Full length article

The networked instructor: The quality of networks in different stages of professional development

Sara Van Waes [a, *], Nienke M. Moolenaar [b], Alan J. Daly [c], Henderijn H.P.F. Heldens [d], Vincent Donche [e], Peter Van Petegem [a, e], Piet Van den Bossche [e, f]

[a] Center for Excellence in Higher Education, University of Antwerp, Venusstraat 35, 2000, Antwerp, Belgium
[b] Department of Education, Utrecht University, Heidelberglaan 1, P.O. Box 80.140, 3508 TC, Utrecht, The Netherlands
[c] Department of Education Studies, University of California, San Diego, 9500 Gilman Dr. La Jolla, CA 92093, USA
[d] Fontys Hogeschool and Eindhoven School of Education, De Lismortel 25, P.O. Box 347, 5600 AH, Eindhoven, The Netherlands
[e] Institute for Education and Information Sciences, University of Antwerp, Venusstraat 35, 2000, Antwerp, Belgium
[f] Educational Research and Development, Maastricht University, P.O. Box 616, 6200 MD, Maastricht, The Netherlands

HIGHLIGHTS

- The interdependence in instructors' teaching networks varied but tended to be low.
- Instructors attributed different types of value to their teaching networks.
- Instructors in varying developmental stages differed in network quality.
- In-depth interviews and social network methods were combined.
- A network mapping tool was used to visualize teaching networks.

ARTICLE INFO

ABSTRACT

This article focuses on the quality of instructional networks in different stages of professional development. Drawing theoretically from social capital theory and literature on teacher interaction, we conducted in-depth interviews with 30 instructors at the university level. Using qualitative social network analysis to capture and analyze networks, we found that the quality of instructors' interactions varied across developmental stages (novice, experienced non-expert, and expert instructors), both in terms of interdependence and opportunities for value creation. These findings offer valuable leverage for shaping educators' everyday professional development and increasing teaching capacity through quality interaction.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In recent years teachers' professional development through informal learning processes has come to the fore (Grosemans, Boon, Verclairen, Dochy, & Kyndt, 2015; Hoekstra, Korthagen, Brekelmans, Beijaard, & Imants, 2009; Van Waes, Van den Bossche, Moolenaar, De Maeyer & Van Petegem, 2015). In contrast to research on teachers' formal learning (Borko, 2004; De Rijdt, Stes, van der Vleuten, & Dochy, 2013), the knowledge base on teachers' everyday learning is limited (Boud & Middleton, 2003; Hoekstra, Beijaard, Brekelmans, & Korthagen, 2007). This article investigates a fundamental aspect of teachers' informal learning: learning through everyday interaction. Specifically, we examined teachers' professional interactions in their everyday practice. For example, collaborating, exchanging material, and sharing stories or experiences about teaching, which are often levers for innovative practice (Bakkenes, Vermunt, & Wubbels, 2010; Thurlings, Evers, &

* Corresponding author.
E-mail addresses: Sara.VanWaes@uantwerpen.be (S. Van Waes), N.M. Moolenaar@uu.nl (N.M. Moolenaar), ajdaly@ucsd.edu (A.J. Daly), h.heldens@ fontys.nl (H.H.P.F. Heldens), Vincent.Donche@uantwerpen.be (V. Donche), Peter. VanPetegem@uantwerpen.be (P. Van Petegem), Piet.VandenBossche@uantwerpen. be (P. Van den Bossche).

Vermeulen, 2015). Scholars have paid increasing attention to the workplace as a space for interaction and learning (Boud & Middleton, 2003; Eraut, 2007). Around the globe, both scholars and practitioners have acknowledged and valued teachers' learning through interaction (Kelchtermans, 2006; Vangrieken, Dochy, Raes, & Kyndt, 2015), and have established its significance for teachers' professional development (Avalos, 2011; Cochran-Smith & Lytle, 1999; Vescio, Ross, & Adams, 2008), and student achievement (Goddard, Goddard, & Tschannen-Moran, 2007; Ronfeldt, Farmer, McQueen, & Grissom, 2015).

The urge to capitalize on teacher interaction is reflected by a growing number of concepts, such as communities of practice, organizational (shared, collaborative) learning, professional (learning) communities, and networks (Carolan, 2014; Louis & Marks, 1998; McLaughlin & Talbert, 2006; Wenger, McDermott, & Snyder, 2002). Although this work has proven its use in highlighting the role of teacher interaction in professional development, it poses some conceptual and methodological challenges. First, this body of research typically assumes in advance the locus of professional communities, focusing on the school, university or on formal organizational structures such as grade-level groups and departments (Coburn & Russell, 2008). Yet a teacher is often embedded in a network of relationships that span subgroups and include individuals inside and outside institutional boundaries (Penuel, Riel, Krause, & Frank, 2009; Spillane, 2005; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). In several cases, informal structures have proven more consequential than formal organizational structures as places of interaction (Bridwell-Mitchell & Cooc, 2016; Brown & Duguid, 1991; Reagans & McEvily, 2003). Likewise, scholars have argued to not only pay attention to the community but to also include experiences of the individual within, whose professional interactions also cross boundaries of communities (Arthur, 2016; P. Hodkinson, Biesta, & James, 2008; Wenger, Trayner, & de Laat, 2011).

Second, the growing body of research on teacher interaction has mostly concentrated on interactions in general. However, a gap in the extant literature is that most studies fail to measure teachers' professional interactions with much precision (Coburn, Russell, Kaufman, & Stein, 2012). They provide descriptions of how many times teachers reported a certain type of interaction (e.g., Bakkenes et al., 2010; Doppenberg, Bakx, & den Brok, 2012; Zwart, Wubbels, Bolhuis, & Bergen, 2008). They describe teacher interaction as a whole, for example, by providing frequency indications of teachers' interactions around storytelling or exchange of material. But they do not actually report on qualitative differences of interactions in detail, nor explore the constellation of teachers' interactions. These descriptions offer an overview of types of interaction and the attributed value, but do not offer much insight into the different types of professional relationships. Further, they do not provide empirical study about the network of relations surrounding teachers. In fact, little is known about the individuals in the network, and the content that moves between teachers in their daily practice. In short, previous work has not focused in detail on whom teachers are actually interacting with and what the quality is of those interactions. A more fine-grained exploration of teacher interaction, taking a relational view, could yield a better understanding of teachers' professional development.

Social capital theory offers opportunities to addresses these conceptual and methodological challenges (Adler & Kwon, 2002). This approach pays careful attention to social capital as a resource that inheres in the social network, tying a focal actor to other actors (e.g., Burt, 1992). When applied to education, social capital theory foregrounds the resources that are available to a teacher through collegial interaction, and posits that particular features are more or less conducive to accessing appropriate resources and creating an environment that enables change in instructional practice (Coburn & Russell, 2008, p. 205). Many social capital theorists draw on *social network analysis* (Carrington, Scott, & Wasserman, 2005) as a methodological approach and a means to capture relevant features of teacher interaction in a more straightforward way (Carolan, 2014; Moolenaar, 2012). Social network analysis, and specifically a personal network approach, permits to investigate "the configuration of teachers' networks from the bottom up rather than to assume in advance the locus of their relevant community" (Coburn & Russell, 2008, p. 206; Fox, Deaney, & Wilson, 2010). It involves systematically mapping social relationships of focal teachers, and determining who interacts with whom.

This article sets forward a personal network perspective to provide further in-depth insight into teacher interaction in light of professional development. We build on organizational studies that have extensively demonstrated the importance of individuals' networks for their professional development (Chua, Madej, & Wellman, 2011; Valente, 1996), and how networks of professionals in different stages of development differ (Borgatti & Cross, 2003; Cotton, Shen, & Livne-Tarandach, 2011; Dobrow, Chandler, Murphy, & Kram, 2012). According to these scholars, the development of professionals cannot be attributed to the individual level alone given the socially distributed nature of professional development. Professional development is no longer regarded as an individual endeavor but is influenced by the people a teacher interacts with and the quality of these interactions. Therefore, we argue that a teacher interacts within a 'network' of people, containing different relationships of differing quality that may be related to their professional development. A specifically under examined set of teachers in this regard, are academics who teach at the university level, or 'instructors' (Roxå & Mårtensson, 2009; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). Up until now, most studies have focused on teachers in primary and secondary education (Doppenberg, Bakx, et al., 2012; Meirink, Imants, Meijer, & Verloop, 2010).

2. Aim

This study explores the quality of existing instructional networks by means of two frameworks, i.e. interdependence (Little, 1990) and value creation (Wenger et al., 2011). These frameworks represent two different approaches to examining the quality of interactions by offering insight into the extent to which instructors are dependent on each other when interacting around their teaching practice (e.g., casually exchanging stories or jointly developing a course), and into the value instructors perceive as resulting from these interactions (e.g., newfound inspiration or a method that will be tried out). Our research aims are guided by the following questions:

RQ1. How do instructors perceive the interdependence in their interactions?

RQ2. If and how do instructors perceive the value that is created in their interactions?

Moreover, scholars suggest that the quality of interaction differs depending on whether one is a novice in the beginning of their career, experienced and/or known for their teaching expertise. Therefore, an additional objective of this work is to examine the degree to which the quality of interactions is related to professional development:

RQ3. If and how do instructors in varying stages of professional development differ in the quality of interactions (in terms of their perception of interdependence and value creation)?

As such, the aim of this study is to illuminate the relationship between the quality of instructors' interactions and their development in varying stages. Our purpose is not to generate findings that can be generalized to a broader population, but rather to contribute to an emerging theory about the relationship between teacher interaction and professional development (Strauss & Corbin, 1994; Yin, 1994). In the next section, we first provide an overview of social network theory. We then move into the quality of those interactions drawing on frameworks of interdependence and value creation. Finally, we bring these frameworks together to understand how instructors in different stages of professional development may differ in the quality of their interactions.

3. Theoretical framework

3.1. A social network perspective on teachers' professional development

Isolated practice is considered by most educators, administrators, policymakers and scholars as an inadequate way of performing teachers' work (Bakkenes, De Brabander, & Imants, 1999; Cox, 2004; Hadar & Brody, 2010; Lima, 2003). Interest in teachers' professional interactions has sparked an important body of research into the meaning and potential of teacher learning (Avalos, 2011; Cochran-Smith & Lytle, 1999; McLaughlin & Talbert, 2006; Vescio et al., 2008), for issues such as student learning (Goddard et al., 2007; Hallinger, 1998; Ronfeldt et al., 2015), and organizational learning (Slavit, Kennedy, Lean, Nelson, & Deuel, 2011; Westheimer, 2008). This work identified facilitating and hindering factors in building teacher relationships, documented the various forms teacher relationships can assume, and mapped the various outcomes they can result into (e.g., Hodkinson & Hodkinson, 2004; Kelchtermans, 2006; Vangrieken et al., 2015; Vescio et al., 2008; Wenger, 1998).

In the last decade, studies on professionals' workplace learning are increasingly taking a relational or social perspective on professionals' development (Boshuizen, Bromme, & Gruber, 2004; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004; Tynjälä, 2008). They emphasize the socially distributed nature of professional development, and the importance of learning from others. A recently developing strand of research explicitly points at the importance of professional relationships or 'networks' as a key contributor for teachers' professional development (Carolan, 2014; Hofman & Dijkstra, 2010; Lima, 2010; Moolenaar, 2012). Scholars have drawn both theoretically and methodologically from social network theory to capture teachers' interactions in a more straightforward and fine-grained way. The assumption underlying a social network perspective is that the patterns of social relationships among teachers (i.e., their networks) offer a valuable framework for examining how, whether and to what degree teacher interaction takes place. Through their web of relationships or 'networks', teachers can exchange knowledge, information, materials and other resources regarding their instructional practice. Network research has established its usefulness by demonstrating the importance of teacher interaction for student achievement (Moolenaar, Sleegers & Daly, 2012), reform and improvement (Penuel et al., 2009), policy implementation (Coburn et al., 2012; Daly & Finnigan, 2010), leadership (Moolenaar, Daly & Sleegers, 2010; Pitts & Spillane, 2009), and professional development programs (Penuel, Sun, Frank, & Gallagher, 2012; Rienties & Kinchin, 2014; Van Waes, Van den Bossche, Moolenaar, Stes & Van Petegem, 2015).

Most extant network research focuses on the patterns or structure of networks (e.g., by investigating network characteristics such as size, density, centrality, reciprocity). While that is important, often questions about the content, meaning and significance of the social relationships are less examined (Bellotti, 2014; Fuhse & Mützel, 2011; Hollstein, 2011). A growing body of empirical studies is suggesting that inquiry into teacher interaction can be advanced by exploring the quality of personal teaching networks, or in other words to capture the 'stories' behind a teacher's network (Baker-Doyle, 2015; Coburn & Russell, 2008; Coburn et al., 2012; Cornelissen, van Swet, Beijaard, & Bergen, 2011).

3.2. The quality of teacher interaction

Two frameworks from different fields of research were used to examine the quality of teacher interaction, i.e., the frameworks of interdependence and value creation. This study applies these frameworks onto the interactions teachers have within networks around their instructional practice. In what follows, we argue the selection of these frameworks to grasp the quality of teacher interaction in detail.

3.2.1. Interdependence

Several studies set forward the importance of the focus and depth in teacher interaction (Vangrieken et al., 2015). A framework that captures these aspects of interaction quality in a fine-grained way is the 'interdependence' framework by Little (1990). It details how teachers' professional interactions can span a wide array of teacher-to-teacher exchange such as telling stories, exchanging material, sharing, helping, teaming etc. Recent work has demonstrated the potential of this framework to grasp the quality of teachers' professional interactions (e.g., Doppenberg, den Brok, & Bakx, 2013; Kwakman, 2003; Meirink et al., 2010). The framework is based in a participatory, social-cultural approach, and describes a continuum of professional interactions ranging from low to strong interdependence among teachers. Specifically, four types of interactions between educators are distinguished: (1) storytelling and scanning, (2) aid and assistance, (3) sharing, and (4) joint work (Little, 1990).

Storytelling and scanning refers to the quick and casual exchange of stories or experiences in occasional contact. These entail low relational interdependence and do not require extensive joint engagement (e.g., a teacher vents about students or talks about how classes went). *Aid and assistance* refers to the ready availability of mutual aid or helping. The interdependence between teachers is relatively low since the interaction is one-directional (e.g., a teacher asks someone else for help or advice). *Sharing* entails high interdependence since teachers expose their work and thinking to each other, which implies reciprocity (e.g., teachers exchanging material and methods). *Joint work* indicates structural encounters among teachers that rest on shared responsibility for the work of teaching. Joint work entails high interdependence since it anticipates collective action (e.g., teachers developing a course or an exam together). There is no intended hierarchy among the different levels of interdependence. Interactions with low interdependence are not more important or better than highly interdependent interactions.

3.2.2. Value creation

Other approaches to the quality of teacher interaction have a more evaluative or outcome-based focus. They examine the benefits of interactions for the instructional practice, and how these are perceived and valued by the teachers themselves. Outcomes associated with teacher interaction were students' improved understanding and performance (Goddard et al., 2007; Lomos, Hofman, & Bosker, 2011), and increased teacher motivation, efficiency, reduced isolation and improved instruction strategies (Vangrieken et al., 2015). The framework of value creation by Wenger et al. (2011)

clearly grasps this outcome-based approach to interaction quality. Recent work has demonstrated the use of the framework to study the quality of interactions in a fine-grained way (Bertram, Paquette, Duarte, & Culver, 2014; Cowan & Menchaca, 2014; Kantanen, Manninen, & Kontkanen, 2014). The value creation framework stems from research on networks and communities of practice and provides insight into the value that interactions may or may not produce. 'Value' is understood as the outcome(s) of collegial interactions as experienced and perceived by the teachers participating in the interaction. The value creation framework outlines different cycles of value creation: (1) immediate value, (2) potential value, (3) applied value, (4) realized value, (5) reframing value, and (6) aspirational value.

Immediate value stands for interactions that produce value in and of themselves (e.g., teachers share a story about something that went wrong in class, and experience this interaction as useful or enjoyable). *Potential value* refers to knowledge capital, whose value lies in its potential to be realized later (e.g., teachers receive ideas, referrals or advice, which they do not implement at that time but regard as potential resources for later). *Applied value* indicates that interactions have caused actual changes in practice (e.g., teachers have actually tried out a suggestion, or adopted received material). Applying new practices or tools can be promising but does not necessarily mean improvement. *Realized value* indicates actual improvement in performance resulting from suggestions or ideas (e.g., teachers indicate that student achievement improves after implementing a peer feedback system, or time is saved when correcting papers or exams). *Reframing value* refers to redefining or reframing goals, values or strategies (e.g., teachers come to a new understanding of how to look at teaching, or what assessing students means). Finally, *aspirational value* describes interactions in terms of the value they are expected to produce. These differ from potential value in that they are future aspirations rather than already acquired resources that show potential in the future (e.g., a teacher indicates that a person is currently not in the network but will be in the (near) future because he will become responsible for a shared course). Most other frameworks mapping the value or outcomes associated with interactions, do not take into account cycle 1 and 2, or do not look at outcomes as interweaved cycles. Since learning is not a linear process, there is no hierarchy among the cycles. Certain cycles of value are not more important than others, and the cycles are not always passed through in the same order or are not necessarily fully completed.

3.3. Teacher interaction in different stages of professional development

Recent research in the field of education has shown that the interactions of teachers with varying levels of teaching experience differ (Bakkenes et al., 2010; Brody & Hadar, 2015; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015; Zwart, Wubbels, Bergen, & Bolhuis, 2007). Novice and experienced teachers have different needs regarding professional relationships and show different interaction patterns (Grosemans et al., 2015; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). In line with this work, organizational research has highlighted how the networks of professionals matter for their professional development (Borgatti & Cross, 2003), and specifically for their expertise development (Gruber, Lehtinen, Palonen, & Degner, 2008). For example, former research indicated that experts tended to invest in relationships that extend their expertise and help them avoid learning biases and career traps (Cross & Thomas, 2008). Their interactions were characterized by diversity rather than similarity. Moreover, experts engaged in behaviors that lead to high-quality

networks, not just large networks. They positioned themselves at key points in a network and leveraged the network around them when implementing plans. Recent work into teacher networks has shown how novice teachers build support networks (Fox & Wilson, 2015; Fox, Wilson, & Deaney, 2011). However, few to none studies have compared the networks of teachers in different stages of professional development. Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al. (2015) examined and compared the network structure of teachers (in higher education) with differing teaching experience and expertise, but little is known about whether teachers in varying stages of professional development differ in terms of interaction quality.

4. Method

4.1. Sample

This study was conducted in a mid-sized, multidisciplinary, public and research-intensive university in Belgium serving 15,000 students and employing 2855 faculty members, among them 830 teaching faculty members. A total of 30 faculty members were selected (31% female; with a minimal teaching appointment of 40%). One participant was Russian, all others were Belgian, aiming for maximum variety across different university departments. The sample included both teaching assistants and teaching professors (most of them combining teaching and research). Participants took part on a voluntary basis (response rate: 93,75%), and consented to have their data reported anonymously.

4.1.1. Stages of professional development

Since teacher interaction has been shown to differ depending on the stage of development, we selected instructors with varying levels of teaching experience and expertise. Consistent with the exploratory theory-building purpose of our study, instructors in different stages of development were purposively sampled, representing three stages: novices, experienced non-experts and experienced experts (Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015) by combining high and low levels of teaching experience and teaching expertise (Bereiter & Scardamalia, 1993; Ericsson, 2006). Experienced experts both had high teaching experience and teaching expertise, experienced non-experts had high teaching experience and low teaching expertise, and novices had low teaching experience and low teaching expertise.

Experienced experts had at least ten years of *teaching experience* ($M = 17.67$ years) (Ericsson, 2006). A thorough strategy was used to define *teaching expertise* by combining both supervisor nominations and student evaluations. Firstly, the chair of education and the educational advisor were asked to nominate four expert instructors in their department. These nominations were based on five criteria: pedagogical content knowledge, subject knowledge, innovative educational ideas, active involvement in educational boards,[1] and commitment towards students (Berliner, 2004; Shulman, 1987; Tsui, 2009). Secondly, the instructors' scores on student evaluations were taken into account. At the sample university, students regularly fill out evaluative questionnaires regarding their instructors' teaching performance. This validated questionnaire consists of 31 items, which comprises 10 Likert scales (including scales on teaching methods, course materials, coaching, evaluation etc.) (Spooren, Mortelmans & Denekens, 2007). Expert instructors had student evaluation scores in the upper quartile of their

---

[1] Educational boards are used to refer to all organs (working groups, quality cells, program commissions etc.) that deal with matters related to the quality of instructional practice.

department, and were nominated by the chair or advisor as expert instructors.[2]

Experienced non-experts (Bereiter & Scardamalia, 1993) also had at least ten years of *teaching experience* ($M = 21.00$ years). However, having many years of experience does not invariably lead to expert levels of achievement. Therefore, these instructors were selected on low *teaching expertise*. They scored in the lower quartile of their department on the student evaluations, and were not nominated as expert.[3]

Novices are beginning instructors with three to five years of teaching experience ($M = 3.31$ years). As most of them had not received (sufficient) student evaluations, we randomly selected beginning instructors across departments, none of which were nominated as expert.

4.2. Data collection

4.2.1. Social network data

We took a personal network (i.e. egocentric network) approach to social network analysis (Borgatti, Mehra, Brass, & Labianca, 2009; Crossley et al., 2015; Wellman, 1993). This means that we mapped networks that were centered on an individual (*ego*). The people that an individual interacts with in his/her personal network are called *alters*, and the relationship between ego and alter is a *tie*. The strength of using a personal network approach is that it allows in-depth investigation of each tie, rather than obtaining an overall description of an instructor's interactions. In addition, the researchers can map instructors' networks from the ground up, instead of assuming in advance the locus of community in pre-existing boundaries. A personal network approach thus allows participants to define their own network boundaries (Crossley et al., 2015), not limiting interactions within the locus of e.g. the department or university. This was an important consideration given our focus on the quality of instructional interaction, to include external professional contacts as well (which cannot be predefined).

4.2.2. Network quality

The participants were interviewed using a semi-structured interview guide (Appendix A). Interviews lasted between 45 and 90 min, depending on the size of participants' networks. Beforehand, several pilot interviews were conducted. The interview guide contained questions designed to gain insight into the quality of instructors' interactions around their teaching practice. A participatory mapping technique was used to gain insight into instructors' networks. The name generating question of the interview asked participants with whom they interacted around their teaching practice. Subsequently, the participant noted the names of these people on post-it notes. A sheet of A3-sized paper with three concentric circles was placed on the table to visualize the participant's network (Fig. 1). Participants were asked to stick the post-it notes onto the network map, where each circle represented the closeness of the contact (Hogan, Carrasco, & Wellman, 2007; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). After

constructing the network map, name interpreting questions were asked to gain insight into the interdependence of the interactions (questions 2a–2d) and the value created through the people they interact with (questions 2e–2g). For member checking purposes, a picture of the network map was sent by e-mail afterwards. A follow-up telephone call was scheduled to verify the completeness of the network, based on the picture of the network map. Additions (of one to four alters) were made by four interviewees.

4.3. Analysis

All interviews were recorded and transcribed verbatim. Transcriptions were analyzed in four steps (Miles, Huberman, & Saldaña, 2014), using QSR NVivo 10. First, all transcript data were selected describing (1) the extent to which instructors are dependent on each other in interactions, and (2) the value of interactions. Focal instructors' personal networks were the key analytic measure for this study. The unit of analysis concerned fragments of meaning; this could be (part of) a sentence or a set of sentences. Fragments were coded thickly to maintain high data density at this stage. When fragments detailed both aspects of interdependence and value creation, they received both labels.

In the second step, the fragments were placed into two descriptive matrices (at subcategory level), one for interdependence and one for value creation. In total 397 fragments were connected to a priori codes suggested by existing research on interdependence (Doppenberg, Bakx, et al., 2012; Little, 1990), and 402 fragments to a priori codes of value creation (Wenger et al., 2011). Peer debriefings were conducted with two of the co-authors to discuss the initial coding work based on three interviews (one from each stage of development). Based on these debriefings two less dense coding schemes were established, including (summarized) text fragments as illustrations for each subcategory.

In the third step, these coding schemes formed the starting point to establish interrater agreement (Cohen, 1960). Twenty percent of the interviews was randomly sampled and coded by the principal researcher and by a researcher unfamiliar with the study
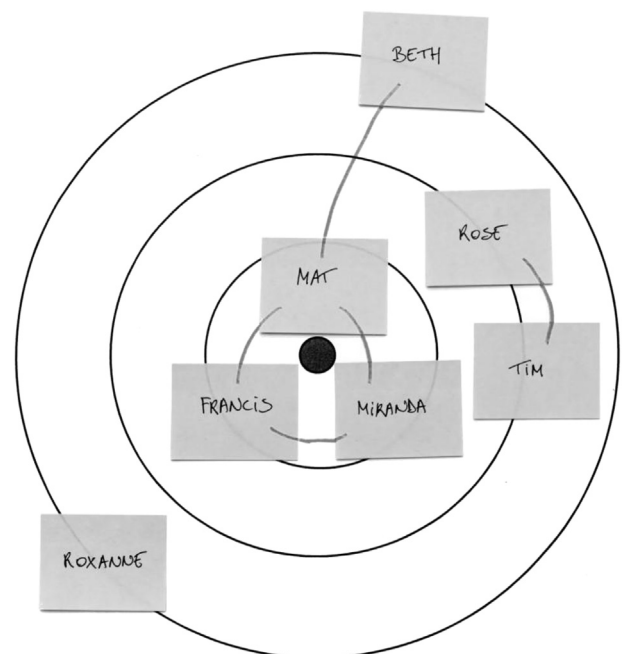
---

[2] Twenty-four chairs of education and educational advisors of the departments across the university nominated 96 people in total; 13 people were nominated twice, so 83 unique instructors were nominated. Fourteen of the nominated instructors did not meet the criteria for inclusion in our sample, as they did not have enough student evaluations or courses evaluated. Of the 69 remaining instructors 49 had outstanding student evaluations (upper quartile in department). We then selected the top performers in each department, maintaining a spread across departments.

[3] Experienced non-experts and experienced experts differed significantly in their scores on student evaluations ($p < .01$).

Fig. 1. Concentric circle map to generate personal network.

but an expert in qualitative research. This independent coding process was performed in two phases. In the first phase, three interviews were randomly sampled from an experienced expert, an experienced non-expert and a novice instructor. Researchers coded the data independently. Inter-rater reliability was calculated, resulting in a Cohen's kappa of 0.78 which is considered substantial agreement. Importantly, most of the disagreements in coding resulted from different interpretations of the codes 'storytelling' and 'immediate value'. After discussing these differences, the coding scheme was fine-tuned, and another set of three interviews (again from an experienced expert and non-expert, and a novice) was coded independently. This resulted in an inter-rater agreement of 0.96 (0.92 for interdependence, and 0.98 for value creation). The remainder of the data was coded by the principal researcher. Challenging or ambiguous data were discussed in peer debriefings until consensus was achieved on the appropriate code to assign.

This step resulted in the final coding schemes for interdependence and value creation (Appendices B and C). For interdependence, four general categories were discerned (Doppenberg, Bakx, et al., 2012; Little, 1990) and retrieved in the data: (1) storytelling and scanning, (2) aid and assistance, (3) sharing and (4) joint work. The four categories were specified into nine subcategories, based on the work of Doppenberg, Bakx, et al. (2012). Minor adjustments were made to the coding scheme. The subcategories 'listening' and 'informing' were grouped together, and the category 'intervision' was replaced by 'observing and reflecting'. The value creation framework consisted of the following categories: (1) immediate value, (2) potential value, (3) applied value, (4) realized value (5) reframing value, and (6) aspirational value.

In a fourth step, the minimum, maximum and average frequencies of (sub)categories in the networks were summarized in matrices (Miles et al., 2014) to provide an overview of how these were spread overall and within the stages of development (Tables 1 and 2). These matrices give an overview of the occurrence of (sub) categories, rather than providing counts of mention (e.g., an instructor providing several examples of 'asking questions' within the same teaching tie, is counted as 'one' occurrence).

To further assess the overall quality of the data collection, analysis and synthesis, a condensed audit procedure was used (Akkerman, Admiraal, Brekelmans, & Oost, 2008). An 'audit trail' was prepared documenting the procedure of data gathering and analysis, including both raw data material (interview scripts), coding schemes, coded interviews and findings. The auditor, an independent researcher and an expert in qualitative research (different from the researcher conducting the inter-rater agreement process), concluded that the research process of data collection, data analysis, and report of results was visible, comprehensible and acceptable.

5. Results

In the section below, an overview is provided of the findings on the quality of instructors' networks. Results are presented regarding the extent to which instructors differ in terms of the interdependence and value created in their interactions, and are linked to the different stages of professional development. In a next step, results are refined by introducing three individual case-level descriptions illustrated with network visualizations, one for each stage of instructional development.

5.1. The interdependence in instructors' personal networks

Table 1 provides an overview of the minimum, maximum and average amount of people with whom instructors engaged in low or high interdependent interactions within their personal

Table 1
Minimum, maximum, and average number of people in the personal network with whom instructors interacted on different levels of interdependence.

Category	Subcategory	Min	Max	M
Storytelling and scanning	Listening and informing	0	8	3.76
	Observing	0	2	0.17
Aid and assistance	Asking questions	0	9	1.69
	Receiving feedback	0	9	1.28
	Organizing	0	7	2.28
Sharing	Exchanging	0	6	1.93
Joint work	Developing	0	6	1.28
	Evaluating	0	4	0.93
	Observing and reflecting	0	5	0.17

networks. For example, on average the instructors listened to stories and informed about experiences with about four people in their network. Overall, instructors engaged with most people in their network in listening to and informing about others' teaching practices as well as talking about organizing courses. Observing others in class during teaching (and reflecting afterwards) was reported the least. Instructors described more low interdependent interactions (storytelling and aid and assistance) than high interdependent interactions (sharing and joint work).

A close inspection of Fig. 2 shows the descriptive measures for the different stages of professional development. On average, experienced experts engaged both in low and high interdependent interactions about teaching. They accessed their networks for storytelling, aid and assistance (which require low dependency in interactions) as well as sharing and joint work (which call for high interdependent interactions). In comparison with the other stages, the experienced experts also showed a tendency for highly interdependent interactions. The experienced non-expert teachers tended to resort to low interdependent interactions, talking to most of the persons in their network about organizing courses and listening to and informing about teaching experiences and stories. Novice instructors also engaged in listening to and informing about the teaching practice of the people in their network. Moreover, they tended to resort to several people in their network to ask for advice and receive feedback, which was reported most within this stage of development. In other words, novice instructors engaged more in aid and assistance in comparison to their more experienced peers.

These measures do not take into account the size of instructors' network: the experienced experts on average had 11.92 people in their teaching network, the experienced non-experts 6.00 people, and the novices 9.87 people. If we take into account the size of the network, we note that on average, experienced experts described that they jointly developed and evaluated material or courses with resp. 17.43% and 12.98% of the persons in their network, compared to 8.02% and 4.06% for the experienced non-experts, and 7.83% and 6.60% for the novices. Meaning, that the experienced expert instructors engaged more in high interdependent interactions.

The interviews also shed light on a meta level finding typical for the experienced expert group. The experienced experts often explicitly expressed how they saw their network as a resource to improve their teaching quality. Moreover, they showed clear insight or awareness of their network and how they used it. Experienced expert Matthew [#16], for example, made a distinction in the types of interactions he had. He described how he had 'strategic' conversations with some people and 'operational' conversations with others, or both:

"In fact I have many strategic talks with him. But nowadays we also have a lot of operational discussions because we started working together for a couple of courses." [Matthew, experienced expert #16]
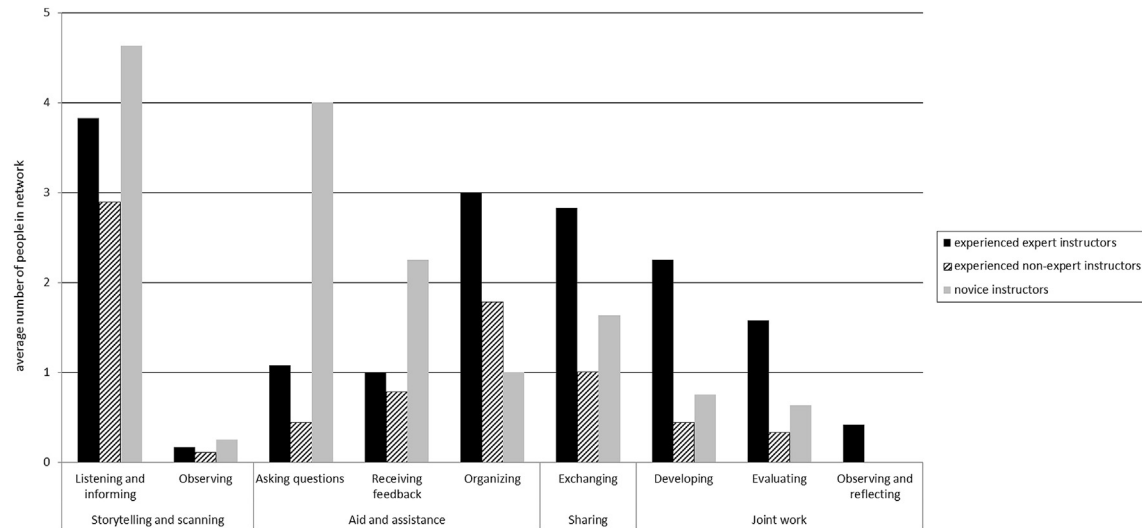
Fig. 2. Average number of people in the personal networks of instructors whom they engage in low or high interdependent interactions, taking into account the stages of development.

Similar statements were described by other experienced expert instructors:

"These people [on the network map] are constantly moving. Especially in my case since I am changing to a new department. You do not want to drop all your contacts, so I try to maintain the base of people that I have built, and then slowly transition new people in here [points towards the map]. These people will move in from the outer circles and some of them gradually towards the inner circle." [Olivia, experienced expert #18]

This awareness of the network was not found in the other stages of development. Moreover, the interviews with the experienced expert instructors also showed that they frequently mentioned conversations about the curriculum in their networks, so that went beyond the course-level. This contrasted with the other stages. Furthermore, the experienced experts used people in their networks for different purposes. For example, within the same tie they shared stories as well as jointly worked on courses. In other words, they used one tie for diverse purposes, which was found less in the other stages. The experienced non-experts, especially, tended to use one tie for one purpose. Their networks often consisted of other experienced instructors. This was in contrast with the experienced experts and the novices, who showed more diversity concerning the people in their networks.

5.2. The value created in instructors' personal networks

Overall, instructors most frequently reported immediate, potential and applied value in their personal networks (Table 2), meaning that their interactions produced value in themselves, leveraged them resources, materials or ideas, or actually caused changes in their teaching practice (e.g., trying out a suggestion, reusing a lesson plan or adopting received material). Realized and reframing value was only reported in 6 ties (out of 287 ties overall the networks). These cycles of value refer to actual reported improvement in performance resulting from suggestions or ideas (e.g., student achievement, accuracy, time saving), and to reframing teaching goals, values or strategies. Aspirational value occurred with almost half of the people in the networks. This type of value

Table 2
Minimum, maximum, and average number of people in the personal network with whom instructors created value.

Category	Min	Max	*M*
Immediate value	0	7	3.41
Potential value	0	11	3.03
Applied value	0	12	2.59
Realized value	0	3	0.21
Reframing value	0	3	0.14
Aspirational value	1	9	4.48

refers to reported aspirations about people that currently do not fulfill a certain role in the network (e.g., joint responsibility for a course in the near future) or new people that are likely to enter the network (e.g., a new teaching assistant). This indicates that, overall, instructors did see new possibilities in terms of value within their current or future network.

Fig. 3 shows the perceived value as described by instructors for each stage of development. On average, experienced experts created immediate, potential and applied value with about four people in their network. Compared to the other stages, they especially reported applied value with more people in their network. Experienced experts also consistently reported value creation with less experienced colleagues.

Taking into the account the size of the networks, we note that experienced experts created applied value with 30.15% of the people in their networks, compared to 19.95% and 21.47% for respectively the experienced non-experts and the novices. The limited realized and reframing value reported, was also found in the experienced expert networks. This shows that experts managed to create all types of value. The experienced non-expert instructors described immediate and potential value with on average two people in their network. Applied, realized and reframing value were only limited or not created within their networks. Novice instructors described immediate and potential value with on average four people in their network (resp. with 49.51% and 37.04% of the people in their network). They reported more interactions resulting in value creation compared to the experienced non-experts. The interviews confirmed that the experienced non-experts perceived their networks as less valuable, compared to the other stages. For example, they did not perceive instructors
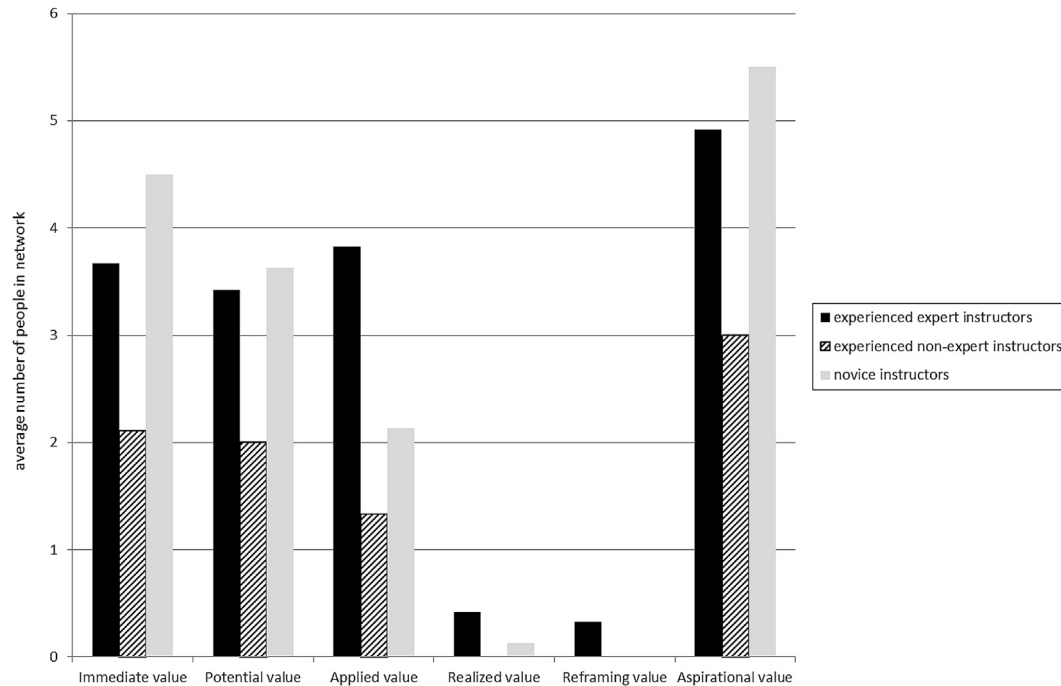
Fig. 3. Average number of people in the personal networks of instructors with whom they engage in value creation, taking into account the stages of development.

who teach a different subject as useful people in their networks:

> "I do not have any colleagues that teach the same language. So one cannot expect that I will discuss my teaching practice with colleagues that do not teach the same language." [Nora, experienced non-expert #11].

Experienced non-experts often saw their teaching practice as something very individual-oriented, rather than describing their networks as valuable. Maintaining or improving teaching quality was described by several experienced non-experts as a matter of time, preparation and personal knowledge:

> "I am responsible for the course so I know well enough if something went or will go wrong. I know well enough how you can teach best and what went wrong if I did not taught well. Mostly it is a lack of time to prepare the class. It is very simple. Everyone can teach a class very well, but you just need to invest time in it." [Julian, experienced non-expert #28]

Finally, in their narratives the novices often directly associated telling stories with immediate value, e.g. described as 'enjoyable', 'interesting', 'relaxing':

> "It mostly happens very informally during lunch with the other teaching assistants. It is not really structured or anything. We share things like 'you know what happened in class'. We complain a bit about the students or just share funny stories. It is more as a soundboard, or just for fun than anything else." [Tom, novice #19]

The majority of the novice participants frequently reported immediate value, often when describing venting with other novices such as sharing war stories about students or exchanging entertaining stories about things that happened during class. These stories were often shared in transitions (e.g., to/from meetings) or in shared spaces (e.g., at the coffeemaker in the kitchen, at the

copier).

5.3. Illustration of differences in network quality with cases for each stage of development

To gain in-depth insight into the quality of instructors' networks, a narrative account of three cases is provided. We elaborate on the networks of one experienced expert, one experienced non-expert and one novice instructor to show how these instructors built and used their personal networks. These three networks were selected based on the descriptive findings as presented in the previous section. For each stage of development the most representative case was selected based on the bar charts in Figs. 2 and 3, meaning those that best matched the average number of people with whom interdependent or value creation interactions were described for each stage. Each case is illustrated with a network map (using Gephi 0.8.2). The nodes in the network maps stand for the people, and the lines represent the ties or relationships between the instructor and the people in his or her personal teaching network. The length and thickness of the lines in the network maps display the interdependence, where thick and short lines stand for ties in which highly interdependent interactions were reported (i.e., sharing, joint work), whereas thin and long lines indicate ties with low interdependence (i.e., storytelling, aid and assistance). The size of the nodes represents the created value, where small nodes represent immediate and potential value, whereas large nodes stand for applied, realized or reframing value.

5.3.1. Experienced expert instructor

Olivia [#18] is an experienced expert of 37 years old with 11 years of teaching experience. She discusses her teaching practice with 12 people in her personal network. As Fig. 4 illustrates, Olivia described several highly interdependent interactions within her teaching network. For example, with Judy [#18.1], one of her teaching assistants who is responsible for the exercise sessions of one of the courses, she discusses the full range: they prepare and select exercises together [joint work: developing], she often walks
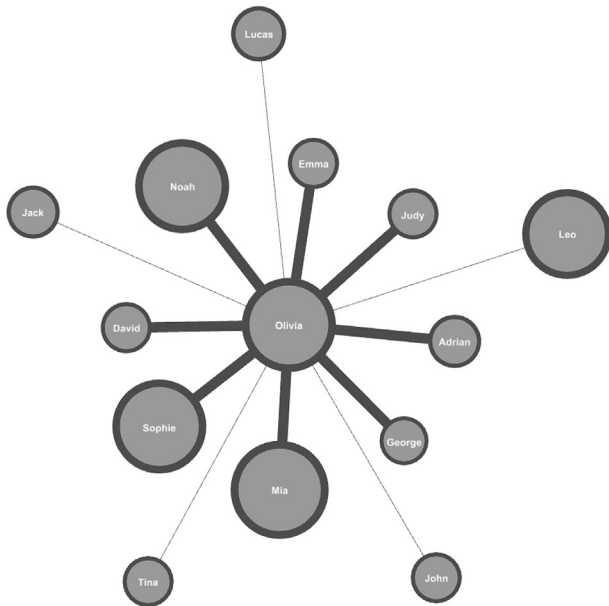
Fig. 4. Personal network map of experienced expert instructor [Olivia, #18].

in during classes to observe how the sessions are going, in between they discuss experiences at length about how students are reacting and how the course is going [informing and storytelling + sharing], and afterwards they sit together on fixed moments to discuss what they want to keep or change towards next year [joint work: evaluating]. Olivia clearly described some seniority and coaching in the relationships with her teaching assistants [also #18.3 and #18.6], but in contrast to most experienced non-experts, she also frequently reported joint work with less experienced colleagues. Olivia's network also shows that she has different types of conversations around her teaching practice with several people in her network. For example, with George [#18.2], one of her colleagues, she both shares experiences and stories about students, as well as develops and evaluates a course with. In other words, she uses one tie for diverse purposes. Olivia also consistently reported value creation in her network with less experienced colleagues. She perceived several of the people in her network as creating value for her teaching practice. Value creation often occurs in cycles. We summarize a cycle of value creation as reported by Olivia: she had been playing around with the idea to integrate the lab work of two courses into one with Noah [#18.5] and Emma [#18.6]. It concerned two courses with a substantial overlap in content, so they thought it would be a good idea [immediate value] to treat the same subject both bottom-up and top-down, integrated into one course. All three of them had some concrete ideas around this new approach which were discussed in detail [potential value]. Recently they decided to try out some small experiments with the students to see what their ideas were worth [applied value], and this actually resulted in positive student feedback: "The students immediately took to this new approach. They felt it was aligned better, and indicated that they preferred this approach." [realized value]. Because of the students' reactions, the instructors were encouraged to further explore this new way of working. This example illustrates how the cycles of value creation can form a dynamic process.

5.3.2. Experienced non-expert instructor

Simon [#22] is an experienced non-expert who is 52 years old and has 26 years of teaching experience. As Fig. 5 shows, he has 5 people in his personal network with whom he discusses his

teaching practice. Simon mostly reported interactions that required low interdependence, such as organizing, listening and informing. For example, he shares responsibility for a course with experienced colleague Logan [22.4]. They always teach their parts in the course separately, each draws up their exam questions, and they paste them together into one exam [aid and assistance: organizing]. Moreover, Simon tends to use each contact in his network for one purpose: he only shares teaching experiences and stories about students with experienced instructors Joshua and Natalie [#22.1 and #22.2], and only organizes his courses with Logan and Aiden [#22.4 and #22.5], also experienced instructors. Simon mostly discusses his teaching practice with other experienced instructors, and especially with people teaching the same subject matter. He only described value creation, and specifically potential value, with Joshua, Natalie, and Logan [#22.1, #22.2 and #22.4].

5.3.3. Novice instructor

Ethan [#27] is a novice instructor who is 27 years old and has 3 years of teaching experience. As Fig. 6 shows, he has 10 alters in his personal network with whom he discusses his teaching practice. In line with other novices, Ethan reported that he regularly asked advice or received feedback from the people in his network:

"There was a student that had been extremely bold during class. Afterwards, I went to Jason [#27.1, senior instructor] and we talked about what happened and I told him how I reacted. I asked him how he would have reacted which really helped me and made me feel understood. This was an extreme case but I can always call on him, no matter if it is about something in the course, something personal or something that happened."

These conversations where novices ask advice or receive feedback, often resulted in potential value. Ethan frequently described how he received tips or advice from the people in his network, for example: "Miles [#27.3] gives me tips on how to deal with difficult students.", or "I get feedback on my preparation work from Jason [#27.1]." Finally, it was typical of Ethan's overall network that he gave many examples detailing the immediate value resulting from
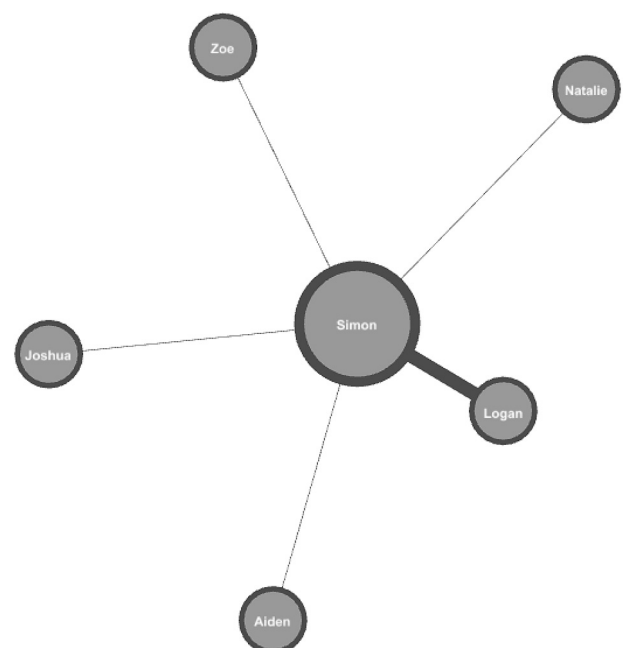

Fig. 5. Personal network map of experienced non-expert instructor [Simon, #22].
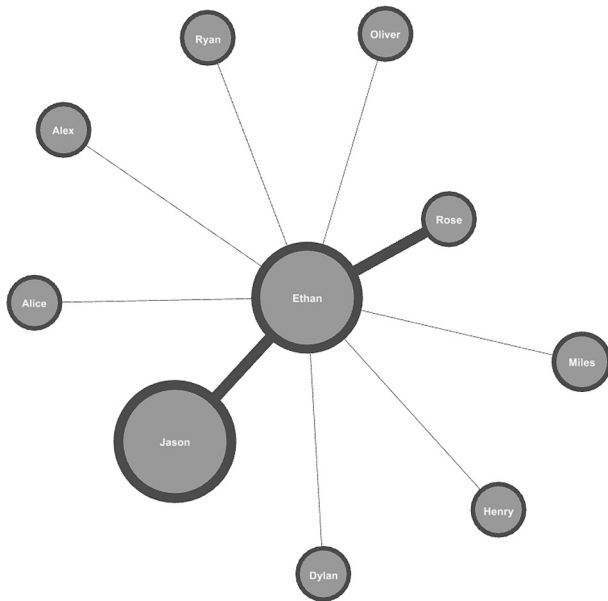
Fig. 6. Personal network map of novice instructor [Ethan, #27].

interactions with other novices during lunch, at the copier or in the hallway: "During lunch we often share experiences with the other assistants about what happened in class. Everyone joins in, of course. We talk about experiences we had with students, or we tell funny stories."

6. Discussion & conclusion

The central aim of this article was to focus on examining the quality of instructional interaction in different stages of professional development. Two frameworks from different strands of research were used to examine the quality of instructors' interactions, i.e. the interdependence framework by Little (1990) and the value creation framework by Wenger et al. (2011). These offered insight into the extent to which instructors are dependent on each other when interacting around their teaching practice, and into the value instructors perceive as resulting from these interactions. By using a personal network approach, instructors' actual interactions were mapped. This provided in-depth insight into the constellation of interactions that instructors engaged in. Personal networks of teachers and instructors in primary, secondary and higher education have been shown to play an important role in their professional development (Coburn et al., 2012; Fox & Wilson, 2015; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). While studies have demonstrated that the structure of networks matters (Daly & Finnigan, 2010; Moolenaar, 2012; Penuel et al., 2009), it is less clear what is behind these structures. This study demonstrated that teaching networks can vary greatly in quality, from swapping stories to substantive conversations or joint work, and from immediate to reframing value. We discuss several major themes as suggested by our study.

6.1. Instructors engaged more in low interdependent than high interdependent interactions within their personal teaching network

Overall, instructors reported more low interdependent than high interdependent interactions. With the people in their teaching networks, they most often exchanged experiences and stories about students and courses (storytelling), and made practical

arrangements for courses (organizing). These interactions entail low relational interdependence and do not require extensive joint engagement. This finding is in line with Little (1990), and other studies adopting the Little framework (Doppenberg, Bakx, et al., 2012; Kwakman, 2003). Furthermore, this study confirms related work by Coburn and Russell (2008; 2012) who found more low depth interactions in teaching networks (e.g., coordination and organization talk, exchange of experiences). Instructors only engaged in interactions that required high interdependence (e.g., joint work) with a fraction of the people in their networks. Doppenberg, den Brok, and Bakx (2012) suggested that high interdependent interactions often emerge from more structural activities or in more formal settings. However, this study demonstrated that structural incentives for joint work (e.g., shared responsibility for a course) did not necessarily result in actual high interdependence for instructors in all stages of professional development (see below).

6.2. Instructors engaged most in interactions that produced immediate, potential and aspirational value within their personal teaching network

This study also focused on how instructors experienced the value of their teaching networks. If they do not perceive the benefits of interactions or find it difficult to grasp outcomes, they are less likely to invest in and spend time on their teaching network. The value creation framework (Wenger et al., 2011) was used to examine different cycles of value, including immediate and potential value which are often not taken into account in research on teacher interaction. Immediate and potential value respectively stand for interactions that produce value in and of themselves (e.g., interactions that are experienced as useful or enjoyable), and for interactions whose value lies in the potential to be realized later (e.g., interactions producing ideas, material or advice). These types of value were reported most frequently in this study. They do not refer to interactions that (necessarily) caused actual changes in instructional practice. The cycle of applied value does refer to interactions that resulted in tangible outcomes (e.g., tried out a suggestion, reused a lesson plan or adopted received material), and was encountered on average with two to three people in the network. Realized and reframing value occurred less in the teaching networks. They imply improvement in performance resulting from interactions (e.g., improved efficiency or student achievement), and the redefinition or reframing of goals, values or strategies (e.g., coming to new understandings of teaching matters). Finally, aspirational value was described most frequently, entailing interactions in terms of the value they are expected to produce. This implies that instructors see possible value for their instructional practice in people that will enter their personal network, or in people that are already part of their network but will fulfill new roles.

6.3. The quality of instructors' personal networks in varying stages of professional development differed

This study also showed that instructors with varying levels of teaching experience and expertise differed in interdependence and value creation when interacting in their teaching network. Specifically, experienced experts displayed higher levels of interdependence compared to experienced non-expert instructors, who tended to resort to low interdependent exchanges, such as storytelling or scanning for ideas. Moreover, the experienced expert instructors used their network ties for multiple types of interactions. For example, they not only shared stories with people in their network but also developed courses together. This is in line with previous work suggesting that high performers have diverse

personal networks in terms of structure, that target and extend their abilities, and leverage innovative ideas (Cross & Thomas, 2008; Mehra, Kilduff, & Brass, 2001; Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). This study adds to these findings by demonstrating that experienced experts also show diversity in the quality of their networks, specifically in the diversity in interdependence of their interactions. This finding contrasted with the experienced non-experts, who tended to use each person in the network for one type of interaction and mostly resorted to low interdependence interactions such as organizing their teaching practice. Little network diversity may cause decay of networks or limit innovation (Burt, 2000). A lack of network diversity might thus cause experienced non-experts to stagnate in their development toward expertise. The described differences in network quality between experienced experts and non-experts indicate that network development is not just a time-age effect. Experienced experts possibly lapse into arrested development which may cause isolation (Bakkenes et al., 1999; Ericsson, 2006), resorting to interactions that require low interdependence, such as organizing and informing. Further insight into the formation of expert networks is timely. Particularly, we need to look into how experts manage to create both low and high interdependent relationships with alters in their network, not only resorting to uniplex relationships like the experienced non-expert group. Finally, novices shared experiences and stories, vented and soundboarded with about half of the people in their network. They sought out people in their network for support, i.e. aid and assistance such as feedback and advice. This is to be expected, given the developmental phase they are in (Fox & Wilson, 2015; Fox et al., 2011).

7. Delimiters and further research

This study into the quality of instructional networks opens up new avenues for research, pointing to the need to further examine the quality of teacher interaction in relation to professional development. To our knowledge, this study is one of the first to link network quality to stages of professional development for instructors in higher education. It is, however, important to be cautious with causal claims of performance as the study design was not set up to do so. Future studies designed to examine directional links will be important. Some questions guiding this future work include: Do experienced experts show a tendency for highly interdependent interactions (such as sharing and joint) and high value interactions (such as applied and realized value) because they are sought more for their expertise? Or, do these types of network interactions support them in becoming experts?

An area ripe for further exploration is to track the quality of teaching networks over time. This study gathered cross-sectional data to examine different developmental stages, an approach which is in line with research on expertise development in workplace learning. Networks are dynamic (Snijders, 2005), so longitudinal network data may allow to gain further insight into how the quality of personal networks evolves over time (Feld, Suitor, & Gartner Hoegh, 2007); providing further points of leverage for novice and experienced non-expert teachers.

Moreover, quality as reported in this study, was based on subjective elements of evaluation by the interviewees. Instructors described the extent to which they experienced their interactions as producing value for their instructional practice. Another area ripe for exploration in network research is to triangulate self-reported network data with other data sources, such as tracking interactions through logs, e-mails or documents (Fox & Wilson, 2015), observing (Coburn et al., 2012) or tracking interactions with sociometric badges (Kim, McFee, Olguin, Waber, & Pentland, 2012), or interviewing/surveying the alters in the network as a

member check (i.e., snowball method). The latter suggestion would also allow investigation of clusters and structure within the networks.

The frameworks of interdependence and value creation were used to examine interaction quality. They provided insight into the extent to which instructors were dependent on each other when interacting, and into the perceived value associated with their teaching ties. Regarding the value creation framework, realized and reframing value were encountered less in the interviews. Deducing these types of value directly from interactions may also be a rather complex process, and may have influenced these results. Other frameworks should be explored to further grasp the quality of teacher interaction. The results of this work raise questions about the relation between the interdependence and value of interactions. What kind of interdependency do we need to obtain interactions that produce value? For example, does joint work inextricably lead to applied or realized value? Or may we underestimate the power of storytelling, listening and informing? This venue was not explored in this study since interdependence and value creation should be linked on interaction level (this study collected data on tie level), and requires a more quantitative multilevel analysis approach.

This study used an innovative approach combining in-depth interviews and social network methods to examine the quality of teacher interaction in detail. Previous network research into teachers' professional development mostly focused on the patterns and structure of networks, demonstrating that teacher networks in different stages of development differed in structure (e.g., Van Waes, Van den Bossche, Moolenaar, De Maeyer, et al., 2015). Our findings, however, suggested that making inferences about social networks from the structure of networks alone may be limited. Therefore, we recommend combining quantitative and qualitative network approaches to further examine differences in structural and qualitative attributes in different stages of development (e.g., do experts and non-experts show different structural network patterns, and to what extent does this link to the quality of their networks?). Follow-up mixed method research (Domínguez & Hollstein, 2014; Fuhse & Mützel, 2011) is timely to capture instructional networks in their totality and may yield additional insights into the social side of teachers' professional development.

A personal network approach was used to map the networks of individual instructors from the ground up, instead of assuming in advance the locus of community in pre-existing boundaries. Moreover, this approach allowed an in-depth investigation of each tie, rather than obtaining an overall description of an instructor's interactions. A limitation of the personal network approach is that one loses the overall 'systems' perspective that is gained by taking a socio-centric approach to network analysis. However, not attending to the individual in favor of just the whole network results in an incomplete picture as well (Kilduff & Krackhardt, 1994). We were not able to map the network structure for entire departments or the university, nor can we ascertain the degree to which the personal networks of the focal instructors are representative of other instructors in the university. Yet this study attempted to interact both the individual and the social relationships surrounding the individual by using a personal network approach. Future work should attempt to complement the personal and socio-centric perspective.

8. Implications for practice

This study makes a significant contribution to the growing knowledge base around teacher interaction by offering important insights into features relevant to professional development in the teaching profession. As policy makers across the world are interested in building qualitative teacher capacity to support increased

student achievement, this article may provide valuable suggestions on how teachers and policy makers in education institutions can stimulate teacher interaction and reduce isolation.

Storytelling was most prominent within the teaching networks. Many studies have demonstrated the power of storytelling in organizations (Brown, Denning, Groh, & Prusak, 2005; Shank, 2006; Sole & Wilson, 1999). This raises questions about the possible power of stories in education and how to stimulate the deft circulation of 'good teaching' narratives and practices. In this study, the importance of shared spaces such as the copier, the coffee machine or the lunch room was often emphasized. Research also documented the merits of informal early morning 'coffee clutches' as informal routine for exchange, or teach meets, lunch and breakfast meetings to expose good practices and narratives (Spillane, 2005). Besides informal meeting points, more structural or formal solutions can also be put in place. Uzzi and Dunlap (2005) wrote about the 'shared activity principle', claiming that potent networks are not forged through casual interactions but through relatively high-stakes activities that connect people with diverse others; bringing together disparate individuals around a shared activity instead of connecting similar people. Education institutions may invest in creating shared spaces and opportunities for teachers to enhance formal and informal sharing of and reflecting on narratives of instructional practice.

Most of the high value interactions were reported by the experienced experts. This seems to imply that experts manage to interact in such a way that they can create realized and reframing value. This may either mean that they are able to create these types of interactions, and/or that they are more aware of the value associated with their personal network. When teachers are more aware of their personal network and its benefits, they can actively shape it (Burt & Ronchi, 2007; Uzzi & Dunlap, 2005). A possible policy implication might be to make teachers in different developmental stages more aware of their professional networks, and of how these can help to foster their teaching expertise. This may also encourage the experienced non-expert teachers to build networks that are of value in their professional competence. The network maps used in this study can provide the tools to enhance insight or intentionality in teachers' networks. Network awareness raising elements can be induced in professional development activities, as several scholars suggested that enhanced networks should be regarded as an important outcome of training programs (Hatala & Fleming, 2007; Van den Bossche & Segers, 2013; Van Waes, Van den Bossche, Moolenaar, Stes, et al., 2015). Yet the balance between fostering network awareness and imposing network building is a delicate and critical one (Brown & Duguid, 1991; Datnow, 2011).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.tate.2016.05.022.

References

Adler, P. S., & Kwon, S.-W. (2002). Social capital: Prospects for a new concept. *Academy of Management Review, 27*(1), 17–40.

Akkerman, S., Admiraal, W., Brekelmans, M., & Oost, H. (2008). Auditing quality of research in social sciences. *Quality & Quantity, 42*(2), 257–274.

Arthur, L. (2016). Communities of practice in higher education: Professional learning in an academic career. *International Journal for Academic Development*.

Avalos, B. (2011). Teacher professional development in Teaching and Teacher Education over ten years. *Teaching and Teacher Education, 27*(1), 10–20.

Baker-Doyle, K. J. (2015). Stories in networks and networks in stories: A tri-modal model for mixed-methods social network research on teachers. *International Journal of Research & Method in Education, 38*(1), 72–82.

Bakkenes, I., De Brabander, C., & Imants, J. (1999). Teacher isolation and communication network analysis in primary schools. *Educational Administration Quarterly, 35*(2), 166–202.

Bakkenes, I., Vermunt, J. D., & Wubbels, T. (2010). Teacher learning in the context of educational innovation: Learning activities and learning outcomes of experienced teachers. *Learning and Instruction, 20*(6), 533–548.

Bellotti, E. (2014). *Qualitative networks: Mixed methods in sociological research*. London: Routledge.

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago: Open Court.

Berliner, D. C. (2004). Describing the behavior and documenting the accomplishments of expert teachers. *Bulletin of Science, Technology & Society, 24*(3), 200–212.

Bertram, R., Paquette, K., Duarte, T., & Culver, D. (2014). Assessing the value created through participating in a graduate studies community of practice. *Transformative Dialogues: Teaching & Learning Journal, 7*(1), 1–14.

Borgatti, S. P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science, 49*(4), 432–445.

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Network analysis in the social sciences. *Science, 232*, 892–895.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3–15.

Boshuizen, H. P. A., Bromme, R., & Gruber, H. (2004). *Professional learning: Gaps and transitions on the way from novice to expert*. Dordrecht: Kluwer Academic Publishers.

Boud, D., & Middleton, H. (2003). Learning from others at work: Communities of practice and informal learning. *Journal of Workplace Learning, 15*(5), 194–202.

Bridwell-Mitchell, E. N., & Cooc, N. (2016). The ties that bind: How social capital is forged and forfeited in teacher communities. *Educational Researcher, 45*(1), 7–17.

Brody, D. L., & Hadar, L. L. (2015). Personal professional trajectories of novice and experienced teacher educators in a professional development community. *Teacher Development, 19*(2), 1–21.

Brown, J. S., Denning, S., Groh, K., & Prusak, L. (2005). *Storytelling in organizations: Why storytelling is transforming 21st century organizations and management*. Burlington: Elsevier.

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization Science, 2*(1), 40–57.

Burt, R. S. (1992). *Structural holes: The social structure of competition*. Cambridge, MA: Harvard University Press.

Burt, R. S. (2000). Decay functions. *Social Networks, 22*(1), 1–28.

Burt, R. S., & Ronchi, D. (2007). Teaching executives to see social capital: Results from a field experiment. *Social Science Research, 36*(3), 1156–1183.

Carolan, B. V. (2014). *Social network analysis and educational research: Theory, methods, and applications*. Thousand Oaks, CA: SAGE Publications.

Carrington, P. J., Scott, J., & Wasserman, S. (2005). *Models and methods in social network analysis*. New York: Cambridge University Press.

Chua, V., Madej, J., & Wellman, B. (2011). Personal communities: The world according to me. In J. Scott, & P. J. Carrington (Eds.), *The SAGE handbook of social network analysis* (pp. 101–115). London: Sage Publications Ltd.

Coburn, C., & Russell, J. L. (2008). District policy and teachers' social networks. *Education Evaluation and Policy Analysis, 30*(3), 203–235.

Coburn, C., Russell, J. L., Kaufman, J. H., & Stein, M. K. (2012). Supporting sustainability: Teachers' advice networks and ambitious instructional reform. *American Journal of Education, 119*(1), 137–182.

Cochran-Smith, M., & Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. *Review of Research in Education, 24*(1), 249–305.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*, 37–46.

Cornelissen, F., van Swet, J., Beijaard, D., & Bergen, T. (2011). Aspects of school-university research networks that play a role in developing, sharing and using knowledge based on teacher research. *Teaching and Teacher Education, 27*(1), 147–156.

Cotton, R. D., Shen, Y., & Livne-Tarandach, R. (2011). On becoming extraordinary: The content and structure of the developmental networks of major league baseball hall of famers. *Academy of Management Journal, 54*(1), 15–46.

Cowan, J. E., & Menchaca, M. P. (2014). Investigating value creation in a community of practice with social network analysis in a hybrid online graduate education program. *Distance Education, 35*(1), 43–74.

Cox, M. D. (2004). Introduction to faculty learning communities. *New Directions for Teaching and Learning, 97*, 5–23.

Crossley, N., Bellotti, E., Edwards, G., Everett, M. G., Koskinen, J., & Tranmer, M. (2015). *Social network analysis for ego-nets*. London: SAGE Publications Ltd.

Cross, R., & Thomas, R. J. (2008). How top talent uses networks and where rising stars get trapped. *Organizational Dynamics, 37*(2), 165–180.

Daly, A. J., & Finnigan, K. S. (2010). A bridge between worlds: Understanding network structure to understand change strategy. *Journal of Educational Change, 11*, 111–138.

Datnow, A. (2011). Collaboration and contrived collegiality: Revisiting Hargreaves in the age of accountability. *Journal of Educational Change, 12*(2), 147–158.

De Rijdt, C., Stes, A., van der Vleuten, C., & Dochy, F. (2013). Influencing variables and moderators of transfer of learning to the workplace within the area of staff development in higher education: Research review. *Educational Research Review, 8*(0), 48–74.

Dobrow, S. R., Chandler, D. E., Murphy, W. M., & Kram, K. E. (2012). A review of developmental networks. *Journal of Management, 38*(1), 210–242.

Domínguez, S., & Hollstein, B. (2014). *Mixed methods social networks research: Design and applications*. Cambridge: Cambridge University Press.

Doppenberg, J. J., Bakx, A. W. E. A., & den Brok, P. J. (2012). Collaborative teacher learning in different primary school settings. *Teachers and Teaching: theory and practice, 18*(5), 547—566.

Doppenberg, J. J., den Brok, P. J., & Bakx, A. W. E. A. (2012). Collaborative teacher learning across foci of collaboration: Perceived activities and outcomes. *Teaching and Teacher Education, 28*(6), 899—910.

Doppenberg, J. J., den Brok, P. J., & Bakx, A. W. E. A. (2013). Relationships between primary school teachers' perceived learning outcomes of collaboration, foci and learning activities. *Learning and Individual Differences, 28*, 1—8.

Eraut, M. (2007). Learning from other people in the workplace. *Oxford Review of Education, 33*(4), 403—422.

Ericsson, K. A. (2006). The influence of experience and deliberate practice on the development of superior expert performance. In K. A. Ericsson, N. Charness, R. R. Hoffman, & P. J. Feltovich (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 685—706). New York: Cambridge University Press.

Feld, S. L., Suitor, J. J., & Gartner Hoegh, J. (2007). Describing changes in personal networks over time. *Field Methods, 19*(2), 218—236.

Fox, A., Deaney, R., & Wilson, E. (2010). Examining beginning teachers' perceptions of workplace support. *Journal of Workplace Learning, 22*(4), 212—227.

Fox, A., & Wilson, E. (2015). Networking and the development of professionals: Beginning teachers building social capital. *Teaching and Teacher Education, 47*, 93—107.

Fox, A., Wilson, E., & Deaney, R. (2011). Beginning teachers' workplace experiences: Perceptions of and use of support. *Vocations and Learning, 4*(1), 1—24.

Fuhse, J., & Mützel, S. (2011). Tackling connections, structure, and meaning in networks: Quantitative and qualitative methods in sociological network research. *Quality & Quantity, 45*(5), 1067—1089.

Goddard, Y. L., Goddard, R. D., & Tschannen-Moran, M. (2007). A theoretical and empirical investigation of teacher collaboration for school improvement and student achievement in public elementary schools. *Teachers College Record, 109*(4), 877—896.

Grosemans, I., Boon, A., Verclairen, C., Dochy, F., & Kyndt, E. (2015). Informal learning of primary school teachers: Considering the role of teaching experience and school culture. *Teaching and Teacher Education, 47*, 151—161.

Gruber, H., Lehtinen, E., Palonen, T., & Degner, S. (2008). Persons in the shadow: Assessing the social context of high abilities. *Psychology Science Quarterly, 50*(2), 237—258.

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.

Hakkarainen, K., Palonen, T., Paavola, S., & Lehtinen, E. (2004). *Communities of networked expertise: Professional and educational perspectives*. Amsterdam: Elsevier.

Hallinger, P. (1998). Educational change in Southeast Asia: The challenge of creating learning systems. *Journal of Educational Administration, 36*(5), 492—509.

Hatala, J.-P., & Fleming, P. R. (2007). Making transfer climate visible: Utilizing social network analysis to facilitate transfer of training. *Human Resource Development Review, 6*(1), 33—63.

Hodkinson, P., Biesta, G., & James, D. (2008). Understanding learning culturally: Overcoming the dualism between social and individual views of learning. *Vocations and Learning, 1*(1), 27—47.

Hodkinson, H., & Hodkinson, P. (2004). Rethinking the concept of community of practice in relation to schoolteachers' workplace learning. *International Journal of Training and Development, 8*(1), 21—31.

Hoekstra, A., Beijaard, D., Brekelmans, M., & Korthagen, F. (2007). Experienced teachers' informal learning from classroom teaching. *Teachers and Teaching, 13*(2), 191—208.

Hoekstra, A., Korthagen, F., Brekelmans, M., Beijaard, D., & Imants, J. (2009). Experienced teachers' informal workplace learning and perceptions of workplace conditions. *Journal of Workplace Learning, 21*(4), 276—298.

Hofman, R. H., & Dijkstra, B. J. (2010). Effective teacher professionalization in networks? *Teaching and Teacher Education, 26*(4), 1031—1040.

Hogan, B., Carrasco, J. A., & Wellman, B. (2007). Visualizing personal networks: Working with participant-aided sociograms. *Field Methods, 19*(2), 116—144.

Hollstein, B. (2011). Qualitative approaches. In J. Scott, & P. J. Carrington (Eds.), *The SAGE handbook of social network analysis* (pp. 404—416). London: Sage Publications Ltd.

Kantanen, H., Manninen, J., & Kontkanen, J. (2014). Emergent dialogue as a prerequisite of learning and innovation in professional virtual communities. *International Journal of Web Based Communities, 10*(2), 211—231.

Kelchtermans, G. (2006). Teacher collaboration and collegiality as workplace conditions: A review. *Zeitschrift für Pädagogik, 52*(2), 220—237. doi: urn:nbn:de:0111-opus-44540.

Kilduff, M., & Krackhardt, D. (1994). Bringing the individual back in: A structural analysis of the internal market for reputation in organizations. *The Academy of Management Journal, 37*(1), 87—108.

Kim, T., McFee, E., Olguin, D. O., Waber, B., & Pentland, A. S. (2012). Sociometric badges: Using sensor technology to capture new forms of collaboration. *Journal of Organizational Behavior, 33*(3), 412—427.

Kwakman, K. (2003). Factors affecting teachers' participation in professional learning activities. *Teaching and Teacher Education, 19*(2), 149—170.

Lima, J.Á. (2003). Trained for isolation: The impact of departmental cultures on student teachers' views and practices of collaboration. *Journal of Education for Teaching, 29*(3), 197—218.

Lima, J.Á. (2010). Thinking more deeply about networks in education. *Journal of Educational Change, 11*, 1—21.

Little, J. W. (1990). The persistence of privacy. *Autonomy and initiative in teachers' professional relations Teachers College Record, 9*(4), 509—536.

Lomos, C., Hofman, R. H., & Bosker, R. J. (2011). Professional communities and student achievement: A meta-analysis. *School Effectiveness and School Improvement: An International Journal of Research, Policy and Practice, 22*(2), 121—148.

Louis, K. S., & Marks, H. M. (1998). Does professional community affect the classroom? Teachers' work and student experiences in restructuring schools. *American Journal of Education, 106*(4), 532—575.

McLaughlin, M. W., & Talbert, J. E. (2006). *Building school-based teacher learning communities: Professional strategies to improve student achievement*. New York: Teachers College Press.

Mehra, A., Kilduff, M., & Brass, D. J. (2001). The social networks of high and low self-monitors: Implications for workplace performance. *Administrative Science Quarterly, 46*(1), 121—146.

Meirink, J. A., Imants, J., Meijer, P. C., & Verloop, N. (2010). Teacher learning and collaboration in innovative teams. *Cambridge Journal of Education, 40*(2), 161—181.

Miles, M. B., Huberman, M., & Saldaña, J. (2014). *Qualitative data analysis: A methods source book* (3rd ed.). Thousand Oaks, CA: SAGE Publications.

Moolenaar, N. M. (2012). A social network perspective on teacher collaboration in schools: Theory, methodology, and applications. *American Journal of Education, 119*(1), 7—39.

Moolenaar, N. M., Daly, A. J., & Sleegers, P. J. C. (2010). Occupying the principal position: Examining relationships between transformational leadership, social network position, and schools' innovative climate. *Educational Administration Quarterly, 46*(5), 623—670.

Moolenaar, N. M., Sleegers, P. J. C., & Daly, A. J. (2012). Teaming up: Linking collaboration networks, collective efficacy, and student achievement. *Teaching and Teacher Education, 28*(2), 251—262.

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.

Penuel, W., Sun, M., Frank, K. A., & Gallagher, H. A. (2012). Using social network analysis to study how collegial interactions can augment teacher learning from external professional development. *American Journal of Education, 119*(1), 103—136.

Pitts, V. M., & Spillane, J. P. (2009). Using social network methods to study school leadership. *International Journal of Research & Method in Education, 32*(2), 185—207.

Reagans, R., & McEvily, B. (2003). Network structure and knowledge transfer: The effects of cohesion and range. *Administrative Science Quarterly, 48*(2), 240—267.

Rienties, B., & Kinchin, I. M. (2014). Understanding (in)formal learning in an academic development programme: A social network perspective. *Teaching and Teacher Education, 39*, 123—135.

Ronfeldt, M., Farmer, S. O., McQueen, K., & Grissom, J. A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal, 52*(3), 475—514.

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.

Shank, M. J. (2006). Teacher storytelling: A means for creating and learning within a collaborative space. *Teaching and Teacher Education, 22*(6), 711—721.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1—22.

Slavit, D., Kennedy, A., Lean, Z., Nelson, T. H., & Deuel, A. (2011). Support for professional collaboration in middle school mathematics: A complex web. *Teacher Education Quarterly, 38*(3), 113—131.

Snijders, T. A. B. (2005). Models for longitudinal network data. In P. J. Carrington, J. Scott, & S. Wasserman (Eds.), *Models and methods in social network analysis* (pp. 215—247). New York: Cambridge University Press.

Sole, D., & Wilson, D. G. (1999). Storytelling in organizations: The power and traps of using stories to share knowledge in organizations. *Training and Development, 53*(3), 1—12.

Spillane, J. P. (2005). Primary school leadership practice: How the subject matters. *School Leadership & Management, 25*(4), 383—397.

Spooren, P., Mortelmans, D., & Denekens, J. (2007). Student evaluation of teaching quality in higher education: Development of an instrument based on 10 Likert-scales. *Assessment & Evaluation in Higher Education, 32*(6), 667—679.

Strauss, A., & Corbin, J. (1994). Grounded theory methodology: An overview. In N. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 273—285). Thousand Oaks, CA: Sage.

Thurlings, M., Evers, A. T., & Vermeulen, M. (2015). Toward a model of explaining teachers' innovative behavior: A literature review. *Review of Educational Research, 85*(3), 430—471.

Tsui, A. B. M. (2009). Distinctive qualities of expert teachers. *Teachers and Teaching, 15*(4), 421—439.

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review, 3*, 130—154.

Uzzi, B., & Dunlap, S. (2005). How to build your network. *Harvard Business Review, 83*(12), 53—60.

Valente, T. W. (1996). Social network thresholds in the diffusion of innovations. *Social Networks, 18*(1), 69—89.

Van den Bossche, P., & Segers, M. (2013). Transfer of training: Adding insight through social network analysis. *Educational Research Review, 8*, 37–47.

Vangrieken, K., Dochy, F., Raes, E., & Kyndt, E. (2015). Teacher collaboration: A systematic review. *Educational Research Review, 15*(0), 17–40.

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.

Van Waes, S., Van den Bossche, P., Moolenaar, N. M., Stes, A., & Van Petegem, P. (2015). Uncovering changes in university teachers' professional networks during instructional development. *Studies in Educational Evaluation, 46*, 11–28.

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education, 24*, 80–91.

Wellman, B. (1993). An egocentric network tale: Comment on Bien et al. (1991). *Social Networks, 15*(4), 423–436.

Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge: Cambridge University Press.

Wenger, E., McDermott, R., & Snyder, W. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Cambridge, USA: Harvard Business School Press.

Wenger, E., Trayner, B., & de Laat, M. (2011). *Promoting and assessing value creation in communities and networks: A conceptual framework*. Heerlen: Open University.

Westheimer, J. (2008). Learning among colleagues: teacher community and the shared enterprise of education. In M. Cochran-Smith, S. Feiman-Nemser, D. J. McIntyre, & K. E. Demers (Eds.), *Handbook of research on teacher education: Enduring questions in changing contexts* (3rd ed., pp. 756–783). New York: Routledge.

Yin, R. (1994). *Case study research: Design and methods* (2nd ed.). Beverly Hills, CA: Sage.

Zwart, R. C., Wubbels, T., Bergen, T. C. M., & Bolhuis, S. (2007). Experienced teacher learning within the context of reciprocal peer coaching. *Teachers and Teaching, 13*(2), 165–187.

Zwart, R. C., Wubbels, T., Bolhuis, S., & Bergen, T. C. M. (2008). Teacher learning through reciprocal peer coaching: An analysis of activity sequences. *Teaching and Teacher Education, 24*(4), 982–1002.