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Teachers' networked learning communities: Does collective participation matter?

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ABSTRACT

Networked professional learning communities (NLCs) have emerged as a promising structure for effective professional development. Drawing from Garet et al's (2001) definition of collective participation as groups of teachers from the same school, department, or grade level engaging in professional learning together, this study uses an embedded case study design to investigate the role of collective participation in promoting teacher learning in a mathematics NLC in the United States comprising three separate learning networks. The first network consisted of only teachers from one school district, while the other two networks served isolated teachers attending without any or only a few school-based colleagues. The varying compositions of these networks enabled us to examine how collective and non-collective participation shaped teachers' learning experiences and later efforts to implement their learning in their classrooms. Drawing from analyses of participant observation and interview data, our findings emphasize the importance of collective participation in professional learning, while also illustrating how some successful teachers with non-collective NLC participation cultivated unique configurations of communities for supporting instructional change.

1. Introduction

Reforms calling for changes in the instructional core of teaching, such as Common Core State Standards in the United States, require teachers of mathematics to deepen their mathematical knowledge and learn new instructional strategies. Teachers who fail to change their knowledge and practice will be unable to provide the learning experiences and mathematical understanding that students require (Schmidt, 2012). To promote enhanced knowledge and practice among teachers, educational leaders must understand how to effectively use professional development (PD) to improve teaching. One promising structure for PD is networked professional learning communities (NLCs), a professional learning community in which educators from multiple schools engage in shared learning (Katz & Earl, 2010). For example, NLCs might take place in summer workshops or yearlong programs offered by county-based intermediate school districts or universities. While research shows that NLCs can be productive sites for teachers to learn from colleagues in other schools (Katz & Earl, 2010), other research suggests that teachers learn best and implement learning more effectively when learning alongside colleagues from their own school with whom they share curriculum and expectations and with whom they collaborate regularly (Garet et al., 2001; Sun et al., 2013). Garet et al. (2001) define *collective participation* as the PD characteristic in which groups of teachers from the same school, department or grade-level learn together. Such *collective participation* of school-based colleagues can be integrated into NLCs when teachers enroll together, but NLCs can also have stand-alone attendees who enroll without colleagues. These possibilities raise unanswered questions regarding how the composition of a NLC influences participants' learning and implementation. Do teachers have more success implementing what they have learned when that learning occurs alongside colleagues from their own school? Can *singleton* teachers in NLCs without school-based colleagues have similarly positive benefits? If so, how do singletons' experiences of implementation differ from those of collective participants? Identifying the implementation experiences and needs of teachers attending with and without colleagues can enable school leaders and NLC facilitators to effectively support the learning and implementation experiences of all teachers.

Using a theoretical framework grounded in human capital and social capital, we conducted an embedded case study to investigate the roles of collective and non-collective participation in a mathematics NLC that hosted three separate learning networks. One network contained only

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teacher groups who worked in the same schools. The other two networks consisted of a combination of teachers who attended with school-based colleagues and teachers who attended alone. The different compositions of these networks - with Network A having exclusively collective participation and Networks B and C having a mix of participation styles - enabled us to examine how interactions between human and social capital for collective and non-collective participants shaped teachers' learning experiences and later efforts to implement their learning in their classrooms.

1.1. Collective participation in professional learning

Research illustrates that collaborative and collective learning are essential facets of effective teacher professional learning. Collective learning can employ a variety of models – from individual teachers working with an expert coach, to a group of teachers collectively examining their practice, to a full school staff working together to adopt a new practice, to a countywide network of teachers jointly attending a series of workshops (Darling-Hammond et al., 2017). Research on learning reveals that learners develop deeper understanding when they externalize and articulate their learning (Sawyer, 2014; Vygotsky, 1978). That is, through the process of explaining their thinking through social interactions, learners develop a stronger grasp on the phenomena they are discussing, and they can reflect upon and become aware of their own understanding in ways that enable metacognition and deeper learning. Additionally, colleagues working together to master new knowledge can scaffold one another as they collectively make sense of new ideas and sort through emergent understandings (Sawyer, 2014; Vygotsky, 1978). In these ways, social interactions among learners create conditions and opportunities to enrich and strengthen learning.

Not surprisingly then, research demonstrates a positive impact of high-quality teacher collaboration on teacher learning and student performance outcomes (Goddard et al., 2007; Wei et al., 2009). For example, Ronfeldt et al. (2015) used survey and administrative data to assess the quality of collaboration experienced by over 9000 teachers and found that teachers who reported higher quality collaboration experienced greater student achievement gains in mathematics and reading than teachers who experienced lower quality collaboration. These researchers conceptualized high quality collaboration as occurring when teachers reported meetings with colleagues to be helpful to their practice and extensive in the depth to which they examined teaching practice. These findings reveal that collaborative experiences that lead to teacher learning, and thus change practice, are grounded in meaningful exchanges among teachers.

Some in-depth qualitative studies on the nature of effective collaboration have similarly focused on opportunities for meaningful teacher learning (Cochran-Smith & Lytle, 1999; Levine & Marcus, 2010). For example, Horn & Little (2010) studied conversational routines among two groups of teachers and found that the group with greater teacher learning tended to take up individual teachers' problems of practice as starting points for rich discussions on principles of teaching, whereas the less effective group focused on solving isolated problems in ways that did not foster discussion to deepen teachers' understanding about teaching and learning. While researchers agree that teacher collaboration is not uniformly effective (Garet et al., 2001; Sun et al., 2013), there are certainly opportunities for considerable learning when teachers work and think together.

This collaborative potential is the reason collective participation is considered ideal for professional learning (Darling-Hammond et al., 2017; Desimone, 2009; Garet et al., 2001). Collective participation allows teachers to discuss concepts, skills, and problems in their work and link them to new learning. Teachers who regularly work together also share students and curriculum, allowing them to collaboratively integrate new learning into a shared context (Garet et al., 2001). Collective participation also enables teachers to build positive relationships that can foster trust, respect, collegiality, shared responsibility for students, and shared expertise within a school (Penuel et al., 2007; Seashore Louis et al., 1996). These social dynamics in teachers' working environments can, in turn, strengthen teachers' satisfaction with their work and their longevity in the profession (Johnson et al., 2012).

Importantly, for teacher professional learning to positively impact student learning, teachers must change their practice in ways that support student learning. This is not always the case. Research shows that teachers often participate in professional learning endeavors with little impact on their learning, instruction, or students' learning (Heller et al., 2012; The New Teacher Project, 2015). This is the impetus for numerous studies and reports that summarize what we know about effective teacher professional learning (e.g., Darling-Hammond et al., 2017; Desimone, 2009; Garet et al., 2001; Hunzicker, 2011; Penuel et al., 2007; Sancar et al., 2021; Sztajn et al., 2020; The New Teacher Project, 2015). These works have concluded that effective PD is subject-matter focused, active, coherent with other initiatives, immediately implementable, sustained over time, reliant upon experts, rich in metacognition and feedback, and undertaken collectively. Networked learning communities are one type of professional learning opportunity that meets these criteria.

1.2. Networked professional learning communities

Networked professional learning communities (NLCs) unite educators from different schools in shared learning experiences (Lieberman, 2000) - that is *networked learning* - by which educators can learn through social interactions, communication, and exchange with a network of professional colleagues that extend beyond their local school networks (Vaessen et al., 2014). NLCs are characterized by bringing together professionals from different organizations around a common goal to exchange knowledge and organizational norms (Pugh & Prusak, 2013).

In the 1980s and 1990s, NLCs became popular forums for teachers to question their practice, seek help, and share expertise across settings (Lieberman, 2000). More recently, NLCs have been used widely in England, where the National College of School Leadership convened leaders and teachers from over 600 schools to share expertise in networks (Katz & Earl, 2010). Within the US, the most widely known NLC is the National Writing Project (Little, 2006), which hosts summer institutes at approximately 200 universities serving several thousand teachers annually in an effort to train teachers to teach writing effectively and to support other teachers in teaching writing effectively (Gallagher et al., 2017; National Writing Project, 2016). Networks within the National Writing Project occur on multiple levels; there are both networks among teachers who participate in a single site but who work in different schools *and* networks across sites (Gallagher et al., 2017).

The distinctive characteristic of an NLC is that participants work in different schools and convene regularly to engage in professional learning for continuous improvement by drawing on the expertise of network facilitators and fellow attendees (Katz & Earl, 2010). The theory behind NLCs is that they support teacher learning by facilitating interactions within and across schools in the network (Katz & Earl, 2010). The inclusion of educators from other schools offers participants access to more resources, ideas, and expertise brought by others, opportunities for self-reflection by needing to explain contextual details to non-school colleagues, and a leadership opportunity in bringing the learning back to their school (Prenger et al., 2019). NLCs are one type of professional learning community (PLC), which is a broader concept denoting a group of educators working collectively to improve student learning through adult learning (DuFour, 2004). PLCs could include any configuration of people, while NLCs intentionally group educators working in different school sites to draw on expertise and experiences across locations to support participants' collective learning (Katz & Earl, 2010). Of course, collective participation of same-school teachers could be part of NLCs, as teachers can participate collectively or independently. The present study sets out to examine how these various types of participation re-

late to teachers' experiences of implementing their learning from NLCs in their classrooms.

2. Theoretical framework

Our theoretical framework integrates human capital and social capital, two facets of professional capital (Hargreaves & Fullan, 2012). *Human capital* is the professional capacity of individual teachers, including cumulative abilities, knowledge, and skills acquired from experience, training, and professional learning (Pil & Leana, 2009). Human capital manifests in teachers' instructional skills, knowledge of content, abilities to convey content to students in ways that support learning and address misconceptions, and competencies in managing their classroom and relating to students (Daly et al., 2014; Shulman, 1986). Research has long examined how teachers' human capital impacts student outcomes. Countless studies using a variety of methodologies, disciplines, and focal points have illustrated strong, significant relationships between teachers' knowledge, skills, and abilities and students' academic performance (e.g., Campbell et al., 2014; Hanushek, 2011; Hill et al., 2005; Rockoff, 2004; Rowan et al., 2002; Stronge et al., 2011).

The importance of teacher capacity raises questions about how school leaders can ensure that all students have teachers with high human capital. In addition to strategic hiring and retention (Donaldson, 2013; Loeb et al., 2012), scholars advocate for focused attention on how teachers work and learn interdependently through in-school collaboration (e.g., Cochran-Smith & Lytle, 1999; Horn & Little, 2010; Johnson, 2010; McLaughlin & Talbert, 2006, 2010). Such interdependent, collaborative relationships generate a form of *social capital* within schools, such that individual teachers and the school collective all benefit from positive, collegial relationships among teachers and the resources and knowledge shared through such relationships. Social capital in this context is defined as the collective resources individual teachers can access through relationships with colleagues (Bourdieu, 1986; Daly et al., 2014). Scholars often assess teachers' social capital by measuring the extent to which teachers consult colleagues about teaching, the depth of their collegial exchanges, the strength of their interpersonal ties, and their levels of trust or mutual respect with colleagues (Baker-Doyle & Yoon, 2011; Daly et al., 2014; Pil & Leana, 2009; Yoon et al., 2017). Using social network analysis, scholars have also found that the social capital available to each member in an organization depends upon the organizational structure of the social network and the member's location within that structure (Coburn & Russell, 2008).

Using surveys and quantitative analyses, researchers have examined statistical relationships among human capital, social capital, and teaching outcomes within groups of teachers (Daly et al., 2014; Pil & Leana, 2009; Yoon et al., 2017). In one study of 239 elementary-school grade-level teams with over 1000 teachers, Pil & Leana (2009) examined how individual teachers' human capital and within-school social capital separately and collectively related to improvements in their students' performance. They found positive effects of teachers' human capital on student gains on standardized assessments and that the strength of social ties among grade-level colleagues predicted student improvement, with the strongest effect for teachers with less human capital (Pil & Leana, 2009). Similarly, Daly et al. (2014) studied 63 teachers in five schools and assessed relationships among teachers' individual human capital, their social networks around reading comprehension, and their students' performance on reading assessments. They found a positive, significant relationship between teachers' human capital and student performance, and that teachers who frequently reached out to colleagues to share knowledge around reading comprehension tended to have higher student reading performance. Teachers who were central in knowledge-seeking networks, meaning those that reached out the most, tended to have higher student performance than those who reached out less. In another study, Yoon et al. (2017) examined relationships among human capital, social capital, and instructional change for 21 secondary science teachers who attended summer PD on problem-based and inquiry-based instruction. Using pre- and post- student surveys to measure how teachers changed instruction, Yoon and colleagues found that only social capital was a significant predictor of instructional change when both social and human capital were included in a statistical model (Yoon et al., 2017). The authors hypothesized that the PD might have had greater impact on practice if they emphasized social capital more (Yoon et al., 2017).

In the present study, we consider teachers' human and social capital to be pertinent for whether and how teachers enact instructional change in response to NLC learning. We initially theorized that teachers attending with school colleagues would have school-based social capital that extended to the NLC and thus supported transfer of NLC concepts to practice. We questioned whether and how teachers attending the NLC individually could transfer their learning to their practice and whether developing human capital through the NLC would be sufficient for changing their instruction without social capital connecting the school and NLC. To examine these dynamics, we used interview and observation data to consider how teachers' various social capital opportunities in their NLCs and schools shaped their use and implementation of NLC learning. That is, building on teachers' individual human capital, we considered the various ways in which social capital was or was not enacted to support implementation of learning. To this end, we examined differences across two groups of teachers participating in county-based NLCs: those who participated with school colleagues and those who did not. We address three research questions:

(1) What were the different ways that teachers report incorporating concepts from the NLCs into their classrooms?
(2) What are the experiences of teachers who participate in the NLCs collectively and non-collectively as they attempt to implement network practices in their teaching?
(3) How do teachers from both groups describe the communities that support their efforts to change their instruction following their network learning?

3. Methods

3.1. Embedded case study

Using participant observation and interviews, we conducted an embedded case study (Yin, 2013) with a countywide mathematics NLC program as the overarching case and three NLCs within the program as embedded cases. An Intermediate School District (ISD) serving a large county in Michigan hosted the program. The program goals (Szajtn, 2011) were to increase teachers' knowledge of how K-8 students understand mathematics, address gaps in teachers' mathematics knowledge, and train teachers in using two specific concepts: rich mathematical tasks and five practices for leading mathematics discussions. Participants attended a two-week, 80 h summer institute led by a college mathematics professor and the ISD-appointed facilitator utilizing an existing curriculum. Participants built on their summer work throughout the school year during nine monthly four-hour network meetings focused on defining, planning, and teaching with rich mathematical tasks and a book study of *5 Practices for Orchestrating Productive Mathematics Discussions* (Smith & Stein, 2011). These monthly NLC meetings were the focus of this study.

The ISD established the context of the NLCs (Sztajn, 2011) and formed the three networks. Network A included 31 K-8 teachers from three schools in one district, with at least five teachers from each school. Network B consisted of 18 K-8 teachers and some special education and support teachers, all from two districts, with a handful from shared schools. Network C included nine elementary teachers, two special education teachers, and a Title I teacher, who came from three districts with only two teachers from the same school. All teachers had a range of experience from first-year teachers to 20-year veterans; they worked in schools that ranged in size from 320 to 540 stu-

dents. All three networks met in the evenings, from 5 pm–9 pm for Networks B and C and from 4 pm–8 pm for Network A. For Network A participants, the district assistant superintendent "highly encouraged" their participation. Participants in Networks B and C reported learning about the NLC from district emails or colleagues who had participated previously.

While the formats for the three NLCs were similar, there were some differences. A different facilitator hosted each network. Alyssa, the Network B facilitator, created and designed the NLCs. Katherine, the Network A facilitator, reported meeting regularly with Alyssa to "plan the direction… the overall arc of where we want to go and the timing of the total NLC." Alyssa supported the Network C facilitator, Nancy, by regularly attending Network C sessions and offering feedback. On her goals for the NLC, Alyssa shared, "I hope that I expose [teachers] to how math can be richer, that it is more than just you have to make sure that you can do these things in a certain amount of time." She described using the *5 Practices* book to "anchor what each session would be about." Likewise, Katherine described her goal as helping teachers gain "the idea of using rich math tasks in the classroom. We've also focused on the five practices of productive discussion." Nancy emphasized the same goals in that she hoped teachers would learn to "discern what makes an actual rich mathematical task" and "facilitating discussions with kids." However, she added the goal of helping teachers become mathematically proficient.

The monthly meetings for Networks A and B followed similar formats. Each meeting began with announcements, celebrations, and a review of group agreements. Then teachers would attempt a rich mathematical task while the facilitator modeled the five practices for mathematical discussions. Participants would take on the role of K-12 students by working the problems and discussing their problem-solving strategies and solutions. Usually an additional activity focused on planning and teaching using these concepts. This activity differed between Networks A and B. In Network A, where teachers sat with grade-level colleagues, they collaborated to either plan the use of a rich mathematical task or assess student work. For example, in April, participants worked in grade-level teams during dinner to "find a task you would like to use with your students." In Network B, teachers engaged in more general discussions of concepts. For example, in February, teachers discussed the relationships between rich mathematical tasks and Bloom's taxonomy; in April, teachers discussed obstacles they experienced when trying to implement these concepts.

While Nancy communicated regularly with Alyssa, her Network C meetings followed a different structure, and each month focused on a different topic. For example, in January, teachers completed traditional mathematics problems from the Intel Math textbook followed by a quick review of rich mathematical tasks and the five discussion practices. In March, she provided time for participants to read the *5 Practices* book, then modeled a rich mathematical task and discussion, and ended with 30 min for teachers to plan a rich mathematical task. In April, the meeting followed the structure of the other networks, with Nancy modeling the use and discussion of a rich mathematical task. While activities differed, all three networks enabled participants to engage with rich mathematical tasks, discuss their practice in groups, and debrief in whole-group discussions.

3.2. Participant selection

Study participants during observations were all 61 participating teachers across the three networks and the three facilitators. After three observations of each network, the first author made an announcement inviting attendees to participate in interviews about the network. Fifteen teachers volunteered, which allowed for maximum variation sampling (Patton, 2002). The interview participants – five from Network A, six from Network B, and four from Network C – represented different schools, grade levels, and years of experience (see Table 1). Interviewees also included the three network facilitators.

3.3. Data collection

The first author engaged in participant observation at all network meetings from January through May 2016, for a total of thirteen four-hour meetings. During each meeting, the first author sat with participants while observing and recording field notes. She also engaged with participants by collaboratively completing the rich mathematical tasks and discussing solutions with teachers at her table. Field notes consisted of running descriptions of the mathematics content covered, topics of discussion among participants and facilitators, and interactions among teachers. In capturing teacher interactions during NLC meetings, she particularly attended to indicators of human capital (e.g., mathematics knowledge and prior teaching experiences) and social capital (e.g., collegial relationships and sharing of resources).

In May, the first author interviewed 15 teachers about their experiences in the NLCs, their efforts integrating NLC concepts into their practice, and their supports for mathematics instruction including curriculum and colleagues. She also interviewed the three facilitators regarding their goals and preparation for network meetings. All interviews followed a semi-structured protocol (see Appendix A), lasted 20–50 min, and were recorded and transcribed.

3.4. Data analysis

We analyzed teacher interviews in two phases. First, we identified the extent to which each teacher reported implementing NLC concepts, classifying teachers into three implementation levels. We used teachers' comments and behaviors, as noted in NLC field notes, to verify reported implementation. We then examined the experiences teachers in each group described in incorporating NLC learning into their teaching, focusing on differences in human and social capital across teachers who participated in the NLCs collectively and alone. Across the two phases of interview analysis, we used observation field notes and facilitator interviews as additional data to enhance our understanding of teacher collaboration within networks, provide context for the NLC program, and triangulate interview data (Lincoln & Guba, 1985).

3.4.1. Classifying teachers' implementation levels

As described above, the facilitators' goals for the NLCs centered around two main concepts: the use of rich mathematical tasks and the five discussion practices from Smith and Stein's (2011) *5 Practices for Orchestrating Productive Mathematics Discussions* book. The five practices are *anticipating, monitoring, selecting, sequencing,* and *connecting*. Based on how teachers described using the two NLC concepts of (a) rich mathematical tasks and (b) at least one of the five discussion techniques, we sorted them into three categories: high implementers, middle implementers, and low implementers. High implementers described incorporating both rich mathematical tasks and at least one of the *5 Practices* discussion routines into their instruction. Middle implementers described implementing one of the concepts: either a rich mathematical task or at least one of the five discussion practices. Low implementers did not describe using either NLC concept.

3.4.2. Analyzing teachers' social networks for mathematics instruction

We used our theoretical framework on human and social capital to examine teachers' collaborative communities. For each teacher, we examined all the people they referenced as collaborators throughout the interview, along with their response to the question – *Who do you to talk to in your school building regarding your math instruction?* (based on Frank et al., 2011 social network survey) – to create ego-centric social network maps describing networks of relationships around mathematics instruction and NLC work. We examined these networks across collective and non-collective participants, and across high, middle, and low implementers, to assess various implementation and community experiences. Across our 15 interview participants, we identified five types of networks that we termed *communities* to capture how they supported

Table 1
Participant information.

Name	Network	Years in Education	Years at Current School	Job Title	District - School
Marcy	Network A	19	2	7th Grade Math Teacher	Fairview-Junior High
Brooke	Network A	12	2	8th Grade Math Teacher	Fairview-Junior High
Tanya	Network A	12	4	8th Grade Math Teacher	Fairview-Junior High
Kelly	Network A	19	15	5th Grade Teacher	Fairview-Upper Elementary
Molly	Network A	10	1	5th Grade Teacher	Fairview-Upper Elementary
Josie	Network B	15	4	4–5 Teacher Consultant	Washington-Bristol Elementary
Matt	Network B	20	4	4–5 Teacher	Washington-Bristol Elementary
Paula	Network B	4	1	1–5 ELL Teacher	Washington-Brooke Elementary
Dione	Network B	30	3	6th grade Math & Science Teacher	Centerville-Middle School
Christine	Network B	35	3	8th Grade Teacher	Centerville-Middle School
Katie	Network B	5	2	4th Grade Teacher	Centerville-STEM Academy
Cassidy	Network C	20	10	1–5 Title 1 Teacher	Ashland-Arlington Elementary School
Jim	Network C	5	1	5th Grade Teacher	Ashland-Prairie Elementary School
Tina	Network C	13	4	3rd Grade Teacher	Ashland-Newport Elementary School
Naomi	Network C	10	10	5th Grade Teacher	Ashland-Dover Elementary School

that teacher's implementation. A person's ego-centric network, or community, can provide important information regarding their relationships and sources of information (Carolan, 2014).

Fig. 1 provides an example of an ego-centric social network map. The circles represent people. The blue circle signifies a study participant. In Fig. 1, Jane is our participant. The gray circles represent the people that Jane indicated talking to regarding her mathematics instruction. We see from this diagram that Jane reported talking about mathematics instruction with a 2nd-grade teacher in her school, who participated in the NLC during the previous year, and her mathematics instructional coach, who had not participated in the NLC.

3.5. Limitations

As with all research, this study has limitations. First, teachers' implementation levels for NLC concepts are self-reported. Thus, we categorized teachers only on the basis of what they said they did and not on the reported "quality" of instruction. A second limitation is our small sample. While 61 teachers participated in the three NLCs, only 15 participated in interviews. It is possible these 15 teachers may have differed somehow from the other 46 NLC participants in terms of integrating NLC concepts into their instruction and professional communities. By maximizing variation when recruiting teachers from all three networks and from a variety of districts, schools, and grade levels, we sought to minimize the effects of these factors. Additionally, each NLC was led by a different facilitator with differing levels of experience, which may have contributed to participants' understanding and willingness to try the concepts in their classrooms. Lastly, our analyses focus on teachers' experiences as participants in the NLCs, not their schools. This focus makes it hard to explain why isolated teachers may have struggled to implement NLC concepts.

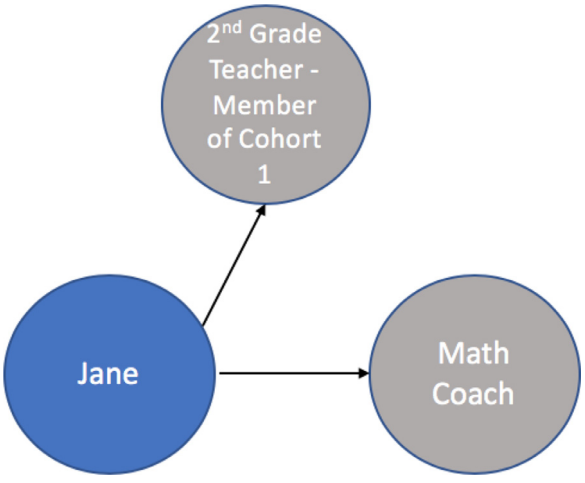

Fig. 1. Sample Ego-Centric Social Network Diagram.

4. Findings

4.1. Implementing network practices in teaching

Teachers reported incorporating concepts from their NLCs to differing degrees. Table 2 provides an overview of each participants' network, implementation level, and implementation community. As the table shows, all Network A interviewees were high implementers, while interviewees in Networks B and C implemented NLC concepts to differing degrees.

4.1.1. High implementers

High implementing teachers described incorporating both rich mathematical tasks and the five discussion techniques into their instruction. All five interviewees in Network A, three of six from Network B, and one of four from Network C implemented NLC concepts at a high level. For example, Matt, a 4–5th-grade teacher in Network B described using a rich mathematical task from the NLC and having students talk through their work: "I used one of those Nrich [online resource] tasks. It was about a monkey and eating peaches and fractions." On students' response, he shared:

Some of them hadn't been exposed to fractions, so they were more listening. It was not quite a fish bowl but kind of like a fish bowl. The kids that were able to do it, talked it out. They modeled how to explain it. It was really pretty cool.

Table 2
Participants' implementation levels and implementation communities.

Name	Network	Implementation Level	Implementation Communities
Marcy	Network A	High	Collective Participation
Brooke	Network A	High	Collective Participation
Tanya	Network A	High	Collective Participation
Kelly	Network A	High	Collective Participation
Molly	Network A	High	Collective Participation
Josie	Network B	High	In-School Mini-Communities
Matt	Network B	High	In-School Mini-Communities
Paula	Network B	High	Outside School Communities
Dione	Network B	Medium	Isolated Implementer
Katie	Network B	Medium	In-School Mini-Communities
Christine	Network B	Low	Isolated Implementer
Cassidy	Network C	High	Teacher-Created Communities
Jim	Network C	Medium	Isolated Implementer
Tina	Network C	Medium	Isolated Implementer
Naomi	Network C	Low	Isolated Implementer

Here, Matt described using the discussion practice of *selecting* students with problem-solving approaches to share.

All high implementers mentioned the challenge of time for incorporating rich mathematical tasks and discussion; however, they all found at least one opportunity to attempt these NLC concepts. From these early attempts, high implementers described looking forward to the next year after having a summer to search for rich tasks that better corresponded to their units. For example, Josie shared her hope, "over this summer… that I can look at how the year is going to be ran and then plug in more of those rich tasks from the Nrich and the other sites that we've learned about."

Drawing on their collective participation in Network A, teachers at Fairview Middle School had a systematic plan. Brooke described:

We have talked about as a team, in our whole building, bringing in more rich tasks for each grade level. Also, ultimately what we would like to do is find one or two rich tasks that we could give in 6th, 7th, and 8th grade so we can see how the students progress in their mathematic maturity.

These quotes imply that while high implementers may have only made a few immediate attempts to implement rich tasks and the *5 Practices*, these early attempts might lead to more routine incorporation in future years.

4.1.2. Middle implementers

Middle implementers used either a rich mathematical task or at least one of the *5 Practices*. One Network B teacher and three Network C teachers were middle implementers. Dionne from Network B described giving students a rich mathematical task but lacking time for discussion. Due to curricular constraints, she gave groups of students a rich mathematical task only after they finished the work required by the district-mandated curriculum. Dionne shared:

I brought them the party problem.… so, it wasn't really a… lesson like Alyssa is leading us through.… To my surprise, many of them did sit down and check through the problems, see what they could do, and I sat with them giving them some ideas. Once I got groups that were finishing, I started to put them in groups together, said let's talk about it, see what you're thinking, and have some of those conversations.

Although students worked in groups, Dionne was not able to facilitate discussion because she was working with students completing the required work. Dionne described the lack of flexibility from her district as the main impediment to incorporating rich tasks in the manner Alyssa modeled. The next school year, she did not expect this problem to be resolved and instead was planning on incorporating a workshop model in which students could attempt rich tasks in one station; however, she still would not be able to incorporate discussion since students would again work independently.

In contrast, Jim from Network C used the *5 Practices*. However instead of doing so with rich mathematical tasks, he used the discussion moves during traditional mathematics lessons by sharing student work under the document camera and leading a discussion. Jim noted that the NLC: made me more conscious of picking out students' work and bringing them to the front.… [The NLC] trained me to do that, to go around observing and picking certain students. Maybe one's more inclined one day to do one method, the other one to do another method, and another method, and just bring them up and show the class.

Here, Jim described incorporating *monitoring* and *selecting*. However, when prompted to describe the mathematics task, he shared that they were working with "the area method for multiplication. When they had to draw the box, and then divide it into half or fourths, or whatever, and multiply it, and write it inside of the box," which was not a rich mathematical task.

4.1.3. Low implementers

Finally, one Network B teacher and one Network C teacher did not describe using either rich mathematical tasks or the *5 Practices*. These teachers focused on more general aspects of teaching mathematics, like classroom culture, or the more concrete tools distributed in NLCs. For example, Christine from Network B described her takeaway from the NLC as "that the culture was important, that the importance of culture and problem-solving that encourages kids to keep going rather than shutting down." Likewise, Naomi from Network C focused on the Common Core State Standards for Mathematical Practice. She shared, "I feel like the Standards for Mathematical Practice, I feel like that's something I focused a lot on and used in my classroom this year." While these teachers had positive takeaways from the NLC, they only described implementing marginal NLC concepts.

4.2. Communities to support implementation of network learning

As expected, we found that collective participation assisted all five Network A interviewees in implementing NLC concepts at a high level. These teachers regularly collaborated inside and outside network meetings to clarify their understanding and translate NLC ideas into their teaching. All five Network A interviewees discussed working with school-based NLC colleagues outside NLC meetings to implement concepts. Marcy shared that the largest benefit of the NLC was:

> mainly just the collaboration with other teachers. The other teacher that I work with, she's also doing it, so we collaborate all the time. Just giving us some ideas on how we could implement some of the stuff into our curriculum, because we don't get a lot of time inside school. It was nice to have a lot of that time to just talk and discuss, and even with the eighth-grade teachers that are also in the program. Just all four of us getting together and working on it.

Marcy clarified how collective participation supported Network A teachers' abilities to implement concepts through collaborative planning. In Fig. 2, the collective participation panel contains the ego-centric social network for Marcy and her colleagues. This diagram shows that Marcy enjoyed connections with Brooke, Tanya, and another colleague who were all participating in the NLC.

Interestingly, we found that the four high-implementation teachers in Networks B and C cultivated similar collective participation experiences for themselves by forming other types of communities with which to co-implement NLC concepts. These cultivated communities took three forms: in-school mini-communities, in-school mini-communities with outside support, and teacher-created communities. Some teachers reported having no connections to people with knowledge of NLC concepts, and so we labeled them as isolated implementers.

4.2.1. In-school mini-community

Although Network B and C participants did not attend NLCs en masse with colleagues, two participants in Network B had school colleagues who attended the NLCs either with them or at other times. Josie, Matt, and another participant all taught in the same hallway in their school and regularly communicated with two colleagues from a prior NLC cohort (see Fig. 2). Josie noted:

A lot of the people that I value and trust in our school have already been through the [NLC]. Those are the people I would tend to talk to about things…. Those are my people. …it tends to be people that have already taken it. We've had, I think—I think there's six people in the building that have already taken it.

Drawing support and expertise from these people, both Josie and Matt reported using a rich mathematical task. Both also mentioned incorporating some of the *5 Practices* by facilitating student discussions of problem-solving strategies. The ties and shared knowledge, the social capital, that Josie and Matt had with members of the prior NLC cohort allowed them to troubleshoot problems when implementing NLC concepts. These teachers created an in-school mini-community around the program. Matt explained, "I do talk to my teaching partners. One of them is in the program… and the other did it the year before. We have our own little mini math learning community, which is pretty nice." This mini-community had the potential to increase human capital from

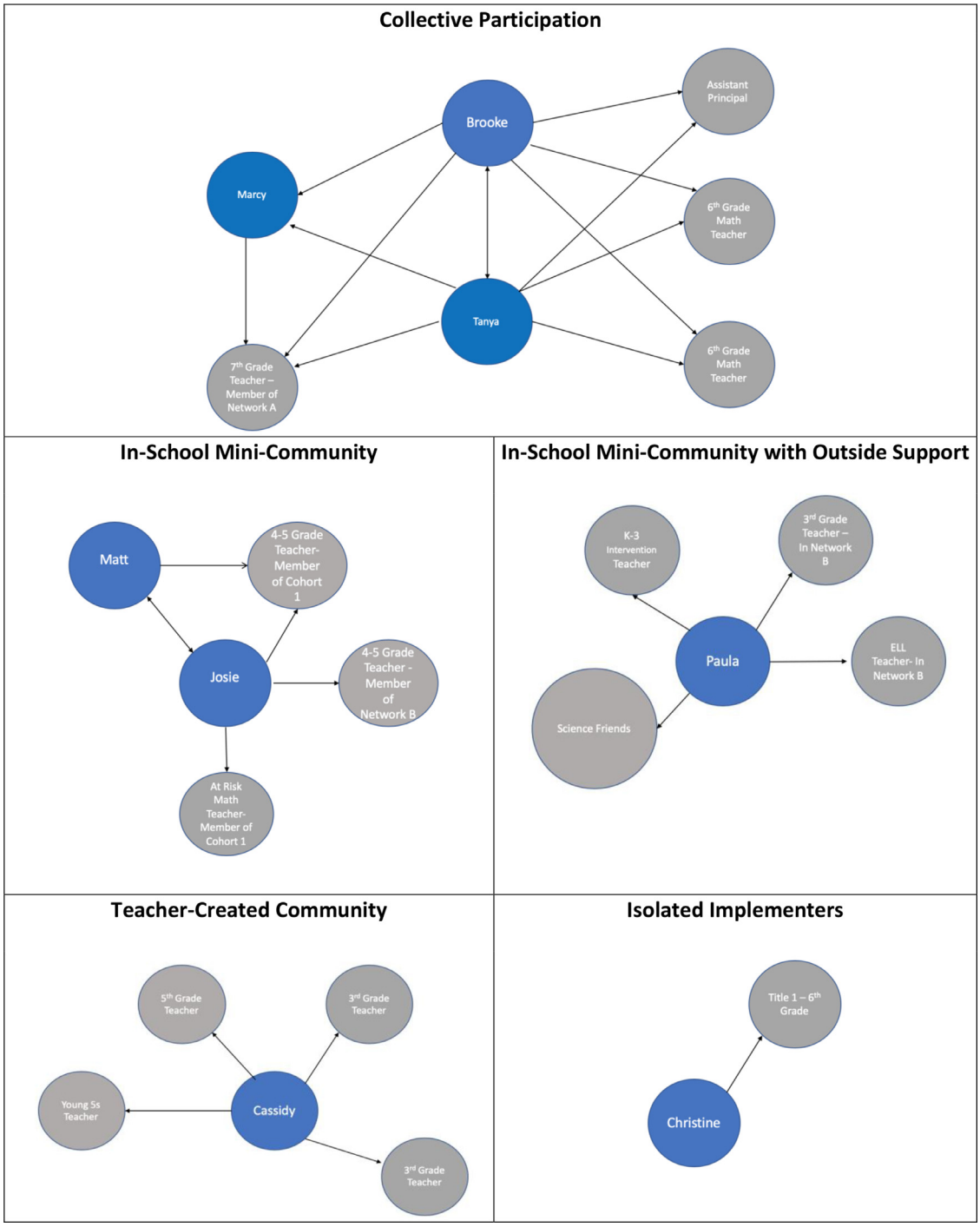

Fig. 2. Ego-Centric Social Network Diagrams.

the NLC through social capital among colleagues who had attended the training.

Importantly, developing a mini-community did not guarantee high implementation of NLC content. For example, Katie in Network B had a community similar to that of Josie and Matt's. To support her mathematics instruction, she reported frequently talking to her grade-level team partner and the special education teacher who both participated in the NLC the previous year. Even with this support, Katie never mentioned using a rich mathematical task. However, she did report using the *5 Practices* daily when reviewing homework. She shared:

> It's harder for the kids who always like to know the answer to step back and let someone else show their work. That's been interesting. If I walk around and I pick, I want them to show their work, and it's not the usual people who always get picked, it's been more of a challenge for them.

Katie highlighted the discussion practices of *monitoring* and *selecting* students to share their work based on the strategies used. However, she theorized that rich mathematical tasks were too difficult for her students. In fact, she cited rich mathematical tasks as the least benefi-

cial aspect of the NLC. Katie shows that simply the presence of a mini-community with knowledge of NLC concepts did not guarantee high implementation. In her case, Katie had personal beliefs regarding her students' abilities that limited her willingness to incorporate rich mathematical tasks without modifications.

4.2.2. In-school mini-community with outside support

One Network B participant who attended the NLC with school colleagues identified colleagues outside of her school with similar teaching beliefs and knowledge for implementation support. Paula worked as an English Language Learner (ELL) teacher and described using rich mathematical tasks with all her students. She also highlighted incorporating the *monitoring* and *connecting* discussion practices by taking notes on different approaches students were using and then discussing with students how repeated addition connected to multiplication.

Paula attributed her ability to implement NLC concepts both to some school colleagues who also participated in the NLC and to her experience during the prior school year in a similar PD program focused on science. She took what she learned in the mathematics NLC to her "science friends" in other schools (see Fig. 2). She described these science friends as essential because she had little opportunity to talk with her colleagues. She reported talking:

> more about this program when with my science friends, because a lot of them are also in special ed. And they're math teachers and so it's interesting to talk about some of the practices that we're uncovering that are so focused on mathematics, and then they're already involved in something that's focused on science. I think it makes the transfer easier in a way.

Paula described her science friends as a community that formed during a science PD program similar to the mathematics NLCs. This community had continued even after the formal program concluded. For Paula, her science friends had become a community that allowed for the exchange of social capital resources pertaining to both science and mathematics instruction.

Additionally, as an ELL teacher, Paula had the ability to push into classrooms and support mathematics and science instruction. As a part of her job, she could discuss mathematics NLC concepts with teachers. She shared:

There are a couple of teachers who are within the… network as well as a couple who are not, where I go into their classrooms during math time and I provide support to my English Language Learner in that time. That's definitely a place where we talk about math, and we talk about resources that work, or resources that might be helpful, share ideas from the NLC with them, and maybe find out if something they've tried worked.

While Paula had implementation support similar to Josie and Matt, she attributed her ability to implement NLC content to her science friends. Further, as an ELL teacher, Paula's role gave her a unique opportunity to collaborate and share NLC content with colleagues.

4.2.3. Teacher-created community

Similar to Paula, a solo attendee in Network C also became a teacher leader and built a community in her school. Cassidy was a Title I reading teacher and oversaw the mathematics tutors and after-school program, which put her in regular contact with classroom teachers (see Fig. 2). As a Title I teacher, Cassidy had opportunities to share resources with teachers. "Because of my role, I kind of have that advantage that I kind of interact with everybody and I share students with everybody." She explained, "The *Five Practices* book that we got. I shared that with the fifth-grade teachers. We shared a few chapters back and forth. They've utilized that in their classrooms too." She went beyond Paula's collaboration practices by asking colleagues to read NLC materials. Consequently, the *5 Practices* book built her colleagues' human capital and became a shared knowledge base. Cassidy also found one fifth-grade colleague willing to try NLC concepts:

> I'm like, "Would you mind doing this if I gave you homework?" She's like, "Sure." I sent her the chapter of the book that we wanted to base stuff on. She's like, "Okay. I read it. What do we do now?"

Working collaboratively around the *5 Practices* book gave Cassidy a school community with whom to discuss and implement NLC concepts. In sharing resources with a colleague willing to do the "homework," Cassidy built a mini-community around NLC concepts.

4.2.4. Isolated implementers

In every case, high implementers reported having or cultivating a community for implementing NLC learning, while half of the middle and low implementers attempted implementation in isolation. For example, while low implementers Naomi and Christine each discussed mathematics with school colleagues, none of their relational ties had participated in the NLCs or received NLC content like Cassidy's colleagues (see Fig. 2 for Christine's ego-centric social network). Consequently, their relational ties lacked knowledge aligned with NLC content. Two examples illustrate these challenges.

Tina was a third-grade teacher and middle implementer who shared that participating in the NLCs made her "be very purposeful when I teach. Again, try to think about what mistakes are going to be made while I'm teaching, or before I teach, and, actually, adding to what I teach." When asked how she used NLC concepts, Tina recounted using the bar method to teach students to add and subtract fractions. While not a focus of the NLC, Tina described teaching this problem-solving strategy through the *5 Practices*. She shared:

We're talking about the five practices, and we're talking about how we select kids, and how we anticipate what they're going to say or do. Then we select those certain kids to show their work, based on that anticipation. I've been utilizing that a bit more. Where I think about who's going to say the right answer, who's going to say the wrong answer, or who's going to say the wrong answer, but I know it's very close. They just, maybe, happened to do the math wrong. I really try to show those examples so that we can learn from our mistakes.

Tina described using four of discussion practices but not any rich mathematical tasks. She cited her implementation community as her curriculum and her third-grade colleague. Her appreciation for the curriculum and her co-planning with a colleague who also used the curriculum may have constrained her from attempting rich mathematical tasks.

Naomi was a fifth-grade teacher and low implementer. When asked how the NLC influenced her teaching, Naomi cited the CCSS Standards for Mathematical Practice and having students reflect on the mathematical practices they used when solving problems. She described, "I might give them a story problem and then they have to write about it, like how did you do this. I'll say what goals from mathematical practice are we thinking about? Then they'll look at the SMPs." For her implementation community, Naomi collaborated with her district's mathematics curriculum coordinator and a couple of colleagues who had not participated in the mathematics NLC. Consequently, they lacked shared knowledge of NLC concepts to support Naomi. Without social capital for implementation support, Naomi only described implementing marginal NLC concepts.

5. Discussion

Our findings support previous research on the importance of collective participation in professional learning (Garet et al., 2001), and we build on prior work by illustrating how some teachers cultivated unique configurations of communities for supporting instructional change. Consistent with previous research, teachers reported implementing PD concepts to varying degrees. Examining whether teachers used the two NLC concepts of rich mathematical tasks and *5 Practices* discussion techniques, we classified nine interviewees as high implementers, four as middle implementers, and two as low implementers. We found impor-

tant relationships between teachers' implementation levels and their instructional communities. First, consistent with prior research, we found that teachers who attended the NLC with multiple school colleagues – those with collective participation – implemented NLC concepts at a high level, due in part to the collective's social capital. But, critically, we found that collective NLC participation was not the only practice that supported high implementation. We identified three additional types of implementation communities. First, Josie and Matt created an in-school mini-community with each other and colleagues from a previous NLC cohort. This shared knowledge enabled development of social capital through collaboration, even when teachers attended the NLCs at separate times. Second, Paula reported an in-school mini-community with outside support. While Paula had school colleagues in the NLC, she collaborated with like-minded "science friends" from a prior PD. Third, Cassidy created her own in-school community by having a colleague read the *5 Practices* book so they could apply the practices together. As such, Cassidy recreated NLC learning with her colleague to simulate collective participation. As these examples show, paired or singleton network attendees developed alternative sources of social capital for implementation. However, isolated implementers did not report any connections to colleagues with NLC knowledge and were less successful in applying their learning. This finding illustrates that a lack of collective participation – whether *actual* or *simulated* – inhibits teachers' implementation of NLC concepts.

Although we cannot be certain why various teachers were able to cultivate collective participation communities when others could not, human and social capital theories provide possible explanations. For example, Josie and Matt taught the same grades and had classrooms near one another, both factors that influenced their likelihood to collaborate and form mutual social capital ties (Horn et al., 2020). Although they were the only NLC attendees from their school, their social capital with one another and colleagues who had previously attended the NLC made them ripe for collective learning. Illustrating a different dynamic, Cassidy drew not only on social capital but also on her human capital as a teacher leader. With colleagues viewing her as having elevated status and the designated role of supporting teacher learning, Cassidy was presumed to have the knowledge (human capital) to teach others. This was evident when her colleague finished reading the *5 Practices* book and said, "Okay. I read it. What do we do now?" Paula also possessed both forms of capital, with her human capital evident in her prior experience implementing reform and her social capital evident in her network of science teaching friends. Paula's case shows how these forces can be mutually reinforcing, as her teaching knowledge grew alongside her social ties.

The five isolated implementers lacked a social network to support implementation and could rely only on human capital and individual interest in implementing NLC concepts. In three cases, this was enough to implement at least one concept, but without an implementation network, none of the five isolated implementers attempted both concepts. These cases show the limitations of human capital without social capital. Comparing isolated implementers to others, we also see that human capital appears to function differently for those with and without social capital to support its development and application. Without a community to support implementation and manage potential challenges, the human capital advancements of attending the NLC are minimized. This finding illustrates the important synergy of human and social capital, reflecting prior research on the critical role of social capital (above and beyond human capital) for enhancing teachers' practice (Daly et al., 2014; Yoon et al., 2017). Of course, this does not necessarily mean that a teacher who attends an NLC alone and does not find or create an implementation community would be unable to fully apply their learning. We do believe that individual teachers could rely on human capital alone to implement their learning; exactly how this unfolds is an important direction for future research.

As a final consideration, we entered our study assuming that teachers valued and were interested in implementing NLC concepts. However, this is not necessarily true. Some low or middle implementers might have intentionally decided not to implement one or both NLC concepts because they did not see value in them for their students. While our participants did not report this in interviews, it is a possible explanation for middle or low implementation.

5.1. Contributions to the literature

While our findings support prior research on the benefits of collective participation in professional learning (e.g., Darling-Hammond et al., 2017; Desimone, 2009; Garet et al., 2001), we also add to the literature in three key ways. First, we extend research on collective participation to the unique setting of NLCs. By design, one strength of NLCs is sharing and collaborative learning among educators from different schools (Katz & Earl, 2010). Yet, our study shows that collective participation in NLCs has distinct advantages for supporting teachers' implementation of network learning. Although teachers who attend NLCs as singletons can compensate for the lack of collective participation in creative ways, there are still clear benefits for teachers who attend with colleagues, as their implementation community extends naturally across their NLC and school contexts and they do not need to find or create a compensatory community. That is, their social capital is sustained across spaces, allowing for shared learning in both the NLC and school.

Second, and most distinctively, we add to the literature by detailing creative ways in which teachers who attend NLCs as singletons or with one school colleague can establish and maintain a local community to support implementation of NLC learning. These teacher-constructed communities – whether mini-communities of school colleagues who *ever* attended the NLC, or communities with like-minded teachers from outside the school, or within-school teacher-created communities to simulate collective participation – reinforce the notion that collective participation is critical for learning, but they add nuance to the structure and location of collective participation for teacher learning. As a result, they offer alternative possibilities for how collective participation could be intentionally designed and how singleton NLC participants could strive to intentionally create supportive communities to reinforce and strengthen their learning.

Third, the experiences of Network A teachers provide insight into one of the means by which collective participation supports implementation of new learning. Reflecting the notion of internal accountability through which school colleagues hold each other to meeting shared norms (Elmore, 2004), it was clear that Network A teachers were driven to change their practice in part because their colleagues were changing theirs. There were shared expectations that everyone would attempt rich mathematical tasks and the five discussion practices, and so everyone did. In espousing the benefits of collective participation, Network A facilitator Katherine noted the need for teachers to "go with somebody else that you can talk to in between the meetings" and to have "partnership" with others to share this work. Beyond the collegial facets, collective participation within Network A also enabled teachers' professional growth by establishing shared language and expectations for instructional improvement to which they then held one another.

5.2. Implications

This new perspective on professional communities can help teachers and PD providers intentionally cultivate innovative communities for implementing instructional change. NLC providers or facilitators could provide singleton participants with strategies for cultivating implementation communities rather than leaving participants to struggle alone. This could include strategic grouping of teachers in the network, such as by grade level or district to allow other types of communities to form. Professional learning providers could similarly help teachers understand the need for an implementation community.

This research also provides a new perspective on how school leaders could think about allocating PD time and resources. For example, it may be valuable to always send at least two teachers to NLCs for collective participation. Additionally, if resources are limited, leaders could consider sending people across years to build an in-school mini-community. Paula's case demonstrates that aligning PD experiences to a particular philosophical orientation allows experiences to build sequentially and helps teachers connect with like-minded colleagues to support implementation. As such, school leaders could prioritize PD models with shared philosophical orientations to create coherent philosophical communities to support changes in practice. Finally, both Cassidy and Paula show how teacher leaders or specialists can bring ideas to others and develop collective work. Positions such as Title-1 and ELL teacher, where teachers push into multiple classrooms, enable teacher leaders to facilitate new learning across colleagues, which differs from co-planning or other collaborative practices.

5.3. Directions for future research

This study offers a number of compelling directions for future research. One important avenue for future inquiry is to test whether NLC facilitators and school leaders can guide teachers toward cultivating their own implementation communities to support instructional change. To this end, future research could examine the extent to which such guidance leads to enhanced teacher collaboration and implementation of new learning. Researchers could also study the characteristics of NLCs that contribute to participants building larger social networks for implementation, which could include examining participants' mathematics social networks before and after participating in an NLC. Conversely, future research could consider whether and under what conditions isolated NLC attendees are able to implement their learning on their own. Although this study of 15 teachers did not generate examples of singleton attendees who became high implementers, another study might find such examples and could identify how such teachers are able to draw on human capital alone to change their practice. Additionally, future research could delve more deeply into how teachers implement new knowledge from NLCs through case studies of individual teachers. In the present study, we assessed teachers' implementation through self-reports with validation from network meeting observation notes. But, deeper inquiry into how NLC learning shows up in teachers' practice could more fully examine these processes. Finally, future research could examine the roles of school culture and local context by considering how different schools support or hinder development of teacher communities to support NLC learning and implementation. Indeed, Opfer and Pedder (2011) conceptualize teacher learning as occurring within embedded systems, such that take-up of learning is impacted by characteristics of the teacher, the school, the district, the professional learning experience, and the broader context. It may be, for example, that local norms or expectations – such as tight curricular expectations – limit the extent to which teachers can implement NLC concepts. Insight into the dynamics of such embedded contexts is important for creating NLC experiences that truly strengthen teaching and learning.

6. Conclusion

Teacher professional learning is essential if teachers are to change their practice to align with the increased expectations of career-and-college ready standards (Schmidt, 2012). NLCs provide a promising structure to increase teacher knowledge and foster collaboration across schools. This study suggests that while NLCs can be beneficial, PD providers and school leaders should find ways to promote collective participation in NLCs. However, our results show that collective participation can take many forms. Overall, collaboration and a form of collective participation provide an essential support for implementing NLC concepts in classrooms.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A: Participant interview protocol

What is your position in this school?

(1) How many years have you worked in education?
   a How many in this school?
(2) Why did you decide to participate in the math network improvement communities?What elements of the math network improvement communities have you found most beneficial to your teaching practice?
(3) What elements of the math network improvement communities have you found to be the least beneficial to your teaching practice?
(4) Overall, how has the experience of participating in the math network improvement community influenced your teaching practice?
(5) Can you tell me about an instance that you applied something discussed in the math network to your classroom?
   a In this instance how did the students respond
(6) What have been your greatest obstacles to implementing the tasks and content from the improvement communities?
(7) Do you talk about the math learning network with colleagues that are not a part of the network?
   a. With others that you lesson-plan?
   b. What do you discuss?
   c. What is their response?
(8) Who do you talk to you in your building about your math instruction?

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