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# Perceived network bridging influences the career commitment decisions of early career teachers

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## Abstract

**Background** Retaining highly qualified science, technology, engineering, and mathematics (STEM) teachers is imperative for meeting demands of the twenty-first century STEM workforce. While multiple studies have revealed several factors that influence teacher retention, little work has examined how these factors interact with one another. This study explored the relationship between two critical factors that relate to teachers' decisions to remain in the profession: teacher identity and communities of practice (CoP) networks.

**Results** Drawing upon scholarship on science teacher identity, CoP, and social network theory, we demonstrate a quantitative relationship between perceived network bridging roles and career commitment, which is mediated through teacher identity.

**Conclusions** The findings from this study have both implications for scholarship in teacher retention and science teacher identity development. Potential solutions for improving novice teachers' self-image through providing opportunities to grow their professional networks both locally and regionally/nationally are suggested.

## Introduction

The retention of highly qualified teachers in K-12 schools has received much attention over the last three decades (Cowan et al., 2016; Darling-Hammond, 2017; Ingersoll & Smith, 2003; Kelly & Northrop, 2015) with an estimated need to exceed 3.6 million teachers to maintain steady progress in science, technology, engineering, and mathematics (STEM) education initiatives (US Department of Education, National Center for Education Statistics, 2020). Retention of early career teachers is even more imperative to the teaching profession with reports suggesting that as many as 50% of teachers leave the classroom within their first 5 years of teaching (Clandinin et al., 2015; Ingersoll & Smith, 2003). Therefore, with regard to preparing students for a STEM literate twenty-first century, it is crucial that stakeholders in educational systems understand the factors related to teacher retention to sustain substantive change in STEM education.

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There are several factors that influence teacher retention such as working conditions, school characteristics, and teacher characteristics (e.g., Inman & Marlow, 2004; Newberry & Allsop, 2017; Paptraianou & Le Cornu, 2014). Teacher identity, for instance, has been shown to mediate teachers' decisions to leave poor working environments (Canrinus et al., 2012; Day, 2002; Moore & Hofman, 1988). Sutherland et al. (2010) suggested that teacher identity is an important target related to retention for early career teachers. Within the first few years of teaching, they can experience significant tensions between their role as a teacher and the demands of the school system in which they work. This can prompt them to leave the classroom or profession. Personal and professional relationships are important for shaping identity and have been shown to be related to teachers' decisions to remain in the profession (Inman & Marlow, 2004; Kelchtermans, 2017). Early career teachers become embedded in communities of practice (CoP) which can provide both emotional and social support (Paptraianou & Le Cornu, 2014), increase their job satisfaction (Day & Gu, 2007), and could ultimately influence their decisions to remain in the profession. However, there is little evidence for how these factors might interact with one another to influence teachers' decisions to remain in or leave the teaching profession. The relationship among factors related to teacher retention is important, because some factors are more operational and, therefore, more easily targeted with interventions. For instance, teacher identity is a multifaceted, dynamic, and internalized perception of oneself; however, teacher CoP and their associated professional networks are more operational and more easily targeted with professional development, including training for collaborations and relationship building (e.g., Newberry & Allsop, 2017).

In our previous work, we have sought to understand the relationship between these variables and how they might predict teacher dispositions to remain in the profession (Zhu et al., under review; Polizzi et al., 2021). In the previous study, we found significant correlations between teachers' network variables (i.e., the presence of bridging) and identity variables. The present study extends that work by demonstrating the path among the variables: teacher identity, social networks, and commitment to the profession. While previous work indicated correlations, this study tested two hypotheses for how these variables might be related: whether networks or identity directly influence teachers' commitment to the profession. The primary contribution of this study is a quantitative model for how teacher networks influence dispositions towards career commitment for early stage STEM teachers.

In the present study, we sought to empirically extend this work and test the empirical relationships between

two key factors related to teacher retention: teacher identity and characteristics of their CoP networks. Our research was guided by the following research questions:

1. How are teacher identity and CoP networks related for the participants in this study?
2. How do identity and CoP networks interact or mediate teacher decisions to remain in the teaching profession for the participants in this study?
3. To what extent do CoP network characteristics or identity factors influence disposition to teach long term for the participants in this study?

## Background

Teaching is inherently a social profession with teachers interacting with students, other teachers, administrators, and parents. These relationships form the framework of teachers' CoP. For early career teachers, transitioning into a new CoP (i.e., school) from being a student-teacher involves navigating tensions with their identity (Nichols et al., 2017) and power dynamics (Rice & Schneider, 1994) that could influence their dispositions of remaining in the profession.

We framed this study within situated learning theories (Lave & Wenger, 1991). Situated learning refers to the contextual nature of learning that occurs through the apprenticeship of novices by more expert others within a CoP. That is, becoming a teacher begins with preservice education and includes induction and training by more veteran teachers. As a novice teacher becomes more knowledgeable and begins learning the norms and values of the profession, they become more centrally located within the teaching CoP and become seen by others as a "teacher." Through the acts of becoming and moving from a legitimate, peripheral participant to a central active participant, teachers are socialized into the norms and values of teaching and begin to assume the role and identities associated with teaching. On the other hand, not being seen as a "teacher," misalignment between teachers' identities and their workplace can lead to feelings of isolation from the teaching CoP and, therefore, mediate desires to leave the profession.

## Dispositions to leave or remain in the profession

Schools consistently struggle to maintain a steady teacher workforce (Cowan et al., 2016). Recent work suggests this issue is due to high levels of teacher attrition rather than low levels of teacher candidates entering the profession (Ingersoll et al., 2018). Decisions to remain in the teaching profession are influenced by external, employment, and personal factors (Inman & Marlow, 2004).

Teachers' dissatisfaction with the teaching profession has been indicated as a critical precursor of teachers' decisions to remain in the classroom (Adio & Popoola, 2010; Inman & Marlow, 2004). Job satisfaction (employment factor) refers to the subjective perceptions one has with work-related experiences and working conditions (Kelly & Northrop, 2015). Low job satisfaction for teachers is often related to poor school characteristics, salary, and feelings of lack of support (e.g., Inman & Marlow, 2004; Newberry & Allsop, 2017). Kelly and Northrop (2015) suggested that early career teachers' plans for remaining in the profession can serve as a measure for their satisfaction with their careers. That is, teachers planning to remain in the classroom longer have higher job satisfaction than teachers planning to leave the classroom. However, in a more recent study by Polizzi et al. (2021) job satisfaction and career commitment were not found to be correlated for early career teachers (less than 5 year experience), but that teachers' CoP networks were associated with their commitment to the profession. This suggests that teachers' dispositions to remain in the profession are socially influenced. Similarly, teacher identity has been identified as both a social and personal factor that is related to teachers' decisions to remain in the profession (Hong, 2010; Moore & Hofman, 1988; Sutherland et al., 2010).

Considering teacher identity from a social perspective, teachers are more likely to consider leaving the profession if they are not seen by others to be an important and contributing member to their school (Kelchtermans, 2017; Kremer & Hofman, 1985; Moore & Hofman, 1988). This lack of social acceptance can lead to feelings of isolation and burnout which then lead to dispositions of leaving the classroom. We have previously shown that teachers' dispositions to remain in the profession are significantly predicted by their identity and CoP network characteristics (Polizzi et al., 2021; Zhu et al., under review). This line of scholarship suggests interactions between teacher identity and CoP networks might influence teachers' decisions to remain in the profession; as such, this study intends to understand these relationships.

### Teacher identity

The role of "teacher" is a broad label given that includes multiple roles (i.e., disciplinary teacher, teacher leader, tutor, mentor, department chair; Beauchamp & Thomas, 2009; Beijaard et al., 2004). Teacher decision-making, related to both instructional practices and dispositions to remain in the classroom, is strongly linked to their identities (Bullough, 1997; Eick & Reed, 2002; Helms, 1998; Leuhmann, 2008; Moore & Hofman, 1988; Sutherland et al., 2010). However, teacher identity is not merely a reflection of the roles a teacher fulfills but also includes

how a teacher defines themselves (Sammons et al., 2007). These definitions of self, or self-image, involve intersections among personal (e.g., mother) and professional identities (e.g., teacher). Conflicts or tensions between a teacher's personal and professional identity influence their decisions to leave or remain in the profession (Sammons et al., 2007; Towers & Maguire, 2017). Due to the scope of the current study, we chose to operationalize teacher identity from a disciplinary perspective (i.e., science or mathematics teacher).

Science teacher identity has previously been suggested to be a combination of personal views and beliefs about teaching, as well as perceptions of how others view you (Beauchamp & Thomas, 2009; Chi, 2009). Chi (2009) developed a model of science teacher identity that included personal experience, community practice, science teaching practice, knowledge and skills, degree of success, social respect, beliefs and values, intrinsic satisfaction, and representation. This model was developed using a sample of preservice teachers in a graduate program. We have recently extended this model and applied it to a sample of in-service, early career teachers in science or mathematics (Polizzi et al., 2021). Using exploratory factor analysis, Polizzi et al. (2021) identified four factors of teacher identity for science and mathematics early career teachers: self-image, social respect, community value, and community action. The self-image factor refers to a teacher's perception of themselves relative to an idealized teacher and is aligned to Chi's (2009) dimensions of beliefs and values, and intrinsic satisfaction. Community value and community action refer to attitudes towards the teaching community and actions engaged in within the community, respectively.

From a situated perspective (Lave & Wenger, 1991), teacher identity is socially constructed through participation within a CoP. This participation, referred to as legitimate peripheral participation by Lave and Wenger (1991), involves the acquisition or development of knowledge, skills, values, and beliefs about teaching from more expert others within a CoP. In this sense, teacher identity is multifaceted, dynamic (Beijaard et al., 2004), and discursively constructed (Gee, 2000). In their seminal work on CoP, Wenger (1998) emphasized the relational aspect of a CoP in which learning, and identity development, is mediated by the interactional nature between people and culture. That is, development and enactment of an identity occurs through social interactions within a CoP (Wenger, 1998).

### Communities of practice and networks

Communities of practice provide a social support system for teachers that can help mitigate effects of emotional stress and burnout (Penuel et al., 2009), thereby positively

influencing job satisfaction and commitment to their career. While teachers engage in multiple CoP (e.g., work/teaching, home, personal/social), Wenger (1998) proposed four common aspects of all CoP: community, practice, meaning, and identity. While the more abstract characteristics (i.e., practice, meaning, and identity) of CoP have been readily studied in teacher education (e.g., Billingsley, 2004; Hausman & Goldring, 2001; Mack et al., 2019), less research has been conducted on the relational characteristics or community aspect (i.e., social interactions) of CoP as discussed by Wenger (1998).

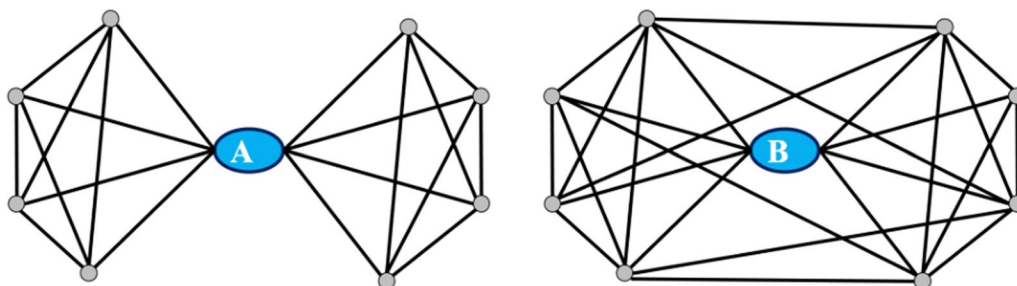
More recently, scholars have begun to explore the interactional nature of teacher CoP using social network analysis (SNA), which is suited to capture the relational nature of CoP in education (Polizzi et al., 2021) and organizational management (Cross et al., 2006; Soltis et al., 2013). SNA lends itself to studying the relational nature of CoP by providing a framework for understanding and visualizing social interactions within a given CoP. Network structures can provide individuals with different types of social capital, defined as the resources, capabilities and/or goodwill cultivated through the individual's social ties (Burt, 2000; Coleman, 1988). Using SNA, researchers can study the structural characteristics of networks, including network size, network density, bridging, and reach. Network size and density describe the number of people in a network and how connected they are, respectively (Burt, 2004; Penuel et al., 2009). The connectedness of a network can influence the diffusion of ideas (Burt, 2004). For instance, networks that are dense and well-connected might lead to greater diffusion of information but dense networks also reinforce ideas and behaviors, including non-favorable behaviors such as adopting instructional practices that are not effective. The bridging network structure exists in networks, where all individuals do not have access to each other, and the person in the bridge position can control the flow of information (Fig. 1). Bridging can be a power position

and is associated with access to novel information (Burt, 2000) and the synthesis of new ideas (Burt, 2004). Reach refers to the extent to which one individual can connect (either directly or indirectly) with others in the network. We have previously shown that the network characteristics of a teachers' CoP are correlated with their identity, self-efficacy (Polizzi et al., 2021), and job satisfaction (Zhu et al., under review). This work provided evidentiary support for using network analytic methods to study the interactional nature of CoP.

### Hypotheses

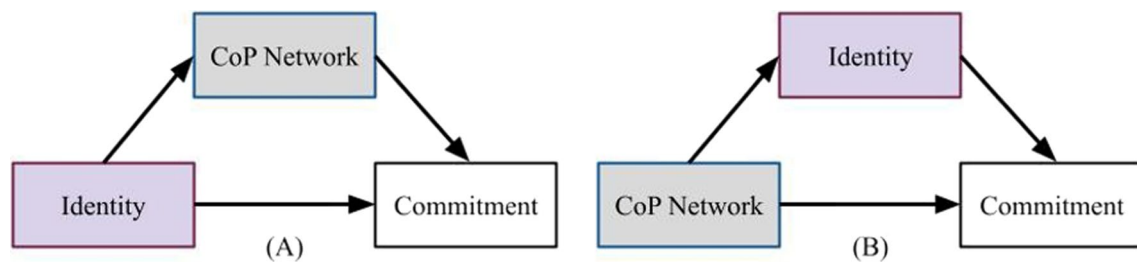
In this study, we build upon both our own and others previous work to capture the relational characteristics of teachers' CoP. We demonstrate the empirical relationship between the relational components of teachers' CoP, their developing identities, and their dispositions to remaining in the profession. To guide our inquiry, we established working hypotheses related to the constructs discussed above (CoP networks, identity, and dispositions to remain).

Based on a review of prior literature, two hypotheses were generated (Fig. 2). The first hypothesized relationship between these three constructs is shown in Fig. 2A and predicts that identity has a direct effect on years remaining in the profession, but this relationship is mediated by CoP network characteristics. In Fig. 2B, the hypothesized relationships suggest that CoP network characteristics are a direct influencer of years remaining, but this relationship is mediated by identity. Currently, literature supports the notion that teacher identity and their CoP are influential to their decisions to remain in the classroom. However, the nature of these relationships is not well-understood or researched. In this study, we test whether (1) teacher identity mediates the effect of CoPs on teacher commitment, (2) teacher CoPs mediate the effect of identity on teacher commitment, or (3) there is no mediation effect.



**Fig. 1** Individuals within a bridging role serve to connect individuals who would otherwise not be connected. Person A serves as a bridge in their network, while person B does not





**Fig. 2** Hypothesized relationships between teacher identity, CoP networks, and commitment to the profession. Model A predicts that identity influences commitment to remaining in the profession but this relationship is mediated by the characteristics of the CoP network. Model B predicts that the characteristics of teachers' CoP networks influence their dispositions on remaining in the profession but this relationship is mediated by their identity

## Methods

### Study design and participants

This study was conducted as part of a broader project to investigate the relationships between teacher characteristics (including identity and self-efficacy), CoP networks, and retention outcomes. Specific to this study, we surveyed teacher identity, CoP networks, and retention disposition using the Qualtrics (Provo, UT) online survey platform. Analyses for this study were conducted using the *lavvan* package (Rosseel, 2012) in R (R Core Team, 2019). Inclusion in the study was based on recent involvement in a teacher preparation program at a higher education institution awarded a National Science Foundation (NSF) Robert Noyce Teacher Scholarship Program grant. Noyce programs were selected at five universities across the Northeast, Southeast, and Midwest US. Survey links were distributed via email blast to approximately 430 teachers. However, we could not confirm which university email accounts were being monitored. For example, some student email addresses were used, even though individuals had graduated, suggesting that completion rates might actually be higher than our observed minimum completion rate of 55% ( $n=237$ ). From that larger population, we have extracted the early career teachers ( $n=201$ ) with 5 or less years of teaching experience as participants in this current study (Fig. 3). Sample sizes are reported in each figure or table if analyses reflect a lower number of participants due to conditional or missing data. Participants were previously enrolled in a university teacher preparation program alone (34.8%), or with additional scholarship/stipend financial supports (62.7%), such as scholarship funds and extracurricular professional development via Noyce (nsfnoyce.org) or Woodrow Wilson Fellowship awards (woodrow.org). Participants were currently teaching one or more classes in Pre-K-12 (Full Time: 85.6%); identified as science (75.1%) or mathematics (24.9%) teachers; spanned ages 23–63; identified as female (55.7%); and were White/

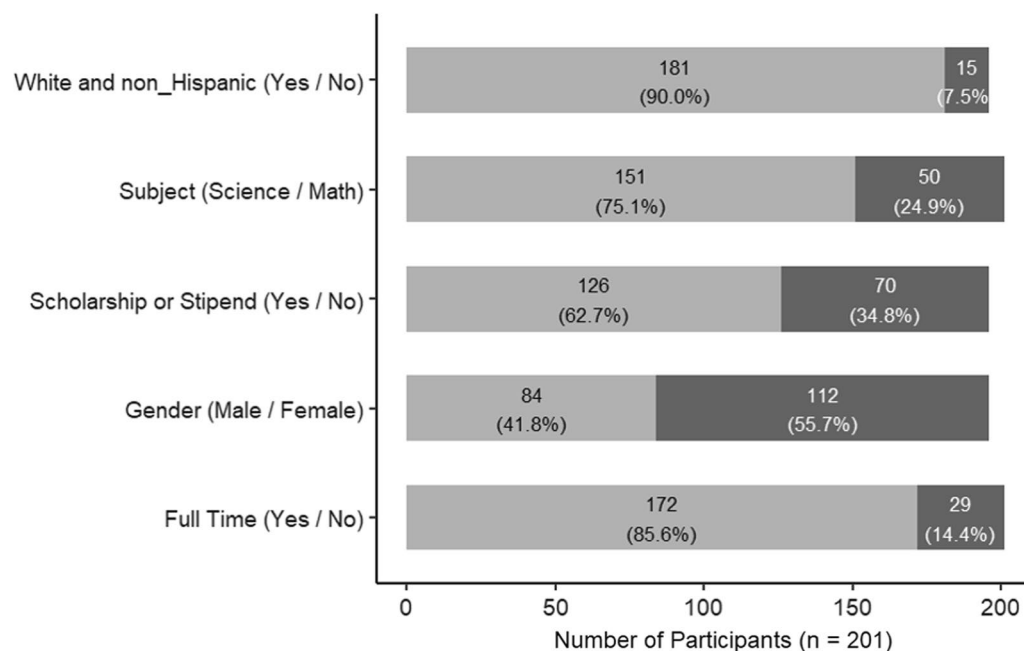
non-Hispanic (90%). Participants were compensated for their time in accordance with IRB guidelines.

### Analytic approach

Components of our analytical approach are summarized here as an overview, and then detailed below after a description of relevant variables. First, we examined correlations between aspects of teacher identity and characteristics of CoP networks. Then, using structural equation modeling (SEM), we tested our hypothesized models (Fig. 2) to determine the pathways between teacher identity, CoP network characteristics, and dispositions to remaining in the profession. The SEM process took place in two phases: analysis of the measurement model and analysis of the structural model. For the measurement model, we proposed a four factor solution using confirmatory factor analysis (CFA). Measurement models demonstrate the relationships between constructs and their indicators. We first assessed the measurement model by examining the reliability (Cronbach's Alpha and composite reliability [CR]) and convergent validity (factor loadings and Average Variance Extracted [AVE]). For reliability of the model, we checked for Cronbach's Alpha and CR values above the recommended threshold of 0.7 (Field, 2013). Evidence of convergent validity was assessed using factor loading metrics and AVE. For the structural model, we used fit indices from the CFA and used a Chi-square test for determining goodness-of-fit of the structural model.

### Instrument

The instrument used in this study consisted of three parts. First, teachers were asked to respond to questions related to their teacher identity. The second section included questions related to the teachers' CoP networks. Finally, the last section was focused on the teachers' commitment to the profession. Each part of the instrument is described in more detail below with a description of each variable in Table 1.



**Fig. 3** Summary of early career teacher participant demographics ( $n=201$ ). \*White and non-Hispanic, Scholarship or Stipend, and Gender variables do not add to 100%, because five participants did not respond to these questions

**Teacher Identity Instrument** For the purposes of this study, we used a modified version of the Science Teacher Identity instrument developed by Chi (2009). In our previous work, we validated a subset of questions (18) from the original (48) with early career science and mathematics teachers (Zhu et al., under review). Zhu et al. (under review) collected evidence of face and construct validity through expert reviews and exploratory factor analysis and showed the valid and reliable properties of the subset of questions. This analysis resulted in a four-factor solution for teacher identity: self-image, community value, community action, and social respect. The self-image factor aligned with both the Intrinsic Satisfaction and Belief & Value dimensions of Chi's (2009) original science teacher identity model. The community value and community action factors aligned with Chi's (2009) community practice dimension. This validation process included modifying the language from science specific to math specific language for mathematics teachers. Participants responded to four-point Likert-scale items (strongly disagree [1] to strongly agree [4]) for each item in the instrument.

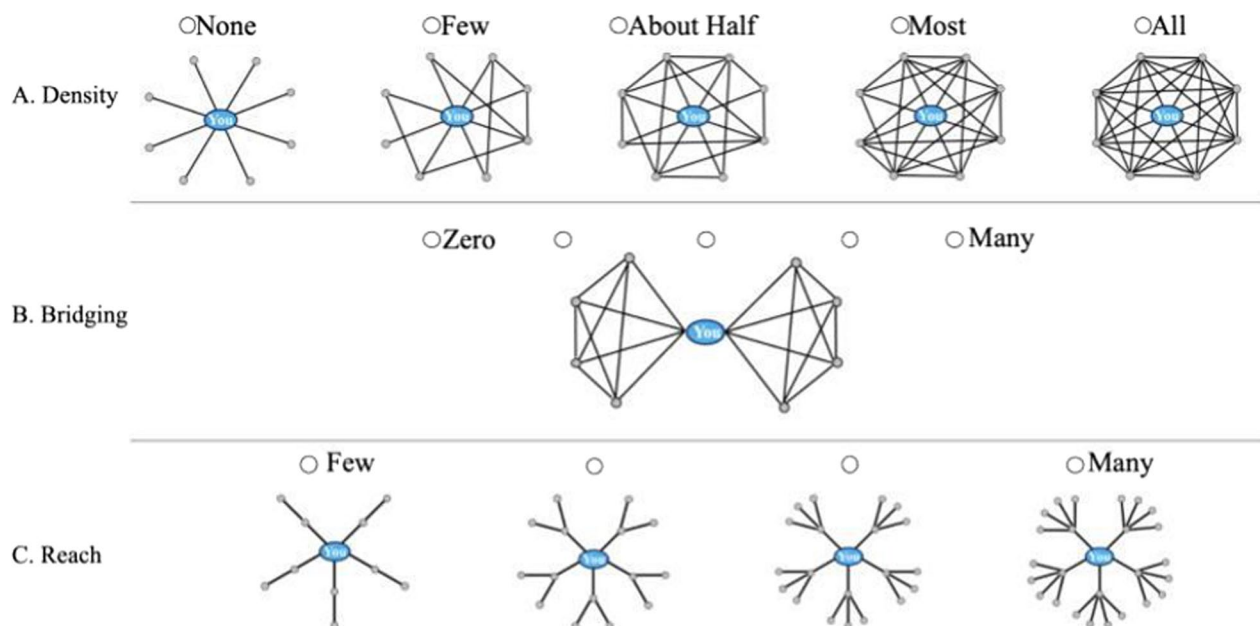
**CoP Network Survey** Polizzi et al. (2019) have previously operationalized teacher CoP as specific types of social networks centered on teachers and shaped by interactions around teaching content and/or pedagogy. These teacher CoP were largely local in proximity, energizing in nature, and frequent in interactions (Polizzi et al., 2019). For the current study, we used the CoP

network instrument to capture participants' perceptions of their teaching CoP. This survey has been previously used to describe teachers' CoP in terms of network characteristics (i.e., density, size, reach, bridging) (Polizzi et al., 2019, 2021). We have previously used this survey to collect teacher-centered (i.e., ego-centric) network data about teachers' CoP (Polizzi et al., 2019, 2021). In this survey, participants list up to ten individuals with whom they interact with related to teaching as well as survey items from visual network scales (VNS) based on the work of Mehra et al. (2014). VNS provides participants with groups of images that represent different measures of density (Fig. 4a), bridging (Fig. 4b), and reach (Fig. 4c). Participants then selected the image that they perceived to best represent their teaching network. Validity evidence has previously been collected using cognitive interviews of teachers and their networks. Data collected from these questions are categorical in nature.

**Commitment to the Profession** We collected teachers' dispositions to remaining in the profession using a question modeled after the Teacher Follow-up Survey (National Center for Educational Statistics, 2019b) and Beginning Teacher Longitudinal Study instruments (National Center for Educational Statistics, 2019a): "How long do you plan to remain in the position of a pre-K-12 teacher?". Responses to this question were continuous and ranged from 0 to 99 years. For responses with a range of years (i.e., 5–10 years), the average was calculated and used for analysis.

**Table 1** Relevant variable descriptions and survey items

Variable	Description	Example survey items
Teacher identity variables		
Self-image (SI)	This variable describes a teacher's perception of themselves relative to an idealized teacher	"I truly enjoy being a science [or math] teacher" "The quality of my teaching contributes to my career advancement." Data represent the sum of scores from items grouped by factor analysis and conform to a four-point Likert scale (Strongly, Somewhat agree, Somewhat-, Strongly disagree)
Community action	This variable describes a teacher's perception of their position in the broader teaching discipline community. Emphasis may be more aligned to group interactions in the community compared to the CoP2 factor below	"I belong to professional associations or groups of science [or math] teachers" "I feel part of a community of math [or science] teachers" Data represent the sum of scores from items grouped by factor analysis and conform to a four-point Likert scale (Strongly, Somewhat agree, Somewhat-, Strongly disagree)
Community value	This variable describes a teacher's perception of their position in the teaching discipline community. Emphasis may be more aligned to one-on-one interactions in the community compared to the CoP1 factor above	"It is helpful to be able to discuss the progress of students with colleagues" "I enjoy sharing ideas and resources about teaching science [or math]." Data represent the sum of scores from items grouped by factor analysis and conform to a four-point Likert scale (Strongly, Somewhat agree, Somewhat-, Strongly disagree)
Social respect	This variable describes a teacher's perception of their identity relative to public or popular opinion	"It is important that my good teaching be recognized in some ways" "I appreciate it when my institutions acknowledge my success as a math [or science] teacher." Data represent the sum of scores from items grouped by factor analysis and conform to a four-point Likert scale (Strongly, Somewhat agree, Somewhat-, Strongly disagree)
VNS variables		
Size	This variable describes a count of the total number of contacts in a teacher's CoP network	Up to ten contacts could be listed at each geographic level [school, district, state, (inter)national] for a maximum overall network size of 40 contacts
Density	This variable describes a teacher's perception of the degree of interconnectedness between contacts in their CoP network	In your opinion, which of the network diagrams best approximates the degree of interconnectedness in your own network of professional interactions at the school level? None/A few/About half/Most/All [1/2/3/4/5]
Bridging	This variable describes a teacher's perception of how often they serve as a bridge between contacts who would not otherwise be connected in their CoP network (not separate geographic levels)	Rate the extent to which you think you occupy a bridge position in your overall personal network of professional contacts related to teaching content and/or pedagogy Zero—Many [1/2/3/4/5]
Reach	This variable describes a teacher's perception of how extensive their network is based on the number of contacts that each of their contacts maintains in their CoP network	In your opinion, which of the network diagrams best approximates your overall personal network of professional contacts related to teaching content and/or pedagogy? Few—Many [1/2/3/4]



**Fig. 4** Visual Network Scales survey items. Participants selected the corresponding image for each of (a) density, (b) bridging, and (c) reach based on their perceptions of their teaching/pedagogically related CoP network

## Results

### Descriptive statistics of the variables

Descriptive analysis of the study variables (i.e., network characteristics and teacher identity) revealed similarities between the science and mathematics subgroups of our sample. On average, teachers' networks consisted of 9 individuals and teachers indicated that their networks were approximately 50% dense ("about half"). Furthermore, both science and mathematics teachers indicated moderate levels of both bridging and reach (Table 2). Analysis of the teacher identity factors revealed more similarities between the mathematics and science teachers in our sample. In particular, both groups held strong

perceptions of their self-image and community value, followed by community action and social respect.

### Correlations between early career teacher identity and communities of practice

Prior research has shown that perceived CoP structures were more significantly correlated with teacher identity than self-efficacy beliefs (Polizzi et al., 2019). Therefore, we were interested in the extent to which CoP-identity correlations existed in the early career teacher sample. Using correlation analysis ( $n=201$ ), we found positive relationships between CoP network characteristics and the community action, community value,

**Table 2** Descriptive Statistics of teacher identity factors and CoP network variables by Subject

	Science				Math			
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Network size	9.03	4.87	0	26	8.94	5.15	0	25
Density_overall	3.01	0.77	2	4	2.96	0.9	1	5
Bridging_overall	2.69	0.98	1	5	2.62	1.09	1	5
Reach_overall	2.84	0.87	1	4	2.64	0.83	1	4
Self-image	20.38	2.79	11	24	20.12	3.51	6	24
Community action	9.40	2.00	4	12	9.42	2.06	3	12
Community value	7.12	1.03	4	8	7.12	1.27	2	8
Social respect	6.52	1.20	2	8	6.20	1.32	2	8



**Table 3** Spearman's correlations between teacher identity factors and CoP network variables

	Identity factors <sup>a</sup>			
	SI	CA	CV	SR
Network size <sup>b</sup>	0.102	0.264***	0.199**	0.102
Density_overall <sup>c</sup>	0.006	0.207**	0.132	0.149*
Bridging_overall <sup>c</sup>	0.169*	0.269***	0.099	0.214**
Reach_overall <sup>c</sup>	0.143*	0.192**	0.265***	0.119

Significance Codes: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ <sup>a</sup> SI: Self-Image, CA: Community Action, CV: Community Value, SR: Social Respect<sup>b</sup> Count of contacts in overall network for each teacher ( $n = 201$ )<sup>c</sup> All teachers were asked about perceived density, bridge positions, and reach in their overall networks ( $n = 201$ )

social respect, and self-image identity factors (Table 3). The most significant correlations existed between CoP characteristics and the Community Action (CA) identity factor. The CA factor was significantly correlated with overall network size ( $r = 0.264$ ,  $p < 0.001$ ), overall density ( $r = 0.207$ ,  $p < 0.01$ ), bridging position ( $r = 0.269$ ,  $p < 0.001$ ), and reach ( $r = 0.192$ ,  $p < 0.01$ ), such that identifying more strongly with the science or math teaching community was associated with, respectively, larger CoP networks, more perceived opportunities to connect stakeholders who would not otherwise be connected, and more perceived access to contacts who are well-connected.

Turning to the Community Value (CV) identity factor, we observed a significant relationship with reach ( $r = 0.265$ ,  $p < 0.001$ ) and size ( $r = 0.199$ ,  $p < 0.01$ ) in the overall network. Unlike CA, CV was not correlated with perceived overall network density ( $r = 0.132$ ,  $p > 0.05$ ) and bridging ( $r = 0.099$ ,  $p > 0.05$ ), despite the significant correlation between CA and network size noted above.

Teacher self-image was significantly correlated with overall network characteristics of bridging ( $r = 0.169$ ,  $p < 0.05$ ), and reach ( $r = 0.143$ ,  $p < 0.05$ ), similar to the CA factor. Furthermore, social respect was found to be significantly correlated with overall density ( $r = 0.149$ ,  $p < 0.05$ ) and overall bridging ( $r = 0.0214$ ,  $p < 0.01$ ). This finding suggests that early career teacher identities might not only be influenced by relationships at the school culture level, but also by broader CoP interactions connecting stakeholders in their state.

Finally, we observed general trends in the CoP network characteristics presented to teachers via VNS images of teachers' overall networks. Increases in both perceived bridging and reach at the overall network level were generally accompanied by stronger teacher identities in three or more of the four identity factors (Table 3). Conversely,

perceived density at the overall level was not as routinely significant, since only significantly correlated with community action and social respect (Table 3). Collectively, these network trends may suggest that using VNS-based methods with teachers to describe overall CoP networks may be less meaningful for density compared to bridging or reach. It may be more useful to explore perceived network density in VNS corresponding to specific CoP spheres of influence.

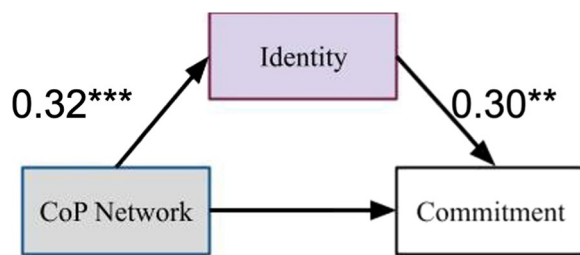
#### Influence of CoP network characteristics and teacher identity factors on dispositions to remain in the profession

The measurement model (Table 4) was confirmed for reliability as values for both Cronbach's Alpha and composite reliability were above the recommended threshold of 0.7 (Field, 2013). Evidence of convergent validity was assessed using factor loading metrics and Average Variance Extracted. Convergent validity was examined in order to test whether the factors loaded similar to the previous EFA conducted (Zhu et al., under review). Table 4 shows that in the model, each factor loading was above the recommended 0.7 threshold and each of the AVE values were above the recommended threshold value of 0.5. Based on these results, the measurement model was confirmed using the four constructs in Table 4 for identity, which allowed us to proceed with the structural model assessment.

First, we examined whether the correlation between bridging and years remaining was mediated by self-image (Fig. 5). We used both hypothesis testing (Chi-square) and coefficient of determination ( $R^2$ ) to determine the fit of the structural model. Table 5 and Fig. 5 present an overview of the hypotheses testing and structural model. Network bridging significantly influenced self-image ( $\beta = 0.32$ ;  $p < 0.001$ ) and that self-image influenced

**Table 4** Model summary for Model 2

Constructs	Items	Beta (Standard Factor Loading)	Cronbach's Alpha	CR	AVE
Community action	Item 4	0.858	0.759	0.762	0.518
	Item 5	0.610			
	Item 6	0.733			
Community value	Item 7	0.698	0.735	0.731	0.576
	Item 8	0.823			
Social respect	Item 13	0.892	0.778	0.785	0.648
	Item 14	0.715			
Self-image	Item 18	0.911	0.916	0.917	0.786
	Item 19	0.850			
	Item 20	0.898			



**Fig. 5** Structural equation model showing the paths between network bridging, identity, and commitment

**Table 5** Structural model effects

Effect	Estimate	Std. Error	p value
Indirect	1.457	0.587	0.013
Total	1.974	0.939	0.035

commitment to the career ( $\beta = 0.30$ ;  $p < 0.01$ ). When controlling for gender, age and network size, the analysis indicated that although there was a significant total effect of bridging on years remaining ( $p < 0.05$ ), the direct effect of bridging was not significant ( $p > 0.5$ ). Instead, the indirect effect facilitated by the mediator self-image was significant ( $p < 0.05$ ). These findings suggest a complete mediation effect rather than a partially mediated relationship. Inclusion of self-image as a mediator limits the significance of bridging, highlights the greater significance of self-image, and improves the model  $R^2$  by over twofold indicating our second hypothesis (Fig. 2B) explains the most variance in our sample.

To be thorough, we also investigated a mediating role for bridging in the correlation between self-image and years remaining (data not shown). In a model controlling for gender, age and network size, the mediation analysis indicated that although there was a significant total effect of self-image on years remaining ( $p < 0.05$ ), the indirect effect facilitated by the mediator bridging was not significant ( $p > 0.5$ ). Instead, the direct effect of self-image was most significant ( $p < 0.05$ ), preventing a significant proportion mediated ( $p < 0.5$ ). The significance of bridging as a mediator was also not apparent after comparing regression models with and without the mediator (data not shown). Inclusion of bridging as a mediator did not limit the significance of self-image, and there was little impact on the  $R^2$  for the model.

The structural model in Fig. 5 shows both path coefficients (Network Bridging  $\rightarrow$  Identity; Identity  $\rightarrow$  Commitment) to be statistically significant at the  $p < 0.01$  level. The SEM was considered a good fit based on metrics of Chi-square of Minimum Discrepancy Test (64.587),

$p = 0.066$ ; CFI = 0.980; TLI = 0.973; SRMR = 0.050; RMSEA = 0.039. This structural model suggests that while network bridging is important for dispositions to remain in the profession, this relationship is mediated by the teachers' identity.

Identity was most strongly associated with Community Action (0.90), followed by Community Value (0.72), Self-Image (0.71), and then least associated with Social Respect (0.28). Together, we interpret these results to mean that while a perception of increased bridging positions in a teacher's network does correspond with a disposition to remain in teaching for a longer period of time, the mode of action is through self-image. That is, having a perception of increased bridging positions promotes a stronger self-image as a science or math teacher, which in turn promotes a disposition to remain in teaching for a longer period of time.

### Limitations

This study may have limitations in generalization, given the sample sizes of early career teachers, and other professional development activities the teachers engaged in at their local levels. It was not our design to control for all of these additional variables. Instead, we selected participants across five distinct university teacher preparation programs to increase diversity in experiences and contexts. It is not clear to us how similar or different our sample of new STEM teachers are to the general population across the country. As such, we do not presume that it is representative, and we are cautious about extending our conclusions regarding the path model more broadly. In addition, there are multiple lenses to guide social network analysis, and our analysis focused on the overall structures of ego networks, rather than interaction (i.e., tie) or content (i.e., attribute) level information. Our comparison of school level density vs overall density suggests more work can be conducted in specific aspects of a teacher's CoP. The nature of our statistical analyses allowed the testing of directional interactions between variables, but not the assignment of causal relationships. Additional qualitative data and triangulation would strengthen the relationships described in our quantitative study.

### Discussion and implications

In this study, we explored the relationships between early career teachers' CoP, their identities, and dispositions to remain in the profession. Retaining highly qualified teachers is an imperative operation for ensuring we meet the increasing demands of the twenty-first century STEM workforce (US Department of Education, National Center for Education Statistics, 2020). Several

characteristics have been theoretically, and some empirically, linked with teacher retention (Inman & Marlow, 2004; Newberry & Allsop, 2017). We focused on two interrelated factors: a teacher's CoP network and their identity. While the extant literature demonstrates that both identity and CoP networks are influential to teachers' decisions to remain in the profession, we have expanded upon the current literature by demonstrating a pathway of influence between identity, networks, and retention dispositions.

Our previous work in teacher professional development utilized CoP network discussions and systems thinking, which leveraged the implicit nature of networks and the potential to capitalize on networks made explicit (Polizzi et al., 2019). This framing suggested an implicit or hidden role for networks in our understanding of teacher retention. Indeed, we found significant correlations between several network characteristics and teacher identity factors. In particular, we found that community value and community action were the most correlated variables with network characteristics. *Action* within the community appears to necessitate the existence of a larger CoP network size, which may be densely centered on the local school setting. In contrast, teachers may recognize the value of the community without perceiving that they maintain a large network, or a school network that is densely connected.

We initially hypothesized two possible models of the relationship between teacher identity, CoP network characteristics, and retention dispositions. These hypotheses were constructed based on relationships documented in the literature and that the relationship between CoP networks and teacher identity with their dispositions towards retention would be partially mediated by implicit networks or teacher identity. Instead, our findings suggest that network characteristics may precede teacher identity on a path to improving retention as evidenced by complete mediation. More specifically, teacher identity mediates how perceived network bridging impacts retention decisions.

This finding may prove more advantageous than our initial hypothesis. If networks can serve as a starting point for influencing identity and retention, then teacher education stakeholders have a target in networks that is more tangible than teacher identity. That is, teachers may be provided opportunities to develop their networks through courses, professional development, and financial support to travel to conferences which could in turn influence their decisions to remain in the classroom and profession. We find support for this position in how education researchers have applied concepts of CoP. In multiple studies, CoP has been used to frame an investigation of teacher identity development (e.g., Beauchamp

& Thomas, 2009; Goodnough, 2010). Furthermore, when assessing teacher identity, studies have looked to interactions with, and position relative to, teacher CoP (Polizzi et al., 2021). Therefore, a contribution of our current work is to quantify aspects of teachers' CoP, and empirically link them to teacher identity characteristics and related retention dispositions.

## Conclusions

At the overall CoP network level spanning school, district, and national contacts related to teaching content and/or pedagogy, our analysis indicated that perceived bridging was more important for retention dispositions than high density networks. Our previous analysis of teacher CoP networks in a smaller sample of experienced teachers showed that bridging often occurred between different geographic spheres of influence (Polizzi et al., 2019). For example, experienced teachers served as a bridge between state level contacts and members of their local school. Such a bridge position could be further exemplified as experienced teachers interacting with state colleagues at a conference and bringing those ideas and best practices back to their school colleagues, since direct access between the colleagues did not exist.

It is tempting to consider the implications of this example of bridging for early career teachers and their retention dispositions. In an education system with distributed leadership and few formal titles for teachers, being in a bridging position may support a stronger personal identity as a successful teacher, and/or recognition by the system as an influential or "go-to" teacher. Considering the nature of what is bridged across different geographic spheres of influence, teachers in this position might be aware of a larger sense of the education system or opportunities for growth as a teacher. In turn, the teacher in a bridging position may feel more positive about remaining in the profession longer. It is also possible that the (new) teachers in our study feel a stronger connection to their CoP, thus influencing their self-image as an emerging STEM teacher. This reinforcement and strengthening of the teacher identity may serve to further establish a commitment to the profession, and improve retention.

The findings from this study highlight several considerations for administrators and teachers:

- Provide opportunities for teachers to expand their networks through coursework, professional development programs, and financial support to travel to conferences.
- Provide opportunities to take on roles that place the teacher in a bridging role.

- Provide access to diverse educational resources and experts, particularly at the regional, state, and national level.

Exposing a teacher to a unique professional development activity, district committee, or community partnership may allow that teacher to serve as a bridge to school colleagues. As a bridge, the teacher may then speak with some expertise or novel information that promotes their own identity as an important part of the school, and raises their profile with peers as a member of the CoP that should be retained in the teaching profession. Identity formation can then occur in two ways that positively impact retention dispositions. First, the teacher identity can be strengthened through interactions with network participants outside of their local school, which connects the teacher to an extended community and increases a sense of belonging. Second, when the teacher brings novel (and hopefully, useful) information and resources to the local community, their intrinsic sense of worth, need, and value to the local community is improved. Both mechanisms serve to reify the teacher as relevant and important to the success of their students and colleagues, and thus improves a disposition towards remaining in the profession.

We are currently gathering qualitative data on teacher bridging to explore these implications in future studies and seek to develop more causal relationships between teacher networks, identity, and persistence.

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#### Author contributions

SJP, BO, MB, MM-S, KS, GR, and GTR made substantial contributions to the conception, design, and interpretation of data in this study presented in this manuscript. YZ, SS, & SJ made substantial contributions to the analysis and interpretation of the data. JWR made substantial contributions to the drafting and editing of the manuscript. All authors read and approved the final manuscript.

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#### Availability of data and materials

Not applicable.

#### Declarations

#### Competing interests

The authors declare that they have no competing interests.

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#### References

- Adio, G., & Popoola, S. (2010). Job satisfaction and career commitment of librarians in federal university libraries in Nigeria. *Library Review*, 59(3), 175–184. <https://doi.org/10.1108/00242531011031160>
- Beauchamp, C., & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*, 39, 175–189. <https://doi.org/10.1080/03057640902902252>
- Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education*, 20, 107–128. <https://doi.org/10.1016/j.tate.2003.07.001>
- Billingsley, B. S. (2004). Special education teacher retention and attrition: A critical analysis of the research literature. *The Journal of Special Education*, 38, 39–55. <https://doi.org/10.1177/00224669040380010401>
- Burt, R. S. (2004). Structural holes and good ideas. *American Journal of Sociology*, 110(2), 349–399. <https://doi.org/10.1086/421787>
- Canrinus, E. T., Helms-Lorenz, M., Beijaard, D., Buitink, J., & Hofman, A. (2012). Self-efficacy, job satisfaction, motivation and commitment: Exploring the relationships between indicators of teachers' professional identity. *European Journal of Psychology of Education*, 27, 115–132. <https://doi.org/10.1007/s10212-011-0069-2>
- Chi, H. J. (2009). *Development and examination of a model of Science Teacher Identity (STI)*. (Unpublished doctoral dissertation), The Ohio State University, Columbus, OH.
- Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology*, 94, S95–S120. <https://doi.org/10.2307/2780243>
- Cowan, J., Goldhaber, D., Hayes, K., & Theobald, R. (2016). Missing elements in the discussion of teacher shortages. *Educational Researcher*, 45(8), 460–462. <https://doi.org/10.3102/0013189X16679145>
- Cross, R., Laseter, T., Parker, A., & Velasquez, G. (2006). Using social network analysis to improve communities of practice. *California Management Review*, 49, 32–60. <https://doi.org/10.2307/41166370>
- Darling-Hammond, L. (2017). Teacher education around the world: What can we learn from international practice? *European Journal of Teacher Education*, 40, 291–309. <https://doi.org/10.1080/02619768.2017.1315399>
- Day, C. (2002). School reform and transitions in teacher professionalism and identity. *International Journal of Educational Research*, 37(8), 677–692.
- Eick, C. J., & Reed, C. J. (2002). What makes an inquiry-oriented science teacher? The influence of learning histories on student teacher role identity and practice. *Science Education*, 86, 401–416. <https://doi.org/10.1002/sce.10020>
- Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, 25, 99–125. <https://doi.org/10.3102/0091732X025001099>
- Hausman, C. S., & Goldring, E. B. (2001). Sustaining teacher commitment: The role of professional communities. *Peabody Journal of Education*, 76, 30–51. [https://doi.org/10.1207/S15327930pje7602\\_3](https://doi.org/10.1207/S15327930pje7602_3)
- Helms, J. V. (1998). Science—and me: Subject matter and identity in secondary school science teachers. *Journal of Research in Science Teaching*, 35, 811–834. [https://doi.org/10.1002/\(SICI\)1098-2736\(199809\)35:7%3C811::AID-TEA9%3E3.0.CO;2-O](https://doi.org/10.1002/(SICI)1098-2736(199809)35:7%3C811::AID-TEA9%3E3.0.CO;2-O)
- Hong, J. Y. (2010). Pre-service and beginning teachers' professional identity and its relation to dropping out of the profession. *Teaching and Teacher Education*, 26, 1530–1543. <https://doi.org/10.1016/j.tate.2010.06.003>
- Ingersoll, R. & Smith, T. (2003). The wrong solution to the teacher shortage. *Educational Leadership*, 60(8), 30. Retrieved from [https://www.gse.upenn.edu/pdf/rmi/EL\\_TheWrongSolution\\_to\\_theTeacherShortage.pdf](https://www.gse.upenn.edu/pdf/rmi/EL_TheWrongSolution_to_theTeacherShortage.pdf)
- Ingersoll, R., Merrill, L., & Stuckey, D. (2018). The changing face of teaching. *Educational Leadership*, 75(8), 44.
- Inman, D., & Marlow, L. (2004). Teacher retention: Why do beginning teachers remain in the profession?. *Education*, 124(4).
- Kelchtermans, G. (2017). 'Should I stay or should I go?': Unpacking teacher attrition/retention as an educational issue. *Teachers and Teaching*, 23(8), 961–977.
- Kelly, S., & Northrop, L. (2015). Early career outcomes for the "best and the brightest": Selectivity, satisfaction, and attrition in the beginning teacher longitudinal survey. *American Educational Research Journal*, 52(4), 624–656. <https://doi.org/10.3102/0002831215587352>
- Kremer, L., & Hofman, J. E. (1985). Teachers' professional identity and burn-out. *Research in Education*, 34(1), 89–95.



- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.
- Luehmann, A. L. (2008). Using blogging in support of teacher professional identity development: A case study. *Journal of the Learning Sciences*, 17, 287–337. <https://doi.org/10.1080/10508400802192706>
- Mack, J. C., Johnson, A., Jones-Rincon, A., Tsatenawa, V., & Howard, K. (2019). Why do teachers leave? A comprehensive occupational health study evaluating intent-to-quit in public school teachers. *Journal of Applied Biobehavioral Research*. <https://doi.org/10.1111/jabr.12160>
- Mehra, A., Borgatti, S. P., Soltis, S., Floyd, T., Halgin, D. S., Ofem, B., & Lopez-Kidwell, V. (2014). Imaginary worlds: Using visual network scales to capture perceptions of social networks. In D. J. Brass, G. Labianca, A. Mehra, D. S. Halgin, & S. P. Borgatti (Eds.), *Contemporary perspectives on organizational social networks* (pp. 315–336). Emerald Group Publishing Limited.
- Moore, M., & Hofman, J. E. (1988). Professional identity in institutions of higher learning in Israel. *Higher Education*, 17, 69–79. <https://doi.org/10.1007/bf00130900>
- Newberry, M., & Allsop, Y. (2017). Teacher attrition in the USA: The relational elements in a Utah case study. *Teachers and Teaching*, 23(8), 863–880.
- Nichols, S. L., Schutz, P. A., Rodgers, K., & Bilica, K. (2017). Early career teachers' emotion and emerging teacher identities. *Teachers and Teaching*, 23(4), 406–421.
- Papatraianou, L. H., & Le Cornu, R. (2014). Problematising the role of personal and professional relationships in early career teacher resilience. *Australian Journal of Teacher Education (online)*, 39(1), 128.
- Penuel, W. R., Riel, M., Krause, A., & Frank, K. A. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College Record*, 111(1), 124–163.
- Polizzi, S. J., Ofem, B., Coyle, W., Lundquist, K., & Rushton, G. T. (2019). Social network data from teacher leader development. *Data in Brief*, 83, 42–53. <https://doi.org/10.1016/j.dib.2019.104182>
- Polizzi, S. J., Zhu, Y., Reid, J., Ofem, B., Salisbury, S., Beeth, M., Roehrig, G., Mohr-Schroeder, M., Sheppard, K., & Rushton, G. T. (2021). Science and mathematics teacher communities of practice: Social influences on discipline-based identity and self-efficacy beliefs. *International Journal of STEM Education*. <https://doi.org/10.1186/s40594-021-00275-2>
- Rice, E. M., & Schneider, G. T. (1994). Decade of teacher empowerment: An empirical analysis of teacher involvement in decision making, 1980–1991. *Journal of Educational Administration*, 32(1), 43–58.
- Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, 48(2), 1–36. <https://www.jstatsoft.org/v48/i02/>.
- Sammons, P., Day, C., Kington, A., Gu, Q., Stobart, G., & Smees, R. (2007). Exploring variations in teachers' work, lives and their effects on pupils: Key findings and implications from a longitudinal mixed-method study. *British Educational Research Journal*, 33, 681–701. <https://doi.org/10.1080/01411920701582264>
- Soltis, S. M., Agneessens, F., Sasovova, Z., & Labianca, G. (2013). A social network perspective on turnover intentions: The role of distributive justice and social support. *Human Resource Management*, 52, 561–584. <https://doi.org/10.1002/hrm.21542>
- Sutherland, L., Howard, S., & Markauskaite, L. (2010). Professional identity creation: Examining the development of beginning preservice teachers' understanding of their work as teachers. *Teaching and Teacher Education*, 26, 455–465. <https://doi.org/10.1016/j.tate.2009.06.006>
- Towers, E., & Maguire, M. (2017). Leaving or staying in teaching: A 'vignette' of an experienced urban teacher 'leaver' of a London primary school. *Teachers and Teaching*, 23(8), 946–960.
- U.S. Department of Education, National Center for Education Statistics. (2020). The Condition of Education 2020 (NCES 2020-144). Characteristics of Traditional Public, Public Charter, and Private School Teachers.
- Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*, 9, 2–3.
- Zhu, Y., Polizzi, S. J., Reid, J. W., Reeder, A., Jiang, S., Salisbury, S., Couch, B., & Rushton, G. T. (Under review). Early career teachers' school networks influence job satisfaction and career commitment. *Teaching and Teacher Education*. Submitted October 2022.

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