network and behavior dynamics. In B. Laursen, T. D. Little, & N. A. Card (Eds.), *Handbook of developmental research methods* (pp. 598–618). Guilford Press.
- Voogt, J. M., Pieters, J. M., & Handelzalts, A. (2016). Teacher collaboration in curriculum design teams: Effects, mechanisms, and conditions. *Educational Research and Evaluation*, 22(3–4), 121–140. <https://doi.org/10.1080/13803611.2016.1247725>
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511815478>
- Wiemann, C. (2010). Why not try a scientific approach to science education? In J. C. Hughes, & J. Mighty (Eds.), *Taking stock: Research on teaching and learning in higher education* (pp. 175–190). School of Policy Studies, Queen's University. <https://doi.org/10.3200/CHNG.39.5.9-15>