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Identifying the Roles of Science Teacher Leaders in Practice

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ABSTRACT

Science teacher leaders have been identified as an important lever for the implementation of science education reform. However, science reform implementation is locally controlled and not uniform across districts; therefore, the work of STLs within a reform context can vary. In this descriptive case study, we explore the work of 11 science teacher leaders who support science education reform in a variety of organizational contexts. Through the analysis of multiple data sources, we describe the roles that these science teacher leaders take up in their work and identified how variation in these roles related to localized contexts and priorities for science education. We identified seven roles that science teacher leaders enacted in their work: activist, ambassador, collaborator, innovator, networker, organizer, and translator. We found that each science teacher leader prioritized one or two of these roles in their work, with other roles supporting these primary roles. While most science teacher leaders named some aspect of collaborator, networker, and ambassador as part of their work, only the district-level science leaders named translator. Furthermore, there were important differences across the science teacher leaders in our sample, which related to their district and/or school contexts. We end with suggestions for leveraging the existing variation in the work of science teacher leaders for designing professional development including opportunities for science teacher leaders to surface the various roles they occupy in their work and to provide choice in professional learning based on those roles.

KEYWORDS

Leadership practices; NGSS reform; science teacher leadership

Introduction

Science teacher leaders (STLs) have been identified as important levers to support improvement in science education (e.g., Whitworth et al., 2022). This is because STLs have the content knowledge and experience in classrooms needed to identify important conceptual and pedagogical shifts in practice and resources to support the implementation of science educational reform (Bae et al., 2016; Whitworth et al., 2022). Reform adoption efforts are not uniform across districts and are often driven by local decision-makers (Spillane, 1996) who may not have the specialized content and pedagogical knowledge of STLs (Spillane & Hopkins, 2013). These localized decisions could lead to variations in the role(s) STLs enact in reform implementation locally. Therefore, the specific goals and objectives for the work of STLs within science education reform could range from introducing teachers to new

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standards, developing, choosing, and piloting new curricula, mentoring and coaching teachers in reform-based science teaching practices, and even supporting school administrators to understand and provide resources for science reform efforts (National Academies of Sciences, Engineering and Medicine [NASEM], 2015, 2022).

Given the potential for STLs to support the landscape of science education reform implementation and that variation in reform implementation can lead to different priorities for the work of teacher leaders, we argue it is important to identify the diverse roles STLs take up in local reform efforts. In this way, researchers, administrators, and science teacher educators can better support STLs and develop professional learning resources that align with the complex nature of STLs' practice (Campbell et al., 2019; Cobb et al., 2009). In this descriptive case study, we investigate the work of STLs in a state that has been in the process of adopting the Next Generation Science Standards (NGSS Lead States, 2013) for 10 years. Specifically, we ask, 1.) What roles do STLs take on in the context of NGSS reform? 2.) How are these roles shaped by STLs' local organizational context and priorities for educational reform?

Conceptual framework

We take the perspective that through individual actors' interactions with their environments, they come to understand both their roles and position in local practice (Holland et al., 2001; Holland & Lave, 2009). Roles are clusters of behavior, which are "expectations attached to positions in networks of relationships" (Stryker, 2001, p. 227). As roles become internalized and recognized by others, science teachers develop identities as leaders (Sinha & Hanuscin, 2017). Several studies on STLs have utilized the concept of identity to understand how STLs develop (Criswell et al., 2018a; Criswell et al., 2018b, Sinha & Hanuscin, 2017; Wenner & Campbell, 2017). Each of these studies highlighted the need to better understand the ways in which the organizational context matters for the ways in which STLs enact their work as leaders. Similarly, a review of research on professional identity noted the need to focus on the professional contexts of teacher identity to better understand the interaction between their sense of self and their work environment (Beijaard et al., 2004). Here we focus on and identify clusters of behaviors and practices (roles) of STLs in relation to their work in schools and districts to contribute to our understanding of how STLs engage in their work.

Definitions of STLs

Teacher leaders have been defined as teachers who lead in and beyond their classroom in collaboration with others to improve educational outcomes and influence educational change (Harris, 2005; Katzenmeyer & Moller, 2009; Rhoton & McLean, 2008; York-Barr & Duke, 2004). In science, definitions of teacher leaders have varied across the literature and generally are described as science teachers who advocate for and work to improve science education through a variety of means (Whitworth et al., 2022). Teacher leaders draw from their own experiences and share their passion for teaching to support and empower others (Fullan, 1993) and improve student learning conditions and outcomes (Fairman & Mackenzie, 2015).

The work of teacher leaders exists along a continuum of formal and informal activities from individual professional learning and action to more collective improvement efforts

that expand beyond individual classrooms and schools (Fairman & Mackenzie, 2015). Examples of formal STL positions from the literature include school-site STEM coaches and resource specialists (Wenner, 2017), department chairs (Rigano & Ritchie, 2003), mentor science teachers (Gul et al., 2019), and district science coaches (Luft et al., 2016). Informal STL roles include classroom science teachers who share resources from participation in professional development (Howe & Stubbs, 2003) or those who participate in local and regional science education organizations (Olson & Labov, 2014). Researchers have found that STLs with informal roles did not identify themselves as leaders and they associated leadership with more formal roles outside of the classroom (Hanuscin et al., 2012; Sinha & Hanuscin, 2017). Therefore, it's important to look beyond job titles and investigate the ways in which STLs approach their work.

Practices of STLs

Similar to the research that defines STLs, research on articulating the work of STLs has relied on general descriptions of teacher leaders' practices (Bae et al., 2016; Lotter et al., 2020; Wenner, 2017). For example, a common framework utilized in describing the work of STLs is York-Barr and Duke's (2004) seven dimensions of leadership practice. These dimensions include organization and management of improvement efforts; curriculum work for their school or district; professional development of colleagues; participation in school-level improvement teams and initiatives; involvement with parents or with the community; contributing to professional organizations for teaching; and acting as a cooperating teacher or instructor of pre-service teachers (York-Barr & Duke, 2004). The research reviewed below has noted important commonalities between the work of STLs and the dimensions of practice articulated by York-Barr and Duke, as well as important differences that the authors relate to the unique needs of teacher leaders in science education improvement efforts.

In an analysis of a group of urban elementary STLs, Wenner (2017) found that these STLs prioritized some of the leadership practices described by York-Barr and Duke over others. STLs had responsibilities related to managing and ordering supplies for science lessons, creating lesson plans for other teachers that aligned with science education reform efforts, and organizing professional development for other teachers. One of the work-based practices surfaced in Wenner's study, organizing and distributing material resources for inquiry instruction, was a new practice not identified in the York-Barr and Duke's original review. Further, Wenner hypothesized that these differences noted in STLs' practices were related to context-dependent features of their work.

Another study utilized the work of York-Barr and Duke (2004) to create a typology of the work of teachers based on a compilation of STL dispositions, work practices, and areas of influence (Bae et al., 2016). They identified three types of STLs, 1.) instructional innovator, 2.) professional learning leader, and 3.) administrative teacher leader. Instructional innovators are classroom-based STLs with a focus on student learning. They model best practices for other teachers, have expert knowledge in teaching and learning science, and are often chosen as mentors for novice teachers. Professional learning leaders focus on teacher learning through collaborative processes. These leaders rely on relationships and collaboration with other teachers. The last type, administrative teacher leaders, focus on system-level change and are involved in policy decision-making at the school and/or district

level. These STLs rely on and build networks with internal and external stakeholders to improve science education.

One study on rural science and math teacher leader development focused on the practices that emerged as classroom teachers engaged in a STEM leadership development program (Lotter et al., 2020). They found that over time the STLs evolved from focusing on their classroom to reaching out to other teachers in their school/district. The emergent practices of these STLs included collaborating with other teachers, providing more and better opportunities for students to learn science and math, building relationships with students, and developing community connections. These STLs described wearing multiple hats and having to navigate between multiple and intersecting roles including classroom teacher, content specialist, and school improvement. These STLs reasoned that the multiple hats were related to the rural nature of their district and the limited school faculty and staff to support all the needs of the schools.

Each of these studies sampled STLs in similar contexts, urban K-8 STLs from high-achieving schools (Wenner, 2017), middle grades STLs in urban contexts all in similar phases of NGSS adoption (Bae et al., 2016), and rural math and science high school classroom teacher leaders (Lotter et al., 2020). The STLs in their samples were either full-time classroom teachers (Lotter et al., 2020), full-time science coordinators outside of the classroom (Wenner, 2017), or a mixture of both (Bae et al., 2016). Furthermore, both Wenner (2017) and Lotter et al. (2020) describe content-specific practices, such as vertical planning of content and material organization, that justify identifying how STLs might be unique in what they do as leaders. While each of these studies contributes to our understanding of the work of STLs in particular contexts, the homogeneity of their samples limits the potential to generalize their findings to STLs in different organizational and geographic contexts. In this study, we contribute to this gap in the literature by identifying the roles that STLs take as they support NGSS implementation reform across different districts and positions within the educational system.

Methods

We utilized descriptive case study methodology (Merriam, 2009) to identify the roles of a diverse set of STLs from a statewide network of STLs supported by the Exploratorium, a large science museum on the West Coast. Descriptive case studies are exploratory in nature and provide rich descriptions of the phenomena under study (Merriam, 2009). In this case, we explored the work practices of a group of STLs supported by the museum network. We analyzed data collected from STLs as part of a larger design-based research study (Cobb et al., 2003) focused on understanding the varied nature of science teacher leadership across the state so that the museum could better support the STLs. In this paper, we report on our analysis of the data collected on STLs' contexts and activities, not on the professional learning design influenced by this research (Heredia et al., 2022).

Network context and sample

The Exploratorium established the STL network in 2016 to support the implementation of the NGSS across the state. The museum recruited STLs from different areas of the state to encourage equitable distribution of resources to all regions and the inclusion of a variety of

roles for STLs defined by their context and experience. To participate in the network, all STLs must work formally or informally with other science teachers as a part of their work. All STLs need to go through an application process to be involved in the network.

In 2020, we recruited 24 STLs who were already members of the museum's statewide network to participate in additional professional learning opportunities to support their work as leaders. Each STL filled out an application and the museum staff selected the participants to include a range of geographic regions in the state and a range of teachers served by each STL. The 24 STLs represented a variety of grade levels (K-12, K-6, 6–8, and 9–12), the number of teachers supported (5–130 teachers), and represented 14 of the state's 58 counties and some of the most rural districts as well as the largest and most urban school districts in the state.

Sources of data

We collected a variety of data from the selected participants including their application to the professional learning program, semi-structured interviews, and a representative sample of a resource they use to support science teacher learning in their school and/or district. The application to participate in the study asked STLs for important information about the organizational context of their work as leaders. This information included their official job titles, the primary entity (e.g., school, district, county) they worked for, how much of their time was allocated for direct work with other teachers, the number of teachers they supported, their school context [public, independent, or charter; Title 1 status; grade levels], and their responsibilities and goals as an STL.

We used interviews as the primary source of data to learn how the STLs described their experiences and activities as teacher leaders. In this way, we were able to hear how individual STLs interacted with their work environment to understand their roles and responsibilities as leaders. We asked them to define science teacher leadership and how these ideas reflected their work as an STL. Additionally, we asked them 1) to describe their typical week as an STL and 2) to share a representative example of a resource they developed and/or shared with other science teachers and how that artifact reflected their work as a leader.

Data analysis

We began our analysis by creating a conceptual matrix (Miles & Huberman, 1994) of the 24 STLs in our sample. We used the data collected in their applications to organize STLs according to their target of influence (classroom, other teachers, and district) to build off the work of Bae et al.'s (2016) typology of STLs. To be included in the network, all the STLs had to engage other science teachers in professional learning as a focus of their work, therefore we used the areas of the classroom and district influences to sort the STLs into categories. We ended up with three categories of STLs: district science education specialists or STLs who worked full-time supporting science education reform efforts (11 STLs); teacher on special assignment (TOSAs), or classroom science teachers who had some of their time bought out by the district for teacher support (3 STLs); and classroom science teachers who taught science full-time and acted as leaders inside and outside the classroom (10 STLs).

Next, we reduced the sample to include comparable STLs from each of these three categories using the data from their application where they described the goals and objectives of their work as leaders. First, all the classroom science teachers taught at the secondary level, so we excluded district science education specialists and one TOSA who only worked with elementary teachers. Second, STLs needed to identify primary responsibilities related to science education because of the unique requirements related to leading in science (Whitworth et al., 2022). Therefore, we excluded STLs that focused on multiple content areas with responsibilities that extended beyond science education reform. Lastly, we wanted to focus on STLs that had identified leadership positions within their school or district, as we were interested in understanding the relationship between their work context and their roles as leaders. Excluded STLs had their own consulting business or held leadership positions within organizations external to their school or district. Table 1 provides information about the STLs in our final sample, which included three district science education specialists (Alexa, Ellen, and Tobias), two TOSAs (Kaia and Lucy), and six classroom science teachers (Allison, Alvin, Aria, Mateo, Michelle, and Rico).

We used inductive coding and comparative methods to analyze data from each of the sampled STLs (Merriam, 2009). First, we used inductive coding of the interview questions to identify how the STLs described their work. Two researchers coded each interview. For each STL, we read through the interview transcript and wrote a research memo that summarized repeated practices and behaviors described by the STL, as well as features of the work environment that STLs noted as they described their practices as a leader. For example, one STL repeatedly discussed connecting other teachers in her district with supplies, lessons, and activities for their science instruction and related that need to the rural nature of her district. Other practices that supported this work included checking in with teachers to understand their needs and leveraging local and external connections to provide teachers with what they needed.

Then, the researchers met and read through their memos and examples from transcripts of the different practices STLs described. These conversations led to the adjudication of identified clusters of behaviors and practices for each STL. Next, we compared these clusters of behaviors to what is described in the literature on teacher leaders and identified roles based on the data and the literature base. We were able to name five roles based on this process and information from the literature including ambassador (Wenner & Campbell, 2017),

Table 1. Description of sampled STLs' leadership job titles and number of teachers supported.

STL*	Job Title	# of Teachers Supported
District Science Education Specialists		
Tobias	Curriculum Specialist	83
Alexa	Science Learning Design Coach	130
Ellen	Science Instructional Support Specialist	55
Classroom Science Teachers		
Alvin	High School Biology Teacher	9
Michelle	High School Life Science Teacher	2
Aria	High School Life science teacher	10
Mateo	7th grade science teacher	36
Allison	8th grade science teacher	25
Rico	7th grade science teacher	6
Teachers on Special Assignment		
Kaia	Teacher on Special Assignment and science teacher	5
Lucy	Teacher on Special Assignment and science teacher	100

*All names are pseudonyms.

Table 2. Example transcript with identified practices coded as roles.

Excerpt from transcript	Practices identified	Coded role
But it's largely as just a support of other teachers in whatever they need. So often that means connecting them with supplies. We're very rural, we live two hours away from a store. So, where somebody might be able to come up with a lesson plan and say, "Hey, I need a straw." Where we are that's not a possibility. And so, it's about connecting teachers with supplies, connecting teachers with lessons, connecting teachers with what our district has	Identifying what teachers need Providing them with those resources	Networker
And then also being a cohort to each teacher because each of our teachers operates in a bubble our K through two teacher is the only K through two teacher.	Partnering with teachers	Collaborator

collaborator, innovator, and networker (Bae et al., 2016), and organizer (Lotter et al., 2020; Wenner, 2017). However, we had two more clusters of behaviors and practices that were not present in the literature, one cluster of behaviors related to improving science teaching and learning for marginalized youth and the other related to creating coherence across multiple stakeholders within an organization. We named these roles activist and translator respectively.

Once we had an agreed-upon set of roles with keywords and their associated behaviors and practices, we went back through the interview transcripts to code for the presence or absence of each role (Table 2). To determine the comparative importance of each role for an individual STL, we divided the number of codes for each role by the total codes applied across the interview questions. We used the percentages to develop a profile for each STL to illustrate the relative emphasis they placed on each of their roles. Each STL's profile was specific to their individual enacted practice and provided an at-a-glance view of all the roles an STL described and the relative emphasis they put on each role in their interview responses. Once we had a leadership profile for each STL, we reviewed other pieces of data (their application and artifact of leadership practice) to confirm or disconfirm the presence of these roles.

To answer the second research question, we returned to the conceptual matrix and added the leadership profiles to the information about the contextual factors of STLs' work environments from their application. We also returned to our original research memos and added features of the work environment that STLs noted as they described their work as leaders. We sorted the matrix to group STLs by their area of influence (classroom, district, or hybrid district/classroom) to see if and how the STLs were similar to one another within each group (Table 3). We noted some similarities related to the area of influence; however, this did not describe all the variations in STLs' profiles. To attempt to better understand the variation within each group, we wrote memos for each area of influence that summarized each STLs' profile of roles and features of the work environment they connected to those practices. We then pulled out common themes across STLs within each group about the relationship between STL profiles and their work environment.

Findings

We identified seven different roles that STLs described in their interviews: activist, ambassador, collaborator, innovator, networker, organizer, and translator. Each STL described characteristics of multiple roles, with an emphasis on one or two primary roles, and mentioned other supporting roles. In the following sections, we provide a brief description of each role and the behaviors and practices that make up that role. Then we describe STLs' profiles,

Table 3. STLs' identified roles. Shaded cells reflect the emphasis of each role by the STLs. Black cells reflect the primary role, dark gray cells are secondary roles, light gray cells are less emphasized roles, and white cells were not identified.

STL	Activist	Ambassador	Collaborator	Innovator	Networker	Organizer	Translator
District Science Education Specialists							
Tobias							
Alexa							
Ellen							
Classroom Science Teachers							
Alvin							
Michelle							
Aria							
Mateo							
Allison							
Rico							
Teachers on Special Assignment							
Kaia							
Lucy							

consisting of multiple roles they exhibited in their work, organized by the three areas of influence: district science education specialists, TOSAs, or classroom science teachers.

Activist

The STLs who acted as activists in their work took steps to reduce the impacts of racial and linguistic harm and oppression within science education. Activist STLs were reflexive of their practices as science teachers. They reflected on their instructional practices, such as lesson design, assessment, and grading, to identify how their instruction might reproduce inequities in the classroom. Through connections with external organizations or through their own research, they addressed the gaps in their instructional practice to make their teaching more equitable. This work included STLs designing and testing new strategies and taking risks in their classrooms to attend to issues of harm and oppression in science learning spaces. We identified three classroom science teachers in our sample who took on the primary role of activist, and all three district science education specialists mentioned aspects of the activist role.

Ambassador

When STLs took on the role of ambassadors, it involved being the "go-to" person for NGSS or science instruction in their district or school. STLs as ambassadors had strong visions for science instruction that they enacted in their classrooms and shared with others. They mentored student teachers and beginning teachers into the profession of science teacher and supported them to realize their vision for science education. They worked to communicate to colleagues what science instruction could look like, by opening their classroom to observation and/or modeling reform-based science instruction during professional development. They often discussed being the only science person at the table and making sure that science was attended to at the district and administrative levels. All the STLs in our sample identified themselves as ambassadors in their work to varying degrees.

Collaborator

As collaborators, STLs worked with other individuals, such as teachers, administrators, or district leaders, to coordinate and implement reform efforts. They partnered with others to develop or choose a curriculum for science reform. They coached teachers in their instructional practice, working side-by-side with teachers to modify and improve their instructional practice. For example, they might co-plan a lesson or unit with another science teacher or develop professional learning resources with other STLs. The STLs as collaborators valued their relationships with other teacher leaders, teachers, and administrators, and worked to maintain those relationships over time. All but one STL in our sample named aspects of being a collaborator in their work.

Innovator

STLs as innovators worked to develop new and innovative ideas and practices in their context to support science education reform. As innovators, these STLs identified problems of practice and developed solutions to those problems within their school or district context, tried out new and innovative practices in their classrooms, and created opportunities to disseminate their solutions to other science teachers. All but two STLs in our sample identified being an innovator as one of their roles. This role was particularly important for classroom science teachers, as they described these practices more so than the other STLs in our sample.

Networker

As networkers, STLs made connections between ideas, places, and people to support science instruction in their local contexts. Networking included knowing what resources were available within the district and connecting teachers with those resources. All the STLs also had some connection with outside resources that they shared or brought to their contexts. Networkers had to be able to identify what the teachers they supported needed and then connect them with that resource. All the STLs in our sample showed some aspect of networking in their work as leaders and mentioned various ways they acted as networkers internally and externally in their organizational contexts.

Organizer

As organizers, STLs coordinated the logistics of science reform initiatives, often dictated by their district. This included sharing information and resources about reform decisions with teachers, making space for teachers to collaboratively make sense of these decisions, and planning or developing professional learning resources to ensure that teachers were gaining the knowledge and support they needed. As organizers, STLs in our sample coordinated and organized space for individuals to share information and resources in a professional, collaborative environment where teachers gained the support and knowledge needed to attend to science reform initiatives. All the district science education specialists, one TOSA, and four classroom science teachers described some aspects of organization and coordination of reform efforts in their work.

Translator

Translator STLs worked to provide coherence across their organizations and acted as liaisons between administrators and teachers to translate policy to practice. To do so, STLs had a vision for science education that "fit" with other district policies, and they developed systems of communication between administration and teachers to enact that vision. They regularly collected and analyzed data on improvement efforts and sought feedback from the teachers they worked with. This role was not as evident in the STLs' description of their practice; only four STLs described translation as part of their practice. Occasionally, STLs would mention working with administrators to help them understand NGSS and science education, however, it did not surface as their primary role. One district science education specialist named translator as his primary role as a leader.

STL profiles

Each STL enacted multiple roles in their work as leaders, which we are calling STL profiles (Table 3). Six of the seven roles had at least one STL that named that role as their primary role, the only exception was the collaborator role. Most STLs in our sample described the collaborator and networker roles as secondary to or supporting their primary role. For example, Mateo's primary role was an innovator. He also took on the role of a collaborator in that he described partnering with other teachers in his school to innovate classroom practice. Similarly, STLs' work as networkers provided them with access to resources that bolstered their primary role. Lastly, the role of translator was only described by the district science education specialists, with the exception of one classroom-based STL who described some aspect of translational work in his practice as a leader.

Each STL named contextual and structural aspects of their work that influenced their work as leaders and necessitated certain roles more than others. For example, the rural nature of Kaia's district necessitated her primary role of networker to make connections across vast physical distances, as well as content and grade level ranges. She also described engaging as a collaborator with teachers and community members to develop extended field trips that connected teachers and students to their rural community–an example of a practice associated with the innovator role . We describe each STL's profile organized by their area of influence.

District science education specialists

The profiles for these three STLs included aspects of each of the seven roles to support NGSS implementation. Each prioritized a different role in their work, which was related to how their work was structured at the district level. Ellen had more autonomy and little oversight and structure for her position. While there were other teacher leaders in her context who had similar positions in other content areas, Ellen was left on her own to structure her time. Alexa, on the other hand, had a more structured work environment and served on a leadership team that had expectations for her position. She described working more extensively with other content-focused teacher leaders in her district. Tobias worked for a charter school district with a lot of oversight, expectations, and structure provided by the charter.

As each of our district science education specialists described their work, they would relate back to the structure of their position at the district. For example, Ellen prioritized organization in her work due to the lack of oversight and structure she experienced. She created structures for her work where there were none provided. She mentioned aspects of each of the other roles as being in service to her primary role of organizer. For example, she described a weekly newsletter she created and shared as her artifact:

> I try to gather what I think is most useful and put those in weekly newsletters … there's a combination of letting people know professional learning opportunities exist either internal or external [to the district]. I try to highlight specific resources in the newsletters. And then I share-out if I am doing collaborations with teachers.

In her role as organizer, she highlighted her role as networker–having knowledge of and creating connections to professional learning opportunities and resources–as well as innovator and collaborator, with her sharing units she co-developed with teachers.

Alexa, on the other hand, prioritized her role as an ambassador for science and NGSS instruction in her district. The leadership team on which Alexa served had a representative from each content area, and she worked to keep science on the table at the district level. She also described her role as an organizer as important to her work as ambassador, particularly in coordinating and facilitating professional development to make sure that all students at the high school level had access to rigorous science instruction. In these professional development workshops, she shared her vision of high school science for all students by modeling instruction for the science teachers she supported. Here she discussed a workshop she offered for her science teachers, focused on engaging student-to-student talk in the virtual classroom space:

> I use the same strategies and tools [with teachers] … for example, one of the biggest things this year that teachers complain about all the time is student discourse, getting kids to talk and interact online. And so, I try to show them, by having them do … I try to show them all the tools as part of the regular PD, but I use all the same tools I would use and did use at the beginning of the year to get the kids to talk.

While she mentioned aspects of the other roles, she prioritized her role as ambassador to be a voice and model for science instruction, as well as an organizer of professional development to support other teachers to align with her vision of equitable science instruction.

Tobias worked as part of a whole team of STLs for a charter school district. Unlike Ellen or Alexa, he had a team of other STLs to work with and his role of collaborator was often in reference to his work with the science team. His primary role was that of translator to support alignment across science teachers, and coherence between standards and practices within the charter network. For example, he and his team developed a document for science teachers that translated the science and engineering practices (SEPs) from NGSS into small, observable, and developmentally appropriate practices for each grade level. Here's how he described this work through his artifact:

> Basically, it is a document that outlines what SEP skills or indicators we want every grade level to hit by the end of the year … the teachers didn't really know what skills students were supposed to come in with and what skills they were supposed to leave with. Because of the way NGSS was designed, looking at the SEP skills, it was just more like, "At the end of eighth grade, these are the skills you're supposed to get. Here's what it's supposed to be like in 12th grade" … And we needed it more fleshed out. What do sixth grade and seventh grade look like for example?"

Here he demonstrated how he translated NGSS documents, specifically science and engineering practices for each grade level to better support his science teachers' desire to support students' science learning across grade levels. In addition, his work as a networker was to connect with STLs in other districts to check that his charter district team's work aligned with other NGSS implementation efforts across the state.

TOSAs

The profiles for the two TOSAs in our sample, Kaia and Lucy, included roles that were specific to the needs and goals of their districts in relation to teacher learning and support. Kaia acted primarily as a networker because of the unique geography of her district. There were only two schools in the entire district, separated by large distances. This meant that Kaia's primary role was to make connections for teachers to curriculum materials, resources, and to place. Kaia took on the role of networker in her large rural district, making and leveraging connections across the district to support science instruction. She focused on the individual needs of the teachers she supported and the features of her rural district that made her work necessary.

> And then I have this little chunk that's allotted to me as a [STL]. But it's largely just the support of other teachers in whatever they need. So often that means connecting them with supplies. We're very rural, we live two hours away from a store . . . most of my position in that format is really just one-on-one meetings, finding out what the teachers need and being a sounding board for them, and trying to figure out how to connect them with whatever it is that they need.

Here she described her job as a networker as connecting teachers to resources for teaching and learning. She also noted that at times she acted as a collaborator if a teacher needed it. She made sure that teachers knew she was there as a resource, supported them in lesson plan development, and created opportunities for connection with one another.

Kaia grew up, lived, and worked in this rural district. She prioritized supporting teachers to connect their students to the outdoors and the resources available to them in their rural community. Therefore, she also took on the role of innovator, as she worked to develop and share resources related to outdoor education and valued the assets and resources of her rural community. In developing these resources, she connected with various community members and local historical sites to create continuous outdoor learning experiences "that we can return to a space, get to know it a little bit more in-depth and also make [field trips] more well-rounded." She leveraged her network and connections in the community, her knowledge of the history of the area, and the land to create place-based lessons that recognized the assets and resources of her local rural community.

Lucy acted primarily as an organizer because of her district's mandate to use professional learning communities (PLCs) as a mechanism for teacher learning; and therefore, Lucy's primary activity was organizing and supporting science teacher PLCs across the district. She organized one PLC of science teachers and one PLC of teacher leaders.

> Some lead teachers, if there's a problem that they're trying to tackle with their group, and they just need some extra support or research, I can go hunt that down for them. Basically, I'm just a thought partner for them. But I also provide a PLC, I don't want to call it professional development. It's more of me facilitating a conversation once a month with all the leads.

She described her primary role as organizer being supported by the roles of collaborator and networker to locate important resources that teachers in her PLCs needed.

Classroom science teachers

The profiles for the six classroom science teacher STLs in our sample include roles that were generally voluntary and related to issues they noticed and surfaced in their classroom teaching practice. Rico, Aria, and Michelle acted primarily as activists in transforming their classrooms to be places where students from minoritized groups saw themselves in science. For Mateo and Alvin, the primary role in their profile was innovator, as they each worked to design and implement new solutions to problems in their schools. Alison described two primary roles in her leadership profile, and described how her enactment of the ambassador and networker roles supported rigorous and discipline-specific science instruction in district middle schools.

Profiles of classroom science teachers who acted primarily as activists. Each of the classroom science teachers who acted primarily as activists leveraged their other roles to support their activist role. Aria, a high school biology teacher, engaged in reflexivity in a variety of ways through her roles as ambassador and networker. In her role as an ambassador, she described working with a beginning teacher to develop more equitable grading practices together.

> We've read some excerpts from *Grading for Equity* and have been working to grade more holistically and for assessing what students actually know and can do versus looking at things like compliance or collaboration and other biases that might happen in our grading systems when we're not really thinking about it.

Here she noted that through their book study, they were able to look for blind spots and biases in their grading practices. Her roles as ambassador (mentor to beginning teachers) and networker (making connections to external groups focused on equity in science education) supported her role as an activist to transform her grading practices to be more equitable.

Michelle and Rico, both teachers of Color, were determined to highlight scientists of Color that were representative of their students' racial and ethnic diversity, and to share their contributions (both willing and unwilling) to science. This led to an increase in the representation of scientists of Color in their instruction. Rico did this work acting as an innovator and networker. He noticed that his students had one reference to a Black scientist, Dr. Neil deGrasse Tyson. Rico stated, "I love Neil deGrasse Tyson, but he can't be the only person of Color that people say when I ask them to name a Black scientist." This prompted Rico to create assignments where students could learn about more current scientists of Color, and used social media platforms to reach out to them. Throughout this process, he worked as an innovator to create new classroom assignments, and leveraged his network to support students to reach out to diverse scientists on social media and to share the resources he developed for his classroom.

Michelle leveraged her network to organize resources to bring more diverse representation of scientists that reflected her students' Afro-Latino identities. Michelle acted as an organizer to bring various resources together from her vast network to increase representation in her classroom. She shared, "I've been putting together different podcasts, and sharing with [students] people who look like them in the area of marine science and sharing with them their beliefs about conservation." She gained access to these resources through her social media network, in particular #BlackinMarineScience week. She also provided her

students with information about people of Color in science shared through the museum network including Henrietta Lacks, Percy Julian, and Mae Jemison.

Profiles of classroom science teachers who acted primarily as innovators. The two classroom science teachers who prioritized the role of an innovator as a priority in their work leveraged either the role of collaborator or organizer to support their work as innovators. Mateo's innovative work also involved a team of teachers at his school. For example, he worked with another science teacher to film lab demonstrations for students, to increase student engagement in the virtual classroom during the COVID pandemic shutdown.

> I started working with another seventh-grade science teacher and then other teachers started to help in the same thing, where we started doing lab demos on Fridays because we also noticed that's when the kids were the most absent . . . most Fridays, we go to school and do different lab demos.

Mateo noted how he collaborated with other science teachers to come up with innovative ways to engage students on days when they had the lowest attendance.

Alvin took on the role of organizer to support his role as innovator to design ways to share their classroom innovations as they shifted their practice to align with NGSS. He focused on creating an organizing structure to provide more opportunities for sharing innovations among the science teachers he worked with.

> I think that's where we break through and start working to help a broader audience of kids. Because it's not just that by working together we might come up with something good that another teacher isn't doing, it's also that other teachers are doing good stuff, and it's not being shared. Like, we don't have a structure to share that good work with everybody else. So that's what I want to develop.

As an innovator, Alvin recognized a problem that required he act as an organizer to create a structure that would bring science teachers together.

Profile of a classroom science teacher who acted primarily as ambassador. Alison's role as an ambassador was in support of discipline-specific science instruction, which was one of the NGSS reform pathways for middle schools. She spoke about the importance of leveraging her network of other middle school science department chairs inside her district to support this focus on discipline-specific science instruction.

> I've focused really a lot of effort on bringing the three middle schools together and to look for opportunities where we can collaborate. And so, we have a network . . . I have a really strong connection between all three middle school department chairs and teachers and we just love each other.

She also named external resources she brought to her network of middle school science teachers in the district that aligned with NGSS instruction at the middle grades level.

> I try and use the [Exploratorium resources] quite a bit to share those with colleagues because you kind of have to have somebody kind of talk you through it too. Rather than, "here's some resources". You have to say, "Oh, I tried this one and it bombed, or I tried this one and it was awesome." And then people are more likely to do it if you tried it yourself.

Alison's work as an STL focused on both being an ambassador for discipline-specific science instruction and leveraging her extensive network to support that work.

Discussion

In this study, we aimed to identify the various ways STLs understood and enacted their roles as leaders within their local contexts. We found that STLs described one or more of seven roles in their work as leaders: activist, ambassador, collaborator, innovator, networker, organizer, and translator. We identified variations in STLs' profiles related to how STLs differentially prioritized certain roles over others and that the structure of STLs' work and local priorities for educational reform mattered for the types of roles that STLs took on. Lastly, we found that the collaborator and networker roles served to support STLs' primary roles as ambassadors, activists, innovators, organizers, and translators.

These roles align with current literature describing work of teacher leaders and provide a different way to categorize the practices that reflects the variety in how these roles can be taken up and/or prioritized by STLs. For example, Firestone and Cecilia Martinez (2007) describe teacher leaders as individuals who moderate the distance between district initiatives for improvement and the classroom. To do so, they distribute materials for reform, monitor progress on reform efforts, and support local professional development efforts. These leadership practices fall within the role of organizer described in our data. Organizers distribute materials for reform to teachers, organize professional development efforts, and communicate decisions about reform efforts to other teachers and administrators.

Like Wenner (2017), we found that the STLs in our sample did not implement all the generalized practices described by York-Barr and Duke (2004). For example, none of the STLs in our sample described work with families as part of their work as leaders. We also identified new STL practices, including the role of translator, related to providing coherence across an organization, and the role of an activist STL, who worked to restructure their classroom instruction to reduce harm to marginalized students. Our analysis also confirms what is articulated in previous reviews of teacher leadership in that the organization of teacher leadership work varies according to local contexts (Wenner & Campbell, 2017).

Implications for supporting science teacher leadership

Given the variation in STLs' profiles identified in our data, we suggest that a one-size-fits-all program or roll-out of science teacher leadership will not be as effective in supporting and empowering teacher leaders to grow and develop their practice as leaders as more tailored or differentiated approaches would be (Luft et al., 2016). Next, we provide recommendations for professional learning of STLs that recognizes variation in the work of STLs as an asset, rather than a problem to be resolved.

The roles we identified in the data align with our understanding of the varied ways that leadership gets enacted in practice (Wenner & Campbell, 2017). When considering the work of STLs, it is important to surface the multiple and often intersecting roles that they occupy, as well as how their institution (school, district, county) structures their work. Having STLs identify and reflect on their roles as leaders can support administrators, science teacher leader educators, and STLs themselves to consider the knowledge, practice, and skills necessary to enact those roles in context (Whitworth et al., 2022). For example, an STL that takes on the

role of collaborator in their work may benefit from learning about protocols for ensuring equitable participation among collaborators (Harris, 2005) or processes for bringing marginalized voices to the table when making decisions about schools, teachers, and classrooms. Therefore, we suggest professional learning include an opportunity for STLs to identify the various roles they occupy and want to develop further. As an example, STLs could be provided descriptions of each role and identified practices and asked to weigh their relative engagement with each of those roles in their work. This could then lead to a discussion of the various work that they do and their professional learning needs in relation to those roles. Additionally, this would support STLs to identify some of their informal work as leaders and strengthen their identities as teacher leaders (Sinha & Hanuscin, 2017).

We identified certain roles that all STLs mentioned as a component of their leadership practice, including the ambassador, networker, and collaborator roles. This suggests that these roles are similar across STLs and could potentially be an area that could be better supported through professional learning. For example, the STLs in our sample named the Exploratorium network as an important resource in their work, as well as their networks of individuals within their organizational context and other external professional organizations. Our data suggests that a network structure for STL professional learning can support STLs to feel less isolated, compare their organizational implementation efforts with other similar efforts in other organizations, and to share resources and innovation.

The variation described by STLs can be an asset for science teacher leader educators to provide targeted support that aligns with the work of STLs. Supporting STLs to describe both their leadership practices and how their work is structured to enact those practices can be an asset for designing different pathways for professional learning and growth that reflects the on-the-ground science education reform work of STLs.

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