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Science Teacher Leadership: Learning from a Three-year Leadership Program

Abstract

Teachers are professional learners and leaders. They seek to understand how their students learn, and they participate in programs that provide new instructional skills, curricular materials, and ways to become involved in their community. This study follows a science teacher leadership program over a three-year period of time. There were approximately 30 participants per year. The teachers who participated in the program came from two different states in the United States. Interviews, documents and surveys were used to follow the development of the program and the professional growth of the participants. The qualitative and quantitative analysis reveals that: not all participants became teacher leaders, there were different levels of difficulty associated with the presented leadership skills and knowledge bases, there are some essential knowledge bases associated with teacher leadership, the follow-up program varied between sites, and teachers engaged in leadership in different ways. For those in science teacher education, this study helps fill the void of research in this area, and it suggests that science teacher leadership should be an option for professional development.

Introduction

Science teachers are professional learners and leaders. As learners, they want to participate in workshops about district curriculum, institutes that support the development of new content knowledge, or professional learning communities that examine instructional practices. As leaders, they want to work with student teachers, participate in school committees, and present studies of their own classroom practices locally and nationally. To fulfill these different roles, teachers need a variety of professional development opportunities at the school, district, or national level.

Keywords: teacher leadership, professional development, science teacher education

Unfortunately, science teachers may not have extra time to spare when it comes to professional development programs. This is evident in the limited amount of time that teachers participate in professional development activities. Over 60% of science teachers reported spending 35 hours or less over three years engaged in professional development programs (Banilower et al., 2013). When they do participate in professional development programs, science teachers reported engaging in mandatory or short-term programs (see Banilower et al., 2013). These programs are often created by school or district personnel, or associated with conference attendance.

Most science teachers would like access to different types of professional development programs (Luft, Ortega, & Wong, 2009). One area of interest among science teachers is leadership development. While teachers do engage in leadership activities, these activities are often narrowly conceived, and little is known about the leadership development process. For instance, the national survey conducted by Banilower et al. (2013) does not ask specifically about leadership development, and assumes that leadership consists of leading a study group, serving as a mentor or coach, supervising student teachers, or directing an inservice program. The narrow conceptualization of leadership aligns with a lack of research in this area (Luft & Hewson, 2014). One of the most important roles of a teacher—being a teacher leader—is often under-conceptualized, and rarely emphasized in professional development programs.

In the midst of this limited understanding about science teacher leadership, reports continue to emphasize the need for more professional development opportunities for science teachers (e.g., Darling-Hammond, et al., 2011; National Research Council [NRC], 2010). These national reports stress the essential role that professional development plays in the process of becoming a teacher leader, and the need for more professional development programs to build the capacity of teacher leaders. These reports will have little traction in the educational community unless more can be done to understand and support the development of teacher leaders.

In an attempt to contribute to the discussion about teacher leadership, this paper shares the findings from a three-year project that attempted to develop the leadership capacity of science teachers. The project involved teachers from two states in the United States. In conducting this study, a conceptualization of science teacher leadership was developed, and empirical evidence was collected from the participants and project leaders. This paper specifically reports on:

1) The conceptualized roles and activities of a science teacher leader,
2) The development of science teacher leaders in the project, and
3) The barriers and pathways to becoming science teacher leaders.

The results of this study provide science teachers with a framework for thinking about teacher leadership development, and suggestions for the professional development of teacher leaders. The results of this study will also be useful for those who are interested in building leadership programs for science teachers.

Theory of Science Teacher Leader Development

In this study, the guiding theory about science teacher leadership comes from Rhoton (2010). In this book, educational

researchers, science teacher educators, and science education leaders discuss the qualities of teacher leadership. Collectively, the chapters build a strong theory about the development of science teacher leaders. This theory suggests that being (1) a teacher leader involves knowledge of education, science education, and science, and (2) a teacher leader impacts the public, policy makers, and the educational field. Figure 1 is a simple model of this theory.

The circle to the left represents the teacher and all of his/her knowledge and skills. The middle circles represent the development of different skills (S) and knowledge bases (K). The different sized circles indicate the potential intensity, duration, or influence of a teacher leader on the different targeted areas. These targeted areas could be classrooms (C), schools (S), districts (D), policy makers, etc.

In this paper, this theory guides the research. That is, the collected and analyzed data will be used to give more understanding to various parts of the theory of teacher development. This will be done in the discussion section of this paper.

Related Research

Defining a Science Teacher Leader

While there are many definitions of a teacher leader, Fullan and Hargreaves (1996) summed it up best when they stated that teacher leadership is the "capacity and commitment to contribute beyond one's classroom" (p. 13). Beachum and Dentith (2004) expanded upon this notion, suggesting that teacher leaders take more responsibility for decision making and activities outside of their classrooms; assist in reforms that impact the organizational processes within their school or district; and work with other school leaders to envision a better future, foster hope and honesty, tackle obstacles and impediments, and build community while improving the educational climate.

Beachum and Dentith (2004) and Fullan and Hargreaves (1996) view a teacher leader as one who makes contributions in the classroom and beyond. However, their discussions of teacher leadership leave out content knowledge, an important focal area for a teacher leader. For instance, science teacher leaders should connect the science standards to their classrooms, or consider the implications of national reports for district policies about the teaching of science. In recognizing the importance of 'science' in teacher leadership, we draw upon Beachum and Dentith (2004) and Fullan and Hargreaves (1996) and suggest this modified definition of science teacher leadership:

> A science teacher leader takes more responsibility for decision-making and activities that involve science within their classroom, their schools, and their districts. In addition, they work to improve various organizational processes, and they work with other leaders to build scientifically literate citizens. Science teacher leaders tackle obstacles and impediments at all levels, and they build community broadly. All science teacher leaders are not alike. They have different strengths that they apply to different areas, at different times.

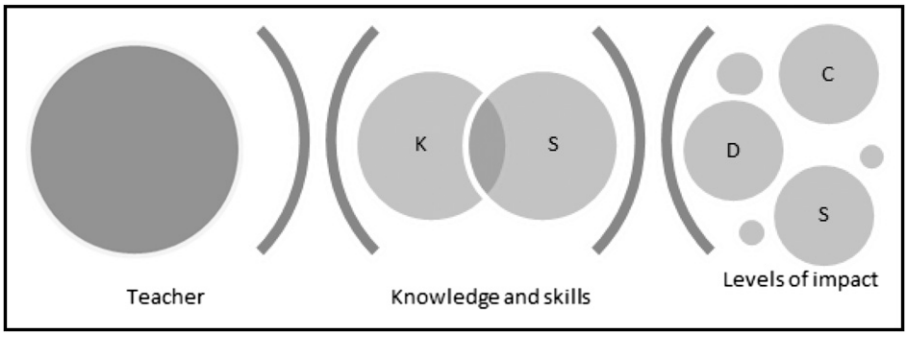

Figure 1. Science Teacher Leader Development

Science Teacher Leadership Development

This is a relatively new area of research in the professional development domain. In a review of research in peer-reviewed science education journals from 2002-2012, only two studies were identified in the area of science teacher leadership (Luft & Hewson, 2014). Both studies explored the formation of leadership skills through different professional development programs.

The first study, by Hofstein, Carmeli, and Shore (2004), followed 18 chemistry coordinators in Israel as they developed leadership abilities, along with content and pedagogical knowledge, at their schools. The goal of the program was multi-faceted, but it targeted school-based leaders with the intention of changing the teaching of science at the school level. Throughout the program, the chemistry coordinators had opportunities to adapt and design classroom lessons, create assessments, and present on topics relevant to the school site. The data sources revealed that the teachers recognized their new roles, adopted new leadership and team management skills, and were able to carry out some of the envisioned leadership activities.

In the second study, Howe and Stubbs (2003) examined how individual science teachers developed into leaders. In this study, three experienced United States middle school science teachers were followed as they participated in a professional development program that was designed to build their science education expertise and leadership abilities. The analyzed data revealed how the teachers evolved as leaders and what constrained or supported their development. All of the teachers identified key components that were important in their development as leaders: mutual respect between teachers and scientists, opportunities for teachers to assume leadership, the development of a community of practice, and challenging tasks.

Both of these studies shed light on the process of teacher leadership development. They suggest that teachers need to be supported locally in order to develop their skills and abilities. However, this emphasis on local support may have been a result of the programs, which focused on local instructional and curricular issues. Howe and Stubbs (2003) examined how teachers developed into leaders in the midst of a professional development program, while Hofstein, Carmeli, and Shore (2004) developed a program that supported teacher leadership by improving science education expertise. Through two different approaches, these studies take steps towards understanding the development and reach of a teacher leader.

Methods

Population and Program

This study is the result of a three-year program that built the capacity of science teacher leaders in two states in the United States. Each year, approximately 20 female science teachers and 10 male science teachers participated in the program. Approximately half of the population had less than 10 years of teaching experience, while approximately half had more than 10 years of teaching experience. Approximately six teachers per year were involved in some administrative post (e.g., supervisor, science coordinator). Most of the teachers were in urban and suburban locations, while a small number of the teachers came from rural school districts. All of the teachers participating were part of a team/network. Table 1 provides more details about the program participants.

Originally, teachers were recruited for two years. Over time, some teachers left the program, yet most continued in the program. New teachers were added to the program when an opening became available. Table 2 indicates the number of teachers who participated in the program each year.

The program – the National Science Leadership Program (NSLP) (pseudonym) – was developed by district science coordinators involved in the National Science Education Leadership Association (NSELA). The project was intended to cultivate a network of leaders who would be encouraged to take on leadership roles in their school/district. These leadership roles could include anything from curriculum development, teacher professional development, professional learning communities, curriculum alignment, or implementation of the new core standards. Over time, the goals for project participants became:

- Learn how to be a change agent
  - Learn about change, how to approach change, how to work with stakeholders, how to construct and share an instructional vision, how to support colleagues
- Learn about professional learning
  - Learn about reforms, best practices/instruction, curriculum, managing resources, technology
- Learn about personal learning
  - Learn to work in a group, to be reflective

Across each of these areas, the goal was to gain an understanding of recent trends in science education and the ability to use effective communication skills.

A multi-year program was developed in order to support the knowledge and skills associated with science teacher leadership. Each year of the program consisted of two parts: a summer institute, and the school-year program.

Table 1. Demographics (Reported in Year 1/Year 2/Year 3)

Gender	Female – 23/19/19	Male -9/8/10	
Ethnicity	Anglo - 28/19/22	Other/no response – 5/8/7	
Highest Degree	Bachelors -13/9/3	Masters – 19/18/24	PhD – 0/0/2
Teaching level	Elementary - 6/4/3	Secondary - 19/19/19	Other - 7/4/7
Years of teaching	<10 years – 16/13/7	> 11 years – 16/14/22	
Location	Rural – 4/3/5	Urban – 14/12/14	Suburban – 14/12/10
State	West - 17/ 14/ 15	South – 16/13/14	

Table 2. Years in Project

Years Participating	1st year	2nd year	3rd year
2011	32		
2012	10	17	
2013	10	9	10

During the summer institute, the teachers met collectively to work with the project directors, worked in small groups, and heard from leaders in science education (e.g., technology, argumentation, Next Generation Science Standards [NGSS] [NGSS Lead States, 2013]). During the school-year program, the teachers worked together in their regions. Groups of teachers met in person or online, or attended different science conferences. By working together over the course of the year, project participants refined their skills as science teacher leaders.

Data Collection and Analysis

The study used both quantitative and qualitative analyses and would be considered a longitudinal mixed methods study (Plano-Clark et al., 2013). As a mixed methods study that used a concurrent approach, the quantitative and qualitative results were collected yearly and used to clarify each other (Creswell & Plano Clark, 2011). The data sources were a pre- and post- summer institute online survey, examples of best lessons, artifacts from the summer institute, documents from meetings and events during the school year, and selected interviews with participants and program leaders.

One data source was an online survey given to the participants prior to and following the summer institute each year. The survey captured information from all of the teachers in the project. Prior to each summer institute, teachers were asked general demographic questions that pertained to their current teaching positions, leadership activities, and professional development program participation. Following each summer institute, teachers were asked to evaluate the summer institute based on the principles of good professional development design (see Garet, Porter, Desimone, Birman, & Yoon, 2001), the goals of building teacher

leadership (e.g., learned about vision building, learned how to work with various leaders), and the quality of the presenters. These data were analyzed descriptively in Excel and SPSS in order to describe the teachers, to evaluate the summer institute, and to document the changes in the teachers' leadership knowledge and skills.

The participants' best lessons served as a second data source, and were submitted prior to the summer institute each year. NSLP teachers were expected to be knowledgeable and able to enact reform-based instruction, and their lessons were used to document their instructional development. The lesson outlines, along with any supporting materials, were provided in this data source. Teachers submitted lessons they developed, as well as lessons that were used by several teachers within a school. Often, student assessments were included with the lessons. These lessons were analyzed for the presence of attention to student prior knowledge, challenging content, differentiation of the content, presence of collaborative groups, technology, and the opportunity for students to collect, analyze, explain, or share data. These areas correspond with guidelines for science instruction found in *National Science Education Standards (NSES)* (NRC, 1996), *Ready, Set, Science: Putting Research to Work in K-8 Classrooms* (Michaels, Shouse, & Schweingruber, 2007), and *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). Lessons were evaluated with a rubric to maintain consistency, and scored as below proficiency, proficient, above proficiency, or not applicable/not evident.

Artifacts from the summer institute were also collected in order to determine how participants were supported in building their leadership capacity. These artifacts included documents, such as: the institute schedule, overhead materials, handouts, notes from the different presenters, and documents generated by the participants. These materials were analyzed qualitatively, following Creswell (2014) and Miles, Huberman, and Saldaña (2013), within the above-mentioned goals of leadership in order to understand how teachers were supported to build their knowledge and skills about leadership.

Following the analysis of the post-summer online survey, an interview protocol was developed that asked about the summer institute, and addressed inconsistencies or strong trends from the quantitative and qualitative analyses. The project director was interviewed each year, and provided extensive information about the summer institute and the school-year program. This interview was recorded and lasted for an hour or more. To supplement this interview, six random participants were interviewed, three from each site. One participant from each site was interviewed in successive years in order to determine the connection of different years of the program. During the interview, the participants were asked to clarify areas pertaining to the NSLP, to discuss their development as leaders, and to elaborate upon specific topics pertaining to the summer institute. These interviews were also recorded and lasted from 20 minutes to an hour. These interviews were analyzed qualitatively following Creswell (2013) and Bogdan and Biklen (2006), and involved coding specific responses in order to clarify areas that were brought to light in the quantitative analysis.

As a longitudinal mixed methods study, data from both the qualitative and quantitative analysis were merged over time and during the interpretation part of the study (Creswell & Plano Clark, 2011), which occurs in the discussion section of this paper. For the interpretation, the quantitative and qualitative data were compared and contrasted with one another in order to understand the "what and why" of the phenomena. This interpretation is associated with the second and third topics of interest in this paper, which pertain to leadership development and the barriers and pathways to becoming a leader. Teddlie and Tashakkori (2009) were followed in developing the emerging inferences themselves.

In reviewing the research process, Teddlie and Tashakkori's (2009) Integrative Framework was used to evaluate the design quality of the study and the intellectual rigor of the conclusions. This framework ensures adequacy in the methods, consistency throughout the study, and the distinctiveness and credibility of the inferences.

Findings

The quantitative results will be presented first, and the qualitative findings will follow. The mixed methods findings will be in the discussion section, and these findings will integrate the qualitative with the quantitative data.

Quantitative Findings

There are three quantitative areas important to this study. The first area consists of the current roles and activities of the teachers, including their leadership and professional development. In this project, the definition of a leader changed over time. As a result, the emerging areas pertaining to leadership were not discussed with the teachers in the earlier years of the program. However, from the data it appears that the NSLP excelled in recruiting participants who were active in leadership, and that some of the returning participants improved their leadership abilities (see Table 3). Areas of growth of the participants consisted of demonstrating how to influence science education in the school and beyond, and guiding colleagues towards professional development activities. Areas that remained constant over time among the participants consisted of improving their content knowledge and their involvement in constructing and sharing their school's instructional vision.

Corresponding to the survey of leadership activities were questions that asked participants to determine how the program supported the development of different leadership areas. The responses of teachers were corroborated by NSLP documents that focused on the summer institute and the school-year program. Table 4 reports these data as they relate to the conceptualization of leadership that existed at the beginning of the project. The responses indicate that participants came with knowledge in some areas and learned about different

Table 3. Current Leadership Activity (Reported in Year 1/Year 2/Year 3)*

	Often	Sometimes	Not very often
Involved in constructing and sharing an instructional vision at school	19/20/23	5/4/4	3/4/2
Guiding other teachers to professional development activities	18/20/25	5/6/3	4/2/1
Providing colleagues with feedback about new innovations in my school or district	17/24/21	6/3/6	4/1/2
Influencing science education at the school level and beyond	16/25/26	5/2/3	6/1/0
Improving content knowledge	24/24/26	3/3/3	0/1/0

*Year 1, N= 27; Year 2, N= 28; Year 3, N=29.

leadership areas during the project. From the view of participants, the NSLP emphasized constructing a vision, learning how to manage activities, supporting the professional development of colleagues, and working at the school level and beyond. Participants expressed that the project was limited in terms of helping them learn how to manage and distribute resources and how to provide feedback to peers.

Ongoing professional development is important for teachers learning how to become leaders in their field. Thus, NSLP participants were surveyed about their professional development activity. The surveys were consistent from year to year, so the average number of teachers participating in the different forms of professional development over three NSLP years are reported in Table 5. From these data it is evident that most participants in the project attended short forms of professional development, and most engaged in deepening their understanding of reform-based instruction (e.g., inquiry, investigations). Most of the participants belonged to a professional organization, but they wanted to engage in STEM research or be more active locally or nationally.

The second area pertains to the instructional ability of the participating teachers. In this project, science teacher leaders needed to have a strong understanding of the reforms, and they needed to demonstrate their knowledge. In order to assess this ability, the lesson plans of participants were analyzed over time against standards in science education. Again, past and new program participants provided lessons, with new participants coming from a network that included past-participants. More than half of the lessons provided by the participants followed the 5E lesson format, which involved Engage, Explore, Explain, Elaborate, and Evaluate (see Bybee, 2002). These lessons, however, varied greatly in their implementation of the different assessed areas. Within all of the lessons there was an emphasis on using scientific practices, providing different learning opportunities, and selecting challenging content. There was not, however, a focus on fostering the use of technology, a public sharing of knowledge, reflection on doing science, or assessment of prior knowledge. The areas emphasized corresponded with areas found in the *NSES* (NRC, 1996) and the *NGSS (*NGSS Lead States*,* 2013). Table 6 shows the assessment of the submitted participant lessons over a three-year period. It should be noted that not all participants submitted lessons each year.

The third area consisted of an analysis of the summer institute materials. This analysis corresponded to the view of leadership that emerged by the end of the project. From the data it is apparent that over time the project directors focused on developing an understanding of being a 'change agent' among the participants. This was done to help NSLP participants understand how to work in their communities in order to implement the *NGSS* (NGSS Lead States, 2013). There was a slight increase in emphasis on the professional learning of participants, and

Table 4. Leadership Areas Addressed During the Summer Institute (Average of the three years)

	Learned about this area	Already knew, but still learned	Knew some, but learned more	Did not learn anything new	Not addressed	Documents
Learned how to construct and share an instructional vision	5	10	2	2	0	There was strong evidence that this existed in the program.
Learned how to manage and develop science activities within a school, district, network	3	9	2	2	3	There was strong evidence that this existed in the program.
Learned how to find and distribute resources	3	7	3	3	3	There was limited evidence that this existed in the program.
Learned how to support the professional development of others	6	9	NA	4	0	There was strong evidence that this existed in the program.
Learned how to provide feedback about innovation and instruction	4	7	3	2	3	There was limited evidence that this existed in the program.
Learned how to influence science education at the school level and beyond	8	8	NA	2	1	There was strong evidence that this existed in the program.

Table 5. Current Professional Development Activity (Average of the three years)

Professional development activity of choice	Conferences (21)	1 to 4 day workshops (17)	Study groups (9)	
Focus of professional development activities	Learning to use inquiry/investigations in science (9)	Learning teaching strategies (3)	Understanding student learning (3)	Deepening content knowledge (3)
Time in professional development during the school year	1 to 5 hours per month (14)	5 to 10 hours per month (6)	11 + hours per month (4)	Less than an hour per month (4)
Time in professional development when school is not in session	1 to 5 hours per month (9)	5 to 10 hours per month (7)	11 + hours per month (9)	Less than an hour per month (3)
The NSLP program teachers	Belong to science education organizations (18)	Give presentations (15)	Mentor new teachers (15)	
The NSLP program teachers would like to	Work with STEM researchers (11)	Participate on national/local committees (10)	Do research in science education (8)	

a steady emphasis on personal learning. With only a week dedicated to the summer institute, the project directors provided more extensive experiences in some areas, as opposed to trying to address all of the leadership areas. Table 7 shows the different areas of emphases of the summer institute over time.

Qualitative Findings

From the interviews, there are two major findings. First, *over time, the participants increased their participation in various leadership roles*. The NSLP participants often took on new leadership roles, primarily in their schools and districts. Several participants attributed this increase to their involvement in the NSLP program. Diana, for instance, was inspired to take on more leadership responsibilities in her district, and even attempted to make an appointment with the superintendent to discuss the new science teaching reforms. Her superintendent, however, did not have time to meet with her, which left her with some degree of frustration in that she did not know what to do next.

Participants were well-positioned to engage in new leadership roles (even if they did not achieve the results they envisioned) because they were part of district networks and they felt supported by these networks. The communities that were formed in the school-year program were vital to the participants who were active in leadership positions, and for those who were aspiring to these positions. Clara indicated that she had no idea she could be a leader, but as she worked in her community, she felt support to take on more leadership roles. Toby, who was already a teacher leader, felt the community gave him clarity in his position. In particular, one community leader was always available to help him navigate any problem he encountered in his school.

Second, the *school-year program looked different in each state.* Participants from the different states were engaged in very different programs over the school year. Initially, the coordination of the summer institute and the school-year program were not developed by the project directors. As a result, one state had a very limited school-year program and the other state had a program that was primarily coordinated by one person. By the second and the third year, the NSLP leaders drew upon the expertise of the local leaders and they forged a connection to a national organization. As a result, the school-year program had more activities for the participants, and specific areas were addressed during the school year.

The national organization provided an e-learning environment and an opportunity for participants to attend the national meetings. The webinars and

Table 6. Assessment of Participants' Lesson Components (Reported in Year 1/Year 2/Year 3)*

Area	Below Proficiency	Proficiency	Above Proficiency	Non-Applicable/Not Evident
Assessment of prior knowledge	5/9/11	6/7/5	0/0/0	1/5/0
Appropriate and challenging content	4/5/3	5/16/13	2/0/0	1/0/0
Different learning opportunities exist	4/8/4	5/11/11	3/2/1	0/0/0
Collection of data	4/6/7	5/13/9	3/2/0	0/0/0
Analysis of data	0/6/6	8/13/10	1/2/0	3/0/0
Students explain their data	3/7/8	6/12/7	1/2/1	2/0/0
Reflection	4/13/12	4/4/2	2/1/1	2/3/1
Collaborative groups	3/6/6	3/11/10	4/1/0	2/3/0
Public sharing of knowledge	1/9/8	1/10/8	2/0/0	8/2/0
Technology use	2/9/9	3/4/4	1/0/1	6/8/2

*Year 1, N= 12; Year 2, N= 21; Year 3, N=16.

Table 7. Emphasis of Important Areas Pertaining to the Reforms and Change

	Year 1	Year 2	Year 3
Change Agent			
Learning about change	NE	AP	P+
Learning how to approach change	NE	AP	P+
Learning to work with stakeholders	NE	BP	P+
Professional Learning			
Learning about reforms	P	AP	AP
Learning about best practices/instruction	P	P	AP
Learning about curriculum	P	P	P
Technology	P	BP+	BP+
Personal Learning			
Learning to work in a group	P	P	P
Learning to be reflective	P	P	AP

BP= Below Proficiency – The area was present, and the participants were just exposed to the topic. For instance, participants listened to a well-planned presentation with little or no opportunity to process the presentation.
P=Proficiency- Participants experienced and discussed the area. For instance, participants learned about a topic and engaged in some form of discussion about the topic in order to learn more.
AP=Above Proficiency – Participants engaged in sustained discussion and analysis of the topic or area. For instance, participants reflected on their own learning and determined how that related to their growth as leaders. A key component in this area is relating the topic purposefully to leadership development.
NE=Not Evident – No documentation existed indicating the area was present in the summer institute.

collaborative opportunities reinforced the summer institute principles in a group structure. At the local level, there were more discussions about the focus of the summer institute, but these occurred in different ways. For one member of a team, the optional meetings were interesting, but not very fulfilling. Samantha, on the other hand, who was from another team, stated, "I have always wanted to be a teacher leader in science education. I learned so much during the summer, and really needed my group over the school year to really put the things I learned into practice. [Our group leader] was critical in holding our group together and sharing information."

Mixed Methods Findings and Discussion

In this section, the integration of qualitative and quantitative data will be used to discuss the last two areas of interest that guided this paper. The first area of interest pertained to defining the abilities and skills of science teacher leaders; this was a result of the project not related to the data collection and analysis. The initial definition of leadership provided by the project directors evolved over time. The directors' understandings changed as they interacted with the participants and as they contemplated the formative evaluation materials that were provided each year. This evolved notion of leadership ultimately impacted how they designed the project and how they supported their participating teachers. The final conceptualization of science teacher leadership that was embedded in the project was shared earlier in the paper, and consists of the categories: Change agent, Professional learning, and Personal learning.

Science teacher leadership is a new and evolving field with few guiding documents or studies (Luft & Hewson, 2014). The studies guiding this paper discussed different meanings of leadership, and situated leadership within a school context (see Hofstein, Carmeli, & Shore, 2004; Howe & Stubbs, 2003). The NSLP project was not bound by a school or district, but existed across states. The nature of this project required that those involved contemplate a description of leadership, and draw upon the experiences of the participants and the evaluation data. This was essential if participating teachers were going to be supported in their development as science teacher leaders. The vision of leadership offered here could be used to guide the learning of science teachers in future leadership programs.

The second area of interest in this paper pertained to the development of science teacher leaders. Simply put, the teachers developed individually. That is, they came to the summer program with different levels of leadership skills and abilities, and each teacher was able to examine his/her abilities during the summer institute. During the school year, a variety of learning opportunities allowed teachers to develop individually and at times as a group. Ultimately, the future teacher leaders each met their own learning needs, which may have aligned with overarching lessons or not.

For instance, during the summer institute there was a strong emphasis on having program participants understand the different contexts of science education. Several national leaders in the field of science education attended the summer institute, including: a state leader in education, the national director of the *NGSS* (NGSS Lead States, 2013), researchers in the field of science education, and district level coordinators. These people were critical presenters, who helped the participants understand local, regional, and national policies that related to the science classroom. During the school year, each participant continued to develop his/her leadership skills, as related to his/her context. As a result, the future teacher leaders were able to engage in their evolving understandings about leadership (e.g., teaching, advocacy), but most were bound by the opportunities provided to them.

The framework for leadership development suggested by Rhoton (2010) is large and challenging. There are a variety of skills, abilities and levels of impact to consider. More importantly, teachers are individuals with different interests, knowledge levels, and opportunities to practice their leadership skills. This was evident in their assessment of the program offerings, and in their performance during the program. For instance, though the teachers were learning

about various instructional reforms, some consistently struggled to demonstrate attention to the prior knowledge of students. A framework for leadership development should include opportunities to learn among other teachers, and an individual professional learning plan that has specific learning objectives. In short, our best support for leadership development among teachers should look like our learning programs for students. There should be a focus on optimizing teacher learning that considers what the teacher is learning within a well-developed professional development plan for emerging leaders.

The third area of interest in this paper pertained to the barriers and pathways toward becoming teacher leaders. The qualitative and quantitative data analyses show areas that supported teachers' growth and areas that constrained them. The areas that supported teacher leadership development included the community of teachers, and the new opportunities to engage in leadership experiences.

Luft and Hewson (2014) point to the importance of collaboration and community during the process of professional learning. This study, like so many, supports the power of professional learning communities. For most teachers, a professional learning community provides an opportunity to discuss personal and professional experiences, and there is an opportunity to make sense of the challenges and opportunities that exist within learning.

The areas that constrained the development of the teachers consisted of the lack of optimization of the school-year program, and the evolving vision of science teacher leadership. The lack of connection between the summer institute and the school-year program has been discussed earlier, and these comments still hold true. The evolving vision of science teacher leadership, however, has not been addressed and is worthy of discussion.

The evolving vision of science teacher leadership was important, but it constrained the development of the participants. The project directors did not set clear leadership goals for participants from the outset. As a result, the goals shifted each year. Even when the vision became clear, it was still difficult to develop a program that supported the leadership development of the teachers. Much has been said about the need for a clear vision in the development of professional development programs (see Loucks-Horsley, et al. 2010).

One last point, which is both a constraint and pathway, is the time that teachers in this project dedicate to professional development. This project revealed that even our most passionate science teachers are engaged in relatively small amounts of professional development. While it is not clear why they spend so little time in professional development programs, it is problematic when science teachers are expected to participate in professional development programs that have a specific time and duration requirement. Those involved in teacher professional development programs must work within the parameters presented by teachers, who express a preference for conferences and short-term learning experiences. Personalized professional learning opportunities that consider the current knowledge and trajectory of the teacher are one way to optimize the learning of a science teacher. Such programs would focus on quality learning experiences, which may enable a teacher to attain specific goals in a shorter period of time.

Implications

From this study it clear that the development of science teacher leaders is essential and important. In addition, this study offers several suggestions related to future work in the area of science teacher leadership. It has been noted several times that there are few studies in this area, and more are certainly needed. Research should continue to focus on understanding how teachers learn to become leaders, and the on learning needed to support different teacher leadership roles (e.g., school, regional, or national).

Another suggestion pertains to the development of individualized leadership plans. A plan should be developed for each teacher leader, offering guidance for professional development programming and collaborative learning opportunities. Since teachers have limited time to engage in professional development programs, individualized leadership development plans may ultimately allow them to develop more quickly and efficiently.

Finally, from this study, it is clear that current teacher leaders and professional development specialists need to consider how to cultivate leadership among science teachers. There are ample opportunities, at every level—department, school, district, community, state, or national—for science teachers to develop into leaders.

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