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Teacher Leader Model Standards in Context: Analyzing a Program of Teacher Leadership Development to Contextual Behaviours of Teacher Leaders

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Abstract: A National Science Foundation-funded Mathematics and Science Partnership program, *Leadership for Educators: Academy for Driving Economic Revitalization in Science* (LEADERS), aimed to develop science teacher leaders who would influence the quality of science teaching in their respective schools. To fulfill a need to evaluate leadership abilities of teachers within LEADERS, a Teacher Leadership Instrument was developed based on our previous work. This paper examines the performance of teachers as outlined in the Teacher Leader Model (TLM) Standards following their enrollment in three teacher leadership courses aligned with these Standards. The study employed a qualitative approach to analyze peer professional development sessions provided by teacher leaders, and to rate leadership behaviours and practices. Results indicate that 31 of the 37 functions were exhibited by the teacher leaders, with most observations occurring at a developing level. Behaviours related to effective presentation and facilitation were observed most frequently, but the teacher leaders also incorporated research-based practices, information about assessments, and links to the community in their sessions. Further, these behaviours linked back to the intended outcomes of the three leadership courses. The results demonstrate one manner in which teacher leaders perform the functions of the TLM Standards in the context of professional development sessions.

Keywords: Leadership behaviours, professional development, science teacher leadership, teacher leader, teacher leader model standards.

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Introduction

With the trend of credentialing, endorsing, or certifying teacher leaders, the “sleeping giant” of teacher leadership has woken up and flexing its muscles (Katzenmeyer & Moller, 2009). Developing teacher leadership and using its influence is seen as being key in school reform (Crotty & Roehrig, 2020; Crowther et al., 2008; Lieberman & Friedrich, 2010; Nguyen et al., 2019). The case for expanding the roles of teachers, particularly through professionalization of their skills and decentralizing leadership functions, is very strong (Harris & Jones, 2019; Yow, Lotter, et al., 2021). While science education leadership is understood to reside in many levels, science teacher leadership can be considered particularly important to meet the contemporary goals of science education because it considers the direct and the pivotal role of teachers in the teaching and learning process and in gains in student achievement (Shen et al., 2020).

The National Science Foundation, through its *Teacher Institute for the 21st Century* program, sought to develop master teachers with both deep content mastery and leadership skills in order to improve K-12 student science achievement (National Science Foundation, 2010). Building the infrastructure to support and deliver excellent science education is a complex process requiring systemic changes (Roe & Nielsen, 2010; Short, 2021). Since teacher leaders are oftentimes critical to reform efforts (Crowther et al., 2008; Lieberman & Friedrich, 2010; Nguyen et al., 2019), developing the tools to train and assess science teacher leaders is vital.

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Literature Review

Teacher Leadership

Teacher leadership, as a concept or practice, has not been clearly or concisely defined in commonly understood terms (Cheung et al., 2018; Katzenmeyer & Moller, 2009; York-Barr & Duke, 2004). One widely-used definition comes from the seminal 2004 paper by York-Barr and Duke that states teacher leadership as “the process by which teachers, individually or collectively, influence their colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement” (pp. 287–288). As seen in this definition, one of the challenges of identifying and measuring teacher leadership is the broadness of the concept. Katzenmeyer and Moller (2009) differentiate the teacher’s role as a leader in the classroom by stressing that teacher leadership also occurs outside of it, and also explicitly place teacher leaders within a community of teacher leaders and learners.

Science Teacher Leadership

Teacher leadership in science, or more broadly Science, Technology, Engineering, and Mathematics (STEM), is particularly important in light of the demands and expectations on science educators from state and national policies (e.g., Integrated STEM learning, 2021; National Science and Technology Council Committee on STEM Education, 2018; Organisation for Economic Co-operation and Development [OECD], 2018; GETChina Insights, 2021). Reformers seek to improve curricula, standards, and assessments to address and increase students’ interest and achievement in the subject – advances that require systemic changes (Mohan et al., 2017; Next Generation Science Standards Lead States, 2013; Roe & Nielsen, 2010). This comes out of the recognition of the need for developing a highly qualified scientifically literate workforce that is able to compete in the global economy. Teacher leadership in science has been noted as an important component towards attaining high levels of scientific literacy and the ability to help the students of the United States develop 21st century work skills (Bybee, 2010; National Research Council, 2011; Rhoton, 2010; Yow, Lotter, et al., 2021).

Science education teacher leadership can help forge connections between the important components of the science education system, including national, state, and local science programs, as well as individual classroom practices such as teaching, curriculum design, and assessment (McKay et al., 2018; Rhoton, 2010). In addition, science educators need excellent instructional leadership (Elmore, 2000), and coherent content coverage (Schmidt & Kher, 2010) to meet the contemporary goals of science education as previously noted. Because of the influence of teacher leaders on their peers, the collaboration between teacher leaders’ peers and other stakeholders makes science teacher leadership a crucial component for successful student learning in a climate of rigorous science education reform and expected outcomes (Mohan et al., 2017).

Measuring Teacher Leadership Behaviours

In 2011, the Teacher Leadership Exploratory Consortium developed the Teacher Leader Model (TLM) Standards to “codify, promote and support teacher leadership as a vehicle to transform schools for the needs of the 21st century” (p.8). The seven domains of these Standards highlight the range of knowledge, skills, and competencies that teacher leaders may display throughout their work (Table 1). The domains include I, *Collaboration*; II, *Using Research*; III, *Professional Learning*; IV, *Improving Instruction*; V, *Assessments*; VI, *Family and Community*; and VII, *Advocacy*. The range of actions within each domain is defined by a set of 37 functions that, they claim, identify the best practices in teacher leadership. Indeed, by comparing how well the TLM Standards align with the goals of four teacher leadership development programs, Berg et al. (2014) found that the standards depicted many of the skills the programs sought to teach.

Table 1. The Domains and Functions of the Teacher Leader Model Standards (Teacher Leadership Exploratory Consortium, 2011)

| Fostering a Collaborative Culture to Support Educator Development and Student Learning | |
|---|--|
| | The teacher leader is well versed in adult learning theory and uses that knowledge to create a community of collective responsibility within his or her school. In promoting this collaborative culture among fellow teachers, administrators, and other school leaders, the teacher leader ensures improvement in educator instruction and, consequently, student learning. |
| | <u>Functions</u> |
| I | a) Utilizes group processes to help colleagues work collaboratively to solve problems, make decisions, manage conflict, and promote meaningful change; b) Models effective skills in listening, presenting ideas, leading discussions, clarifying, mediating, and identifying the needs of self and others in order to advance shared goals and professional learning; c) Employs facilitation skills to create trust among colleagues, develop collective wisdom, build ownership and action that supports student learning; d) Strives to create an inclusive culture where diverse perspectives are welcomed in addressing challenges; e) Uses knowledge and understanding of different backgrounds, ethnicities, cultures, and languages to promote effective interactions among colleagues. |

Table 1. Continued

| | |
|-----|--|
| | <p>Accessing and Using Research to Improve Practice and Student Learning</p> <p>The teacher leader keeps abreast of the latest research about teaching effectiveness and student learning, and implements best practices where appropriate. He or she models the use of systematic inquiry as a critical component of teachers' ongoing learning and development.</p> |
| | <p><i>Functions</i></p> |
| II | <p>a) Assists colleagues in accessing and using research in order to select appropriate strategies to improve student learning;</p> <p>b) Facilitates the analysis of student learning data, collaborative interpretation of results, and application of findings to improve teaching and learning;</p> <p>c) Supports colleagues in collaborating with the higher education institutions and other organizations engaged in researching critical educational issues;</p> <p>d) Teaches and supports colleagues to collect, analyze, and communicate data from their classrooms to improve teaching and learning.</p> |
| | <p>Promoting Professional Learning for Continuous Improvement</p> <p>The teacher leader understands that the processes of teaching and learning are constantly evolving. The teacher leader designs and facilitates job-embedded professional development opportunities that are aligned with school improvement goals.</p> |
| | <p><i>Functions</i></p> |
| III | <p>a) Collaborates with colleagues and school administrators to plan professional learning that is team-based, job-embedded, sustained over time, aligned with content standards, and linked to school/district improvement goals;</p> <p>b) Uses information about adult learning to respond to the diverse learning needs of colleagues by identifying, promoting, and facilitating varied and differentiated professional learning;</p> <p>c) Facilitates professional learning among colleagues;</p> <p>d) Identifies and uses appropriate technologies to promote collaborative and differentiated professional learning;</p> <p>e) Works with colleagues to collect, analyze, and disseminate data related to the quality of professional learning and its effect on teaching and student learning;</p> <p>f) Advocates for sufficient preparation, time, and support for colleagues to work in teams to engage in job-embedded professional learning;</p> <p>g) Provides constructive feedback to colleagues to strengthen teaching practice and improve student learning;</p> <p>h) Uses information about emerging education, economic, and social trends in planning and facilitating professional learning.</p> |
| | <p>Facilitating Improvements in Instruction and Student Learning</p> <p>The teacher leader possesses a deep understanding of teaching and learning, and models an attitude of continuous learning and reflective practice for colleagues. The teacher leader works collaboratively with fellow teachers to constantly improve instructional practices.</p> |
| | <p><i>Functions</i></p> |
| IV | <p>a) Facilitates the collection, analysis, and use of classroom- and school-based data to identify opportunities to improve curriculum, instruction, assessment, school organization, and school culture;</p> <p>b) Engages in reflective dialog with colleagues based on observation of instruction, student work, and assessment data and helps make connections to research-based effective practices;</p> <p>c) Supports colleagues' individual and collective reflection and professional growth by serving in roles such as mentor, coach, and content facilitator;</p> <p>d) Serves as a team leader to harness the skills, expertise, and knowledge of colleagues to address curricular expectations and student learning needs;</p> <p>e) Uses knowledge of existing and emerging technologies to guide colleagues in helping students skillfully and appropriately navigate the universe of knowledge available on the Internet, use social media to promote collaborative learning, and connect with people and resources around the globe;</p> <p>f) Promotes instructional strategies that address issues of diversity and equity in the classroom and ensures that individual student learning needs remain the central focus of instruction.</p> |
| | <p>Promoting the Use of Assessments and Data for School and District Improvement</p> <p>The teacher leader is knowledgeable about the design of assessments, both formative and summative. He or she works with colleagues to analyze data and interpret results to inform goals and to improve student learning.</p> |
| | <p><i>Functions</i></p> |
| V | <p>a) Increases the capacity of colleagues to identify and use multiple assessment tools aligned to state and local standards;</p> <p>b) Collaborates with colleagues in the design, implementation, scoring, and interpretation of student data to improve educational practice and student learning;</p> <p>c) Creates a climate of trust and critical reflection in order to engage colleagues in challenging conversations about student learning data that lead to solutions to identified issues;</p> <p>d) Works with colleagues to use assessment and data findings to promote changes in instructional practices or organizational structures to improve student learning.</p> |

Table 1. Continued

| | |
|-----|---|
| | <p>Improving Outreach and Collaboration with Families and Community The teacher leader understands the impact that families, cultures, and communities have on student learning. As a result, the teacher leader seeks to promote a sense of partnership among these different groups toward the common goal of excellent education.</p> <hr/> <p><i>Functions</i></p> <p>a) Uses knowledge and understanding of the different backgrounds, ethnicities, cultures, and languages in the school community to promote effective interactions among colleagues, families, and the larger community;</p> |
| VI | <p>b) Models and teaches effective communication and collaboration skills with families and other stakeholders focused on attaining equitable achievement for students of all backgrounds and circumstances;</p> <p>c) Facilitates colleagues' self-examination of their own understandings of community culture and diversity and how they can develop culturally responsive strategies to enrich the educational experiences of students and achieve high levels of learning for all students;</p> <p>d) Develops a shared understanding among colleagues of the diverse educational needs of families and the community;</p> <p>e) Collaborates with families, communities, and colleagues to develop comprehensive strategies to address the diverse educational needs of families and the community.</p> <hr/> <p>Advocating for Student Learning and the Profession The teacher leader understands the landscape of education policy and can identify key players at the local, state, and national levels. The teacher leader advocates for the teaching profession and for policies that benefit student learning.</p> <hr/> <p><i>Functions</i></p> <p>a) Shares information with colleagues within and/or beyond the district regarding how local, state, and national trends and policies can impact classroom practices and expectations for student learning;</p> |
| VII | <p>b) Works with colleagues to identify and use research to advocate for teaching and learning processes that meet the needs of all students;</p> <p>c) Collaborates with colleagues to select appropriate opportunities to advocate for the rights and/or needs of students, to secure additional resources within the building or district that support student learning, and to communicate effectively with targeted audiences such as parents and community members;</p> <p>d) Advocates for access to professional resources, including financial support and human and other material resources, that allow colleagues to spend significant time learning about effective practices and developing a professional learning community focused on school improvement goals;</p> <p>e) Represents and advocates for the profession in contexts outside of the classroom.</p> <hr/> |

One analysis of leadership assessments in the literature found that a variety of assessment methods, including surveys, self-reports, peer-rating instruments, and authentic assessments were in use (Jackson et al., 2010). Notably lacking when this study began was an instrument that measures leadership effectiveness *via* direct observation of teacher leadership behaviours in context. To that end, the LEADERS research team developed and validated the Teacher Leader Model Standards Instrument (TLMSI) (Doraiswamy et al., 2016). Based on the TLM Standards, this instrument allows researchers to define and rate the particular leadership behaviours performed by teacher leaders during their work.

Context for the Study

The study was conducted in the context of LEADERS (hereafter 'the program'), a National Science Foundation funded Mathematics and Science Partnership (MSP) program (Award #0927996). In this partnership, school districts, The University of Toledo, industry, and informal science educators collaborated to support the development of science teacher leaders in an urban school district who would deliver professional development (PD) to area teachers. The three-year training for the teacher leaders focused on instruction in Project-Based Science (PBS) (Krajcik & Czerniak, 2018) and science content related to renewable energy. Broadly, the program was designed to bring cutting-edge, renewable energy science content and research-based science education strategies into classrooms with the long-term goal of community economic redevelopment. The program aimed to educate and develop teacher leaders who would, in turn, disseminate the learned pedagogy and science content to peers through PD sessions. These sessions were developed and delivered by the teacher leaders for their respective school districts.

Leadership Courses

The program participants completed graduate-level science content courses in physics, chemistry, Earth science, and engineering that were jointly taught by a scientist and a science educator, along with one pedagogical course in PBS. Of greatest interest to this study is the leadership course that the teacher leaders underwent during each of their three years in the program. The three leadership courses focused on the psychology of teaching and learning in science, use of data to improve student achievement, and multicultural education research and practice to address issues of diversity and equity for students as well as with their peers. The courses were connected to the teachers' work in the context of their own classrooms and schools as well as to the professional development sessions that they would deliver monthly to their peers during the academic year. Further, these courses addressed the seven domains of the TLM Standards and focused on teaching and learning, research and assessment to enhance student learning, and teaching diverse learners.

Science Leadership I

The science leadership course focused on educational psychology introduced teachers to basic educational psychology theories and principles in the context of teacher leadership. It was designed to help teacher leaders develop and implement high quality teacher professional development aimed at improving science teaching and learning in K-12 schools. The course concepts were consistent with psychological principles of student learning of science, developing teachers' leadership skills, gaining skills needed to deal with school reform and change, and gaining an increased understanding of adult learning principles needed to work with peers as a teacher leader.

This course was primarily aligned with domains I (*Collaboration*), II (*Using Research*), III (*Professional Learning*), and IV (*Improving Instruction*). These standards were addressed through the course outcomes in the context of leadership, change, and professional development, how students learn science, and adult learning. The concepts included qualities of a teacher leader; different leadership styles, professional development, change theory for individuals (adults), change within organizations; adult learning theory & principles, group processes, conflict management, and professional learning communities.

Science Leadership II

The science leadership course on research and measurement was designed to help science teacher leaders develop and implement better assessment practices in their own classrooms as well as improve assessment practices in K-12 schools through professional development. Designing and using quality assessment practices is difficult for novice and veteran teachers alike. As such, this course focused on first learning to develop quality assessments consistent with best practices. And second, this course helped teacher leaders prepare professional development on assessment practices aligned with project based learning in science.

This course addressed two of the Teacher Leader Model Standards through the course outcomes: Domains VI (*Improving Instruction*) and V (*Assessments*). Learning objectives, taxonomies, objective items, constructed response items, rubrics, formative assessment, standardized testing, affective assessments, data-driven decision-making, and action research were the concepts covered in the course. These concepts were assessed by two main projects. First, teachers were required to develop a summative assessment that was aligned with a PBS unit they had previously created. This summative assessment underwent expert review as well as a cognitive interview process with students at an appropriate age level to ensure high quality items were being used. Second, teachers created a formative assessment plan that was aligned with either their PBS units or their professional development lessons and implemented the plan during the school year.

Science Leadership III

The science leadership course on theory of social foundations offered multicultural education research and practice within the particular context of the program. The course also addressed differentiated instruction (Tomlinson & Allan, 2000) to prepare teacher leaders to address issues of diversity and equity in science classrooms and with their peers. The course aimed to help science teachers translate multicultural education frameworks and its dimensions into relevant science classroom praxis. In the process, it included differentiation of content, process, and product through instructional and classroom management strategies, and development of pedagogical approaches that are equitable and community based as opposed to just offering a theoretical foundations course.

The course addressed teacher leadership because it is particularly important for science education in the current policy context that requires teachers to assure equitable learning opportunities (Lee & Buxton, 2010), to capitalize on diversity, and to ensure science learning for all in a robust manner that addressed the connections within and outside classrooms, and at school, district, state, and community levels. The course was aligned with domains VI (*Families and Community*) and VII (*Advocacy*), and can be specifically considered as being important to issues of educational equity and diversity that are of prime importance in the science education policy, reform, and standards (National Research Council, 2012).

Professional Learning Community

The teacher leaders extended their leadership strategies through monthly meetings during the academic year of a professional learning community (PLC). A virtual meeting space, entitled Science Café, was used to facilitate communication and networking among the program teacher leaders and program staff during these sessions. Some sessions focused on issues specific to PD sessions, such as how to support the district teachers attending the PD sessions as they began to implement PBS in their classrooms and how to motivate teachers to change their practice. This PLC complemented the leadership development that began during the summer leadership courses.

Professional Development Sessions

PD sessions were the primary vehicle for the program teacher leaders to disseminate the knowledge, content and pedagogy they learned while enrolled in summer institute courses. The teacher leader PD sessions were oriented to general grade level strata of elementary, middle and high school levels. Some sessions consisted of multiple teacher leaders working collaboratively to develop and deliver PD. Individual delivery sessions featured one teacher leader developing and delivering the session. Attendees at the sessions consisted of district teachers who sought to fulfill PD requirements for their respective districts. The sessions varied in number of attendees and length of session based on the district in which they were provided.

Methodology*Research Design*

The study used a qualitative approach to analyse the PD sessions by teacher leaders for their peers for leadership behaviours and practices, and also to rate the same. Due to the need to assess whether the program helped teachers develop leadership skills, the program created an instrument to measure leadership behaviours based on the seven domains of the TLM Standards. Having established that the instrument could be used to measure teacher leadership (Doraiswamy et al., 2016), the current qualitative case study examined whether and to what extent its participants demonstrated leadership behaviours as outlined by the TLM Standards, which speaks to how they met the intended leadership course outcomes. Specifically, it set out to answer the following research questions:

1. How do teacher leaders enact the TLM Standards in the context of a program designed to develop science teacher leadership?
2. How did the intended outcomes of the three leadership courses match to displayed behaviours?

Sample and Data Collection

Study participants consisted of 23 teacher leaders from an urban school district who delivered PD to their district peers over their three-year enrollment with the program. All PD sessions were video recorded, and select sessions were purposefully chosen from the video catalog to ensure review of all participants across their years in the program.

Analyzing of Data

The program research team undertook an extensive review of the PD videos. Researchers provided detailed comments on observed behaviours identified as the functions of the TLM Standards domains. They further rated the observed behaviours as *developing*, *proficient*, or *accomplished* as described in Doraiswamy et al. (2016). *Developing* was defined as “demonstrates minimum competency in performance;” *Proficient* as, “demonstrates competency in performance;” and *Accomplished* as, “consistently exceeds expectations for performance.”

Following individual viewing, commentary, and rating, the research team met to discuss findings and came to a consensus on ratings for the observed teacher leaders as well as how the behaviours correlated with interventions in the program. Specifically, three researchers on the team rated the videos and presented their analysis to the entire team for discussion and review. To analyze the patterns of behaviour, the team tallied the frequencies of observations for each function and domain. The detailed qualitative observations and ratings within each domain were then analyzed and triangulated via discussion, with members of the research team noting which functions earned the highest and lowest ratings and frequencies. Lastly, the overall pattern of observations was analyzed to develop a broad picture of the behaviour of teacher leaders in the context of presenting professional development and how they matched the intended outcomes of the leadership courses.

Findings

To answer the research question, *How do teacher leaders enact the TLM Standards in the context of a program designed to develop science teacher leadership?*, the TLM Standards were broken down into detailed observations by domain and function. The analysis demonstrated that the group of teacher leaders performed 31 of the 37 functions defined by the TLM Standards on a continuum, accessing certain functions frequently and others not at all (Figure 1). Our analysis also showed that most behaviours were performed at a *developing* level. This pattern reflects the context in which they displayed their leadership and outlines one possible model of behaviour for teacher leaders when developing and delivering professional development. In the following section, the results are presented by domains and ordered from most frequently observed behaviours to least frequently observed.

Domain III: Promoting Professional Learning for Continual Improvement

Domain III focuses on professional learning for continual improvement, and the underlying functions range from using new technologies to collaborating with administrators to plan and deliver effective professional learning sessions. Most obviously, function III.c was well represented, as the program required its participants, the teacher leaders, to create and deliver PD sessions to help district teachers to learn more about new content standards, PBS, and relevant technologies that can be used to teach both. Most observations of this function occurred at the *proficient* and

accomplished levels. At the *accomplished* level, Dwayne*† led a session on science projects that included discussion among PD participants about the misconceptions displayed by students and pros and cons of reasoning strategies used by teachers. He also invited PD participants to discuss what they had learned from implementing their PBS units and pushed them to consider the experience of the students who participated.

The other functions of this domain generally occurred at the *developing* level. Heather invited school administrators to her PD sessions and aligned those sessions to the newest science standards (function III.a), Beth, Brian, and Meredith used appropriate technologies such as iPads, SmartBoards, and Edmodo for their presentations, though not toward differentiated learning (function III.d). Rachel discussed the importance of budgeting time and preparing lessons with the PD participants (function III.f).

Other frequently observed functions include III.g and III.h. Most teacher leaders performed these behaviours at a *proficient* level; for example, Heather advocated for the use of research-based classroom methods such as PBS in her sessions. In addition, after the PD participants prepared their PBS lesson plans, Kathie and Shani provided feedback on those plans and listened to the teachers' concerns (III.g). This important step was enabled by the teacher leaders' experience with the issues that can arise when implementing PBS from their own classroom experience. No examples of using information about adult learning to respond to the diverse learning needs (function III.b) or disseminating data about the effects of quality professional development (function III.e) were observed.

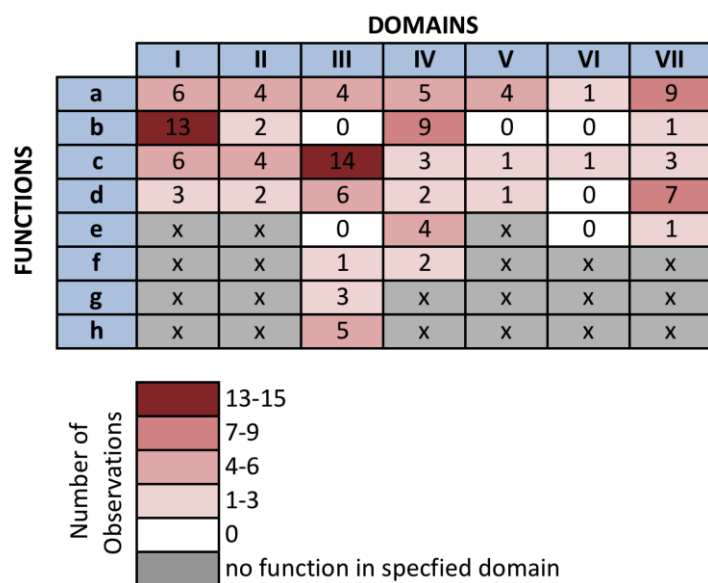


Figure 1. Relationship between Leadership Domains and Number of TL Observances of the Domain and Function.

*The number within each box represents the number of observations of that function; "x" denotes absence of function within domain, i.e., Domain I has functions a-d only (see also Table 1).

Domain I: Fostering a Collaborative Culture to Support Educator Development and Student Learning

The functions of Domain I were well represented in this data set. This domain is about facilitating group work and collaboration; consequently, it is supported by a host of behaviours/performances that can be readily identified in the context of the observed program PD videos. The particular challenge of this domain is the orientation toward student learning specifically.

The teacher leaders frequently rated *proficient* in modeling effective skills and providing engaging content focused on science pedagogy, content, and experience in adopting new methods (function I.b). Janelle and Armita were observed facilitating collaborative work among PD participants through discussion and feedback on issues (function I.a). Observations ranged from *developing* to *proficient* based on the ability to integrate relevance to teacher/student learning. These behaviours are in line with effective presentation skills, and the ratings in this sub-domain were predominantly *proficient*.

A broader range of behaviours falling under function I.c were observed, which is about employing facilitation skills. These observations ranged from *developing*, with Jill and Caroline encouraging sharing though not facilitating purposeful sharing, to *accomplished*, with Armita eliciting feedback and reflection on her participants' classroom experiences, along with incorporating discussion and activities to facilitate trust among her participants. Further

† All names are pseudonyms

observations of this function include examples of facilitating the development of collective wisdom through group activities to modify and advance established lessons and stressing the value of learning-by-doing over time. Effort to build ownership and action toward student learning were observations with Dwayne's PD session themed "How can we get our students to think more like scientists," which focused on facilitating activities that advance student learning.

Domain IV: Facilitating Improvements in Instruction and Student Learning

Domain IV concentrates on the teacher leaders' skills and abilities to affect improvements in instruction and student learning. The associated functions focus on the specific actions that a teacher leader might perform as a facilitator of change, such as engaging in reflective dialogue, supporting colleagues' reflection, using knowledge to guide colleagues, etc.

While these functions were frequently seen, most of the teacher leaders' scores ranked as *developing*. An examination of the comments shows that the teacher leaders focused on communicating their messages more so than in facilitating discussion and integrating the PD participants' experiences. For example, Jill, Caroline, and Kacie promoted the use of in class formative assessments to evaluate student understanding, with many employing these techniques within the course of the PD sessions to give a hands-on experience (function IV.a). In addition, Jill and Heather shared examples of student engagement and artifacts and offered their thoughts about how their PBS units had worked in their own classrooms (function IV.b). For these examples, the teacher leaders mostly discussed their personal classroom examples but engaged in little facilitation of discussion with the district peers in the PD.

Proficient observations were noted when teacher leaders facilitated group discussion about student grouping during cooperative learning in the science classroom and engaged the PD participants to share and reflect on their experiences. One observation that scored *proficient* notes that Armita acted as a coach when she shared her own experiences as well as promoting sharing among the participants (function IV.c). She made an effort to elicit discussion from the participants on ways to refine existing practices towards students understanding and learning through methods of formative feedback. Indeed, observation of function IV.d, which only occurred once, came from Armita, who does hold a cross-grade science coaching position. She acted as a team leader for her participants within the session and also spoke about how she had worked with them beyond a specific session to help address curricular expectations and student learning needs, supporting the idea that she had acted as a coach. Armita's role in the district as a science coordinator may contribute to her strengths with these functions.

Engaging in reflective dialog seemed to be a difficult task for some teacher leaders, as they may not have learned the necessary skills for asking probing questions about the successes and failures of a lesson in a group setting. When participants were willing to share, the ensuing conversations often lacked depth. The nature of the PD environment, the group dynamic and the skills of the presiding teacher leaders, among other factors, could make these skills difficult to perform.

Domain VII: Advocating for Student Learning and the Profession

In general, many functions of Domain VII were not often observed in the program PD sessions because the PD sessions did not function as venues for advocacy. Functions VII.b, c, and e were rarely observed, and generally occurred at the *developing* level. In those cases, the teacher leader would mention resources for research on meeting the needs of all students (VII.b) or bringing in community resources (VII.c) but not provide evidence that they had advocated for these.

On the other hand, function VII.a, sharing information regarding how trends and policies can impact classroom practice, was frequently observed. The teacher leaders extensively discussed standards such as the *Next Generation Science Standards* (National Research Council, 2012). Those who rated *proficient* specifically connected those standards to classroom practices and student learning. In addition, many used examples from their own classrooms, such as Kacie explaining how she had changed her instructional practices by incorporating PBS to meet the expectations of the upcoming standards.

In addition, function VII.d, advocating for access to professional resources, frequently came up. Teacher leaders who were *developing* offered ideas for resources that their peers can use towards meeting the needs of their students - such as the program Business-Science Liaison, local experts in science content, science support teachers, the teacher leaders themselves, and the existing knowledge of peers that can be collectively used to improve instructional practice and student learning. The teacher leaders that scored as *proficient* or *accomplished* advanced beyond offering ideas for resources to helping teachers set them up, such as helping the teacher leaders develop course platforms on Moodle or book guest speakers for their classrooms.

Domains II, V, and VI

These three domains were observed less frequently, and generally at lower ratings. Most ratings in these domains are *developing*. Domain V focuses on promoting the use of assessments to facilitate school and district improvement. While teacher leaders did discuss assessments (function V.a), generally sharing examples from their own classrooms, they

tended to discuss them in general terms rather than connecting those assessments to either learning standards or the science content. In addition, some of their work related to assessments was classified as belonging to different functions, such as IV.a, in which teacher leaders “facilitate the collection of classroom data” by demonstrating methods of assessment. Along those lines, the PD sessions generally focused on what the participating teachers could change about their own classrooms, rather than how they would change their school or district. Since many of the functions of domain V focus more on creating change at the school and district level, they were less likely to be observed in the context of the program PD sessions.

In general, the teacher leaders spent little time discussing research. Domain II was rarely observed even though many of the PDs focused on teaching research-based practices, such as PBS. However, the teacher leaders did not often articulate the actual research behind the success of such practices. When the research behind the practice was not mentioned, the researchers did not count those behaviours as belonging to domain II.

The functions of domain VI were less of a priority for the administrators who outlined the standards that they wanted the program participants to follow when planning PDs, meaning that these issues took a back seat to science content and pedagogy. Interviews with the teacher leaders indicate that while many of them recognized the importance of addressing issues of diversity, equity, and home and community, they were unable to contribute meaningfully to their peer knowledge due to factors such as minimal discussion, lack of networking and reflective opportunities, and relevant and practical references for ease of practical application, superficial meaning making, inadequacies in PD structure, as well as viewing themselves as leaders mainly in reference to science content and pedagogy expertise rather than as being knowledgeable about inclusion of diversity and equity (Doraiswamy, 2015). When these behaviours were seen, they were generally rated as *developing*, as the teacher leaders would simply mention community, business, and family resources without promoting long-term, systemic connections to them.

| | | DOMAINS | | | | | | |
|-----------|---|---------|----|-----|----|---|----|-----|
| | | I | II | III | IV | V | VI | VII |
| FUNCTIONS | a | 6 | 4 | 4 | 5 | 4 | 1 | 9 |
| | b | 13 | 2 | 0 | 9 | 0 | 0 | 1 |
| | c | 6 | 4 | 14 | 3 | 1 | 1 | 3 |
| | d | 3 | 2 | 6 | 2 | 1 | 0 | 7 |
| | e | 0 | x | 0 | 4 | x | 0 | 1 |
| | f | x | x | 1 | 2 | x | x | x |
| | g | x | x | 3 | x | x | x | x |
| | h | x | x | 5 | x | x | x | x |

| | |
|--|---------------------------------|
| | Science Leadership I |
| | Science Leadership II |
| | Science Leadership III |
| | stressed throughout LEADERS |
| | no function in specified domain |

Figure 2. Crosstalk between LEADERS Interventions and the Functions of the Teacher Leader Model Standards

Behaviours Compared to Intended Course Outcomes

Direct lines can be drawn between many of the behaviours performed by teacher leaders and the Science Leadership courses that taught some of those skills. Figure 2 shows the links between Domains, functions and the courses that taught those skills. A few functions, such as VII.a (sharing information regarding how trends and policies can impact classroom practice), were reinforced multiple times throughout the program and were not linked to a single course.

Science Leadership I stressed communication skills, conflict resolution, and implementation strategies that would be needed as teacher leaders guided their peers to critique their own practices and go through the difficult process of making substantial changes. Teacher leaders used these skills when facilitating *Collaboration* (I.a, I.b, I.c), *Improving Instruction* (IV.b, IV.c, IV.d), and critically reflecting on *Assessments* (V.c), all of which relate to the use of group processes in different contexts. The teacher leaders used their knowledge of adult learning theory extensively when they engaged in the behaviours of Domain III. Further, the teacher leaders gained significant science pedagogical knowledge from this course, which they used when disseminating the research-based practices they had learned in their PD sessions (II.a) and when helping their peers work directly with researchers and higher education staff (II.c).

The teacher leaders used their knowledge of assessment practices extensively in their classrooms, but also spent significant time on assessment in the PD sessions. Functions IV.a and V.a, which emphasize using assessments to improve instruction, are well represented in the observations. Teaching the PD participants how to use the data they obtain from assessments (II.b, II.d) was also observed. In general, the knowledge of assessments was applied at the

classroom level rather than the district level, as stated in *Domains II, V, and VI*. Lastly, the intended outcomes for Science Leadership III were among the least frequently observed functions in this study (see section *Domains II, V, and VI* for discussions).

Several frequently observed functions are more likely linked to multiple interventions in the program as opposed to a single course. Functions III.h (uses information about emerging education, economic, and social trends in planning and facilitating professional learning) and VII.a (shares information with colleagues within and/or beyond the district regarding how local, state, and national trends and policies can impact classroom practices and expectations for student learning) encompass trends from all three leadership courses and the science content courses. Similarly, as technology was emphasized throughout the program courses and coaching, the teacher leaders used technologies from all aspects of the program in their PD sessions (IV.e). Observations of VII.d often occurred when the teacher leaders obtained resources for PD participants *via* the program staff, and the resources shared came from multiple program interventions. Function VII.e (represents and advocates for the profession in contexts outside the classroom) was not frequently observed, but the teacher leaders were given financial support to do so by attending and presenting at conferences for science teachers, which is more attributable to the program as a whole than a single course.

The program teacher leaders were observed performing 31 of the 37 functions of The TLM Standards. It is not to be expected that any single teacher leader would perform all of those behaviours in one context, as the Standards were broadly written to capture the wide range of functions that teachers might perform in multiple contexts. However, it is notable that the collection of 23 program-trained teacher leaders performed such a significant number of them. The teacher leaders had to balance the needs of their administrators, PD participants, and the program grant requirements in order to carry out their PD sessions, and they used a wide-ranging set of behaviours to do so. Importantly, this analysis provided evidence that the teacher leaders' behaviours correlated with skills and knowledge that they received during their program training.

Discussion

Feasibility of the Model Teacher Leader Standards

Some of the most frequently observed behaviours from our PD sessions were excluded from this analysis because they are not captured in the TLM Standards. A major focus of the PDs was teaching advanced science content and pedagogical techniques, which was an important component of the training that the program teacher leaders received. However, the TLM Standards do not define functions for teacher leaders related to their content and pedagogy expertise.

Berg et al. (2014) also noted this discrepancy in their analysis of the TLM Standards. Snell and Swanson (2000) also note the importance of disciplinary expertise for teacher leaders. Considering that teacher leadership is often defined in relation to improving student learning (York-Barr & Duke, 2004), and that the TLM Standards were specifically written to support good teaching and student learning, it is interesting that they do not define functions that would help teacher leaders improve student learning in their own classroom. Indeed, it has been argued that perhaps the definition and measurement of STEM teacher leadership needs to change (Nachtigall, 2019), and Yow, Crisswell, et al. (2021) argue that disciplinary, program-specific content is needed in teacher leadership programs. Using the same TLM standards in a study, Bailey (2020) found that STEM teacher leaders had an affinity for the disciplinary content. A framework that specifically targets STEM teacher leadership may also be needed (Crisswell et al., 2016).

Another important area of feasibility of the TLM standards in science teacher leadership is the lack of meaningful contribution by teacher leaders to peer knowledge in PDs from certain domains. For example, even though teacher leaders understood the valuable goals of *Domain VI*, the demonstration of leadership behaviours at low frequency and only at the developing level resonates with Doraiswamy's (2015) findings on the difficulty and complexity of systematic, ongoing, and sustainable addressing of social justice issues in PDs.

Teacher Leadership Takes Time to Develop

As in our previous work (e.g., Doraiswamy, 2015), we endorse the provision of adequate time and clarity in PDs for better meaning making for teacher leaders and peers, connections of standards and reforms to science classroom practices and student achievement, and effective professional development frameworks focused on adult learning. Our results show that the teacher leaders were most likely to rate as *proficient* or *accomplished* in functions that resemble the behaviours of classroom teachers, such as III.a (collaborating to plan professional learning) and I.b (modeling effective skills for group processes, etc.). Teacher leaders were more likely to be rated *developing* in functions that required them to act in more of a facilitator role, such as IV.b (facilitating reflection by serving as a mentor or coach), and in functions that were less frequently seen, such as assisting colleagues in using research to improve learning (function II.a). This does not imply that the teacher leaders are not capable to performing these functions at a high level, but high-level observations were not made in the context of PD sessions. It should be noted that these observations were made after three courses in leadership and practice as a teacher leader in the teachers' schools. These findings are consistent with other research showing the development of teacher leaders as a complex process that takes time

(Hunzicker, 2017). Hunzicker found that there were four developmental stages of teacher development, and helping teachers see themselves as leaders is oftentimes difficult.

School Structures Are Needed to Support Teacher Leaders

Organizational structure also influences teacher's abilities to become STEM leaders in urban school districts (Hutchinson, 2020). Wenner and Campbell (2017) conducted a review of the literature on teacher leadership and concluded that principals, school structures, and norms are important in the development and empowerment of teacher leaders. Bailey (2020) also affirmed that principal support and school structures could be barriers to teacher leadership.

Conclusion

In conclusion, while the Teacher Leader standards offered well-articulated ideas of what best practices in teacher leadership should be, teacher educators should make explicit connections regarding how those standards and functions can be placed at the center of good science teaching and learning through the various roles teacher leaders are expected to perform. Stronger awareness, understanding, and clarity of teacher leadership behaviours in professional development, along with a sustained professional learning community, are central and essential for capacity building in school reform.

Overall, the TLM Standards provided a framework for assessing the behaviour of teacher leaders in a variety of contexts. This framework, which the research team also tested as a quantitative instrument (Doraiswamy et al., 2016), constitutes a flexible tool that can be used to assess teacher leadership and its development, thus providing a model for developing teacher leaders. The resulting qualitative pattern of behaviour in this study shows that the teacher leaders transferred many of the skills that they presumably use in their classrooms to the situation of teaching PD sessions and also used a variety of other leadership skills to carry out that complex task. The analysis also shows that their behaviours correlate with expected outcomes from the program leadership courses.

Recommendations

We offer four recommendations for future research. Firstly, though the teachers in our program developed and demonstrated leadership skills, it is unclear from our work how those skills developed over time. In a future study, it will be important to test how those behaviours developed over time and explore ways to support the development of these skills.

Secondly, we recommend the need to bridge the gaps in teacher learning and professionalization in ways that will help science educators understand, attend to, and strengthen the various contextual roles teacher leaders are expected to play in addressing standards and reform. The demonstration of a higher number of developing level of leadership behaviors in the domains calls for the strengthening of collaborative professional learning communities and systemic conversations on what contributed to the leadership behaviours over time. Understanding of the contextual factors affecting teacher leader behaviours is important for better teacher leader understanding of leadership standards and functions as being central to science teaching and learning.

Thirdly, given the importance, urgency, and complexity of teacher leaders addressing issues of equity and diversity to create adequate meaning making for their peers, we recommend the need for more research on exploring the relationship between teacher leadership and social justice to bridge the gaps. Wenner and Campbell's (2017) review of the literature noted that very little teacher leadership research focused on equity and social justice.

Last, as our literature review demonstrates, most studies on teacher leadership in general and science teacher leadership specifically are from the United States. This is consistent with those of Schott et al. (2020) who call for cross-country research designs on teacher leadership. Future research should examine comparative studies across countries to see international contextual factors influencing antecedents, enactment, or outcomes of teacher leadership.

Limitations

The study data was restricted in several ways. As this research pertained to a group of teacher leaders that underwent three leadership courses and the ensuing teacher behaviours and outcomes in professional development, many findings cannot be generalized or extrapolated to other situations. However, many science educators and PD providers will be familiar with similar evidence in their practice. The teacher leaders in the context of the program were not expected to perform every function of the leadership standards in every PD session, so many not applicable ratings were assigned thereby giving an impression that all standards were not met. Further, since the teacher leaders offered PDs, their differing roles did not allow demonstration of the same leadership behaviours at the same levels for each one.

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Authorship Contribution Statement

Doraiswamy: Significantly contributed to the concept and design, data acquisition, data analysis, results, interpretation, drafting manuscript, critical revision of manuscript, and writing and editing of the paper. Wilson: Significantly contributed to the conceptualization, data acquisition, data analysis, results, interpretation, drafting manuscript, statistical analysis, and editing of the paper. Czerniak: Significantly contributed to the concept and design, editing, securing funding, admin, technical, and material support, supervision, and final approval of the paper. Tuttle: Significantly contributed to the design, analysis, editing, revision, and supervision of the paper. Porter: Contributed to the data acquisition, data analysis, and results of the paper. Czajkowski: Contributed to the concept, admin, technical, and material support of the paper.

References

- Bailey, C. A. (2020). *STEM teacher leadership* (Publication No: 28154498) [Doctoral dissertation, The University of North Carolina at Greensboro]. ProQuest Dissertations Publishing.
- Berg, J. H., Carver, C. L., & Mangin, M. M. (2014). Teacher leader model standards: Implications for preparation, policy, and practice. *Journal of Research on Leadership Education*, 9(2), 195–217. <https://doi.org/10.1177/1942775113507714>
- Bybee, R. W. (2010). *The teaching of science: 21st century perspectives*. NSTA Press. <https://doi.org/10.2505/9781936137053>
- Cheung, R., Reinhardt, T., Stone, E., & Little, J. W. (2018). Defining teacher leadership: A framework. *Phi Delta Kappan*, 100(3), 38-44. <https://doi.org/10.1177/0031721718808263>
- Crisswell, B., Rushton, G., Polizzi, S. J., Coyle, W., Rosengrant, D., Barrett, D. J., Alemdar, J., & Cappelli, C. (2016). *A Multi-Pronged Exploration of a STEM Teacher Leadership Framework*. National Association for Research in Science Teaching.
- Crotty, E. A., & Roehrig, G. H. (2020). Teacher leadership for STEM programming. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), *Handbook of research on STEM education* (pp. 428-442). Routledge.
- Crowther, F., Ferguson, M., & Hann, L. (2008). *Developing teacher leaders: How teacher leadership enhances school success*. Corwin Press.
- Doraiswamy, N. (2015). *A case study on science teacher leadership to address diversity and equity through professional development* (Publication No: 10029048) [Doctoral dissertation, The University of Toledo]. ProQuest Dissertations Publishing.
- Doraiswamy, N., Porter, K., Wilson, G., Paprzycki, P., Czerniak, C. M., Tuttle, N., & Czajkowski, K. (2016). Development and validation of an instrument to assess teacher leadership behaviors in an NSF-funded MSP. *Journal of School Leadership*, 26(5), 726-755. <https://doi.org/10.1177/105268461602600501>
- Elmore, R. (2000). *Building a new structure for school leadership*. Albert Shanker Institute.
- GETChina Insights. (2021, December 10). *China's STEM education in action: Observations, initiatives and reflections*. Medium. <https://bit.ly/3MhtYep>
- Harris, A., & Jones, M. (2019). Teacher leadership and educational change. *School Leadership & Management*, 39(2), 123-126. <https://doi.org/10.1080/13632434.2019.1574964>
- Hunzicker, J. (2017). From teacher to teacher leader: A conceptual model. *International Journal of Teacher Leadership*, 8(2), 1-27.
- Hutchinson, A. E. (2020). *Perceptions of teacher leadership: The influence of organizational structure on the professional identity of urban STEM teacher leaders* [Doctoral dissertation, University of Cincinnati]. ProQuest. <https://bit.ly/3L2en1X>
- Integrated STEM learning. (2021). *Department of education, skills and employment*. Retrieved April 3, 2022, from <https://bit.ly/394flrd>
- Jackson, T., Burrus, J., Bassett, K., & Roberts, R. D. (2010). *Teacher leadership: An assessment framework for an emerging area of professional practice* (RR-10-27). Educational Testing Service. <https://doi.org/10.1002/j.2333-8504.2010.tb02234.x>
- Katzenmeyer, M., & Moller, G. (2009). *Awakening the sleeping giant: Helping teachers develop as leaders* (3rd ed.). Corwin Press.

- Krajcik, J. S., & Czerniak, C. M. (2018). *Teaching science in elementary and middle school: A project-based learning approach*. Routledge.
- Lee, O., & Buxton, C. A. (2010). *Diversity and equity in science education: Research, policy and practice*. Teachers College Press.
- Lieberman, A., & Friedrich, L. D. (2010). *How teachers become leaders*. Teachers College Press.
- McKay, S. R., Millay, L., Allison, E., Byerssmall, E., Wittmann, M. C., Flores, M., Fratini, J., Kumpa, B., Lambert, C., Pandiscio, E. A., & Smith, M. K. (2018). Investing in teachers' leadership capacity: A model from STEM education. *Maine Policy Review*, 27(1), 54-63. <https://bit.ly/3EBg5VW>
- Mohan, L., Galosy, J., Miller, B., & Bintz, J. (2017). *A synthesis of math/science teacher leadership development programs: Consensus findings and recommendations* (Research Report No. 2017-02). BSCS.
- Nachtigall, D. (2019). *Collaborating, mentoring, and liaising: Analyzing what teacher leadership frameworks say and what STEM teacher leaders do* (Publication No: AAT 27665336) [Doctoral dissertation, State University of New York at Stony Brook]. ProQuest Dissertations and Theses database.
- National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering and mathematics*. The National Academies Press. <https://doi.org/10.17226/13158>
- National Research Council. (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press. <https://doi.org/10.17226/13165>
- National Science and Technology Council Committee on STEM Education. (2018). *Charting a course for success: America's strategy for STEM education*. National Science and Technology Council. <https://bit.ly/392WGS1>
- National Science Foundation. (2010). *Math and science partnership program*. <https://bit.ly/3MhtIMt>
- Next Generation Science Standards (NGSS) Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies Press.
- Nguyen, D., Harris, A., & Ng, D. (2019). A review of the empirical research on teacher leadership (2003–2017): Evidence, patterns and implications. *Journal of Educational Administration*, 58(1), 60-80. <https://doi.org/10.1108/JEA-02-2018-0023>
- Organisation for Economic Co-operation and Development. (2018). Canada- Innovation and Skills Plan. <https://community.oecd.org/docs/DOC-131551>
- Rhodon, J. (2010). Preface. In J. Rhodon (Ed.), *Science education leadership: Best practices for the new century* (pp. xi-xv). NSTA Press.
- Roe, C., & Nielsen, N. (2010). New models of leadership and collaboration to improve science education: The role of business. In J. Rhodon & P. Bowers (Eds.). *Issues in science education: Professional development leadership and the diverse learner* (pp.17-32). NSTA Press.
- Schmidt, W. H., & Kher, N. (2010). Content coverage and the role of instructional leadership. In J. Rhodon & P. Bowers (Eds.). *Issues in science education: Professional development leadership and the diverse learner* (pp.65-94). NSTA Press.
- Schott, C., van Roekel, H., & Tummers, L. G. (2020). Teacher leadership: A systematic review, methodological quality assessment and conceptual framework. *Educational Research Review*, 31, 100352. <https://doi.org/10.1016/j.edurev.2020.100352>
- Shen, J., Wu, H., Reeves, P., Zheng, Y., Ryan, L., & Anderson, D. (2020). The association between teacher leadership and student achievement: A meta-analysis. *Educational Research Review*, 31, 100357. <https://doi.org/10.1016/j.edurev.2020.100357>
- Short, J. B. (2021). Commentary: Making progress on curriculum reform in science education through purposes, policies, programs, and practices. *Journal of Science Teacher Education*, 32(7), 830-835. <https://doi.org/10.1080/1046560X.2021.1927309>
- Snell, J., & Swanson, J. (2000, April 24-28). *The essential knowledge and skills of teacher leaders: A search for a conceptual framework* [Paper presentation]. American Educational Research Association Annual Meeting, New Orleans, LA. United States.
- Teacher Leadership Exploratory Consortium. (2011). *Teacher leader model standards*. <https://bit.ly/3JXweG3>
- Tomlinson, C. A., & Allan, S. D. (2000). *Leadership for Differentiating Schools & Classrooms*. Association for Supervision & Curriculum Development.
- Wenner, J. A., & Campbell, T. (2017). The theoretical and empirical basis of teacher leadership: A review of the

literature. *Review of Educational Research*, 87(1), 134-171. <https://doi.org/10.3102/0034654316653478>

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research*, 74(3), 255-316. <https://doi.org/10.3102/00346543074003255>

Yow, J. A., Criswell, B. A., Lotter, C., Smith, W. M., Rushton, G. T., Adams, P., Ahrens, S., Hutchinson, A., & Irdam, G. (2021). Program attributes for developing and supporting STEM teacher leaders. *International Journal of Leadership in Education*, 1-24. <https://doi.org/10.1080/13603124.2021.2006794>

Yow, J. A., Lotter, C., & Criswell, B. (2021). The need for STEM teacher leadership. *School Science and Mathematics*, 121(3), 123-126. <https://doi.org/10.1111/ssm.12461>