Becoming a Master Teacher: Situated Experiences of Middle Grades Science Teachers

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Abstract

This work focuses on the development of science teacher leaders in high-need public school districts in the state of Michigan, USA. While there has been an emerging consensus about the generalized attributes that define teacher leadership, there has not been sufficient attention devoted to the meaning of this concept in specific contexts. The data sources were surveys of teachers and interviews of a sub-set of three teachers. The survey questions focused on participants' experiences and development as teacher leaders. Interview questions were designed to gain a deeper understanding of the contexts of the participants' work and the factors that impacted their development as leaders. The interviewees were drawn from large urban school districts and a small rural school district. We discuss the ways in which leadership identities have developed and the factors that account the development.

Keywords: Keywords: teacher leadership; education reform; professional identity; science education; Next Generation Science Standards

1. Purpose and objectives

The focus of this work is on the development of science teacher leaders in high-need public school districts in the state of Michigan, USA. A range of scholarly studies have discussed the concept teacher leadership. While there has been an emerging consensus about the generalized attributes that define teacher leadership, there has not been sufficient attention devoted to the meaning of this concept in specific contexts. The interest in teacher leadership is motivated by concerns about school improvement and student achievement, most notable in science, technology, engineering, and mathematics (STEM). Data from the Program for International Student Assessment (Gurria, 2016) indicate that 15-year-olds in the U.S. scored 24th in science

and 38th in math (out of 71 countries). In the state of Michigan, the most recent data indicate that only 14.7% of 4th graders, 23.9% of 8th graders, and 33.0% of 11th graders pass the science section of the Michigan Student Test of Educational Progress (M-STEP) (MDE, 2016). Significant attention has focused on underperforming schools, also defined as "high-need" schools. The term "high-need school" is legally defined and broadly refers to a public elementary school or secondary school that is in an area in which the percentage of students from families with incomes below the poverty line is 30 percent or more.

In response to the pressing need for reform, the U.S. National Academies released the *Framework for K-12 Science Education* in 2012 (NRC, 2012). This document describes a vision for science education reform. The vision formed the basis of the Next Generation Science Standards (NGSS). Michigan has adopted new standards that align with the NGSS while also reflecting the specific interests of the people in the state.

Concurrently, teacher leadership has been increasingly recognized as a resource for instructional improvement (Berg, Carver & Mangin, 2014). The Michigan Teacher Leader Preparation Standards are a case in point. There are seven standards designed to promote seven interrelated qualities teacher qualities and abilities. These are:

- Promoting a shared school vision, mission, and goals of learning
- Fostering a collaborative culture to support educator development and student learning
- Accessing and using research to improve practice, student learning, and using authentic assessments
- Promoting professional learning for continuous improvement
- Facilitating improvements in instruction and student learning
- Improving outreach and collaboration with families and community
- Advocating for student learning and the profession

2. Conceptual framework
2.1 Professional knowledge

A dominant model of teacher professional knowledge has focused on building teachers' pedagogic content knowledge (Kang, Donovan & McCarthy, 2018). The term pedagogic content knowledge was first introduced by Lee Shulman in 1986. In doing so, he recognized that knowledge of the subject matter and how it is taught (pedagogy) are interdependent. Nevertheless, there is also a recognition that teacher expertise and effectiveness is also situationally dependent. In other words, we cannot fully understand expertise independent of contexts of practice. As Berry (2010) has argued we can only fully grasp the meaning of teacher and teaching effectiveness by going beyond individual teacher attributes and including the whole structure of the school in which that individual teacher is embedded. In other words,

"effective teaching is not just about teachers' knowledge, skills, and dispositions, but also about the conditions under which they work" (p. 6). This is especially important for high-need schools where concerns about the quality of teaching and student achievement have been longstanding. The discourse on teacher leadership aims to re-define and extend the nature of teacher professional knowledge beyond pedagogic content knowledge. The Michigan Teacher Leader standards are a case in point.

2.2. Insights from international comparative

Comparative analysis of teaching and learning between the USA and Finland provide important insights for this study. Finland has been one of the countries that consistently scores at the top of international assessments. A core strand of comparative research between Finland and the United States has focused on the professional work of teachers. The findings highlight the important role of both teacher knowledge and context as a determinants of teacher effectiveness (Sahlberg, 2011). When compared to the USA, teaching in Finland is perceived as an autonomous, independent, and highly valued profession. Data indicates that American teachers spend significantly more hours per week working compared to Finnish teachers. So, commitment to work is not the issue. The difference is on the nature of teachers' work. The data indicates that Finnish teachers devote a greater proportion of their time to instruction. American teachers are being asked to perform many different types of tasks that are not of an instructional nature (Hemphill, 2018).
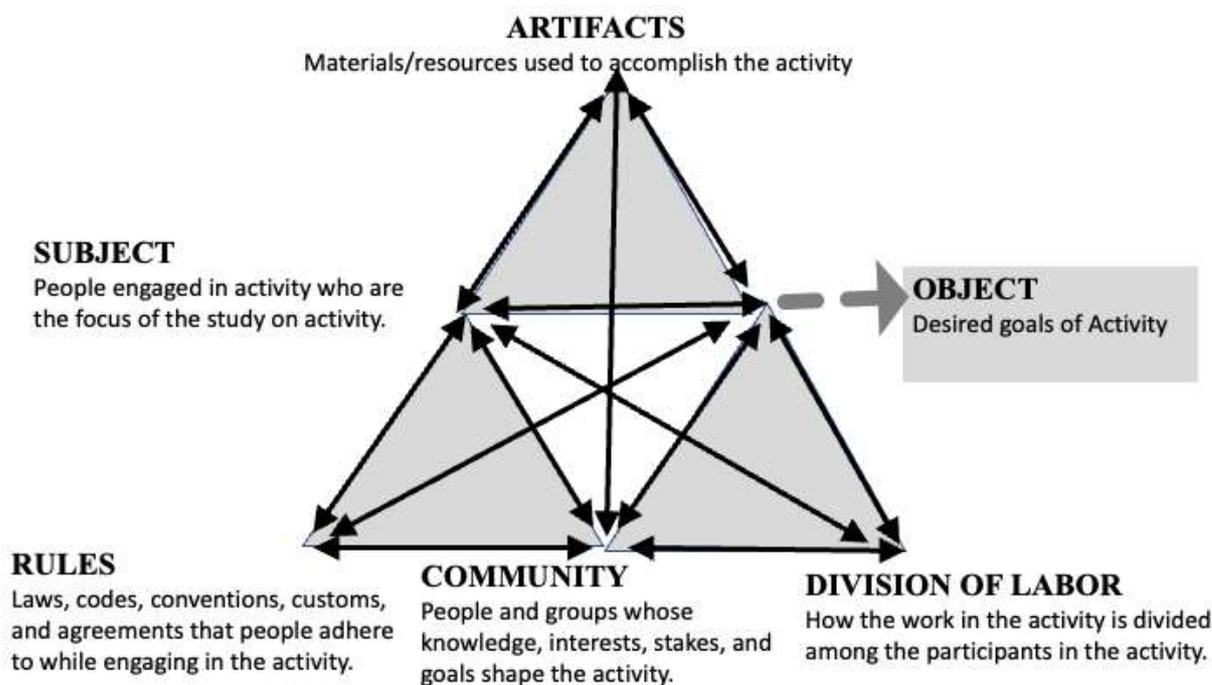
American classrooms are also more diverse in terms of students' backgrounds and preparedness for learning. Teachers in high need urban schools have above average proportions of English language learners (ELL), that is students whose first language is different from the language of instruction. According to Hemphill (2018), about 9% of Finnish teachers report working in a school with more than 10% of students whose first language is different from the language of instruction. The comparable figure in the USA is about 22%.

Other contextual factors to consider include class size, resources for teaching, assessment practices, and the evaluation of teachers' work. For example, Finland does not use high stakes assessment to evaluate school outcomes. These contextual factors call for more ecologically valid models of the work of teachers and what it means to be a teacher leader.

2.3 Teachers professional work through the lens of Activity Theory

Activity Theory (AT) provides a framework for the analysis contexts of work in terms of the overarching goal (motive) of the activity, the community of participants engaged in the activity, the norms and rules that define the activity, the division of labor, and the resources or tools used. AT was originally developed by Lev Vygotsky (1978) with elaboration by others, and most recently by Engeström (2015). Figure 1 indicates the theoretical structure of an activity.

The triadic structure, with arrows, implies interacting relations between sub-systems within the activity. An example of a sub-system is the triadic relation defined by community-subject-rules (figure 1). In the context of this study, this would refer to this would be teachers (as subjects) in communities, and the norms and regulatory framework in which they operate. There is a potential for tensions and contradictions which is a key principle of AT. The nature of these, if they exist, is an empirical question, specific to each context. Included in the overall activity system are artifacts, which may be understood as resources that are used to mediate the activity Some of the resources may pre-date the activity and others may be created specifically for the activity. Examples may be computer tools and curriculum materials. An activity will have a motive or *raison d'etre*. In the case of schooling, this may be understood as student learning and development. Studies informed by AT seek to investigate the ways and extent to which the object is realized, and the extent to which the elements in the system as a whole align with the intended outcomes. Applications of AT in studies of education include Hirsh & Segolsson (2019).   In this and other studies, AT provides a way of applying a qualitative methodology to analyze the functional dynamics of contexts.

*Figure 1. Activity System Diagram (Adapted from Engeström, 2015)*

ARTIFACTS
Materials/resources used to accomplish the activity

SUBJECT
People engaged in activity who are the focus of the study on activity.

OBJECT
Desired goals of Activity

RULES
Laws, codes, conventions, customs, and agreements that people adhere to while engaging in the activity.

COMMUNITY
People and groups whose knowledge, interests, stakes, and goals shape the activity.

DIVISION OF LABOR
How the work in the activity is divided among the participants in the activity.

3. Approach to teacher professional development
3.1 Background

The National Science Foundation funded Michigan Middle School Master Teachers Fellowship Program (MTP) is designed to prepare middle school (grades 6-8) teacher-leaders

to guide science educational reform efforts in their home districts. The MTP team recruited teachers drawn from regions 1, 4 and 7 of the state of Michigan (see map). Teachers had to apply to participate and recommendations from school administrators were required as part of the application package. The overriding selection criterion was potential for leadership as a classroom teacher. Each participant was required to commit to maintain a full-time classroom teaching position for the 5-year duration of the program. Each teacher was eligible to receive a stipend of $10,000 of participant support for a total of five years.   The program has been mostly successful in retaining the teacher participants. Three teachers left the program in 2022 when they ceased to be classroom teachers

Figure 2: Michigan's 10 education regions (source MASA, 2022)

Participating schools are from regions 1, 4 and 7
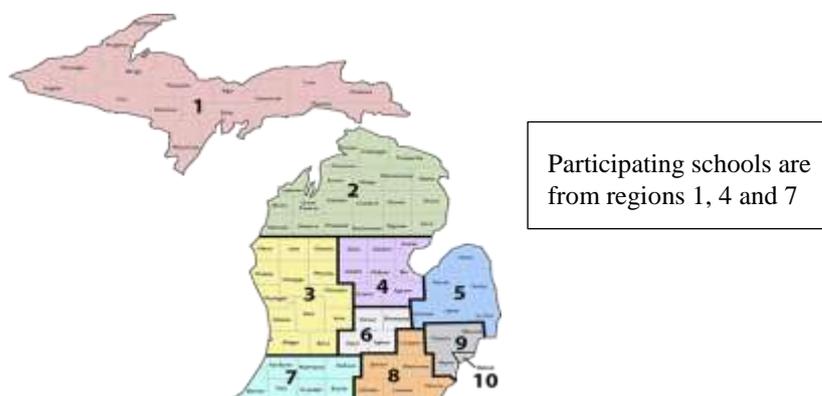
3.2   Elements of the program
3.2.1 Coursework and related experiences

The MTP program originally recruited 20 teachers. Half of the teachers, designated cohort 2, had a masters degree in science education. They were to complete additional coursework that focused on teacher leadership. The other half of the teachers, designated cohort 1, were supported to complete a graduate program as part of their professional development. Their coursework covered the Next Generation Science Standards, assessment and evaluation, teacher leadership and research. They also completed the Professional Learning Facilitator (PLF) training program and the Leadership Professional Learning Community (PLC) for Teacher Trainers. The overall objective was to create a peer mentoring relationship between the two cohorts.

3.2.2 Lesson study

Beginning Fall 2021, the teachers participated in a Lesson Study (Stepanek et al., 2007). Groups of teachers identified an aspect of instruction that was of joint interest. An example was the use of questioning to support student learning. Teachers collaborated in planning a lesson that featured that aspect. A member of the team was nominated to teach and record the lesson in their school. Following the teaching, the teachers convened to discuss how it went and what aspects could be improved. A revised lesson was then created and taught by a different teacher. The cycle of joint planning and teaching continued until the team was satisfied with the outcome. The use of videoconferencing platforms made it possible to support the activity for geographically dispersed group members.

3.2.3 Professional learning communities

The development of teacher professional learning community (PLC) has been a major feature of the project. PLCs have supported teams of teachers to share and develop ideas that enhance their teaching practice and create effective learning environments. For example, one team has focused on formative assessment, and another on career connections.

3.2.4 The Michigan Science Teaching and Assessment Reform program (MI-STAR)

The MI-STAR has been designed to support the teaching and learning of science in the middle grades through curriculum resources that are aligned with the Next Generation Science Standards. MI-STAR is also a network of teachers and instructional coaches. Not all the schools on the MTP program have adopted the MI-STAR curriculum. However, the network has been an integral part of the professional development program for all teachers, contributing knowledge of pedagogy as well as creating opportunities to learn. Figure 3 illustrates the ways in which the components of the program.

Figure 3: Summary of the conceptual framework of the context
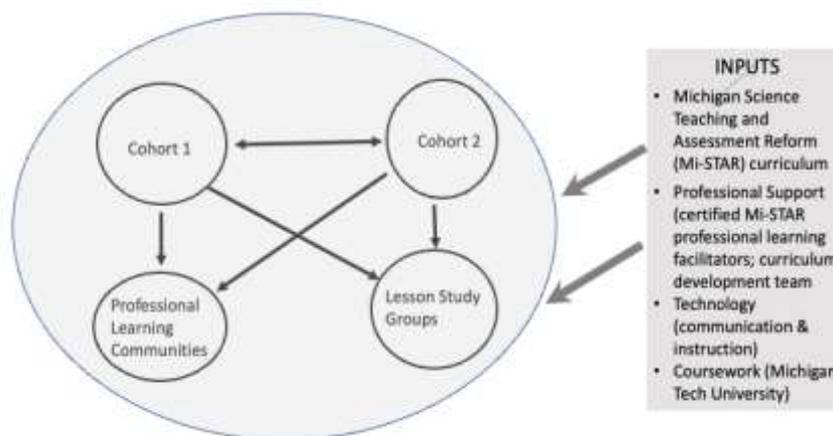
4.   Methods

The primary data for the study are derived from surveys and interviews of teachers. One survey provided information on the leadership activities that teachers were engaged in. The survey was completed by 17 teachers. A second survey focused on participants' experiences and development as teacher leaders, including networking. Thirteen teachers who had at least 3 years on the program completed the survey. Three teachers from representative districts were interviewed. The interviewees were drawn from large urban school districts and a small rural school district. Interview questions were designed to gain a deeper understanding of the contexts of the participants' work and the factors that impacted their development as teacher leaders.

5.   Findings
5.1   Overview

In discussing the findings, the guiding framework is Activity Theory. The goal is understanding the overall context of teachers' work and the ways in which the elements within the context align or are in tension with the overall goal of the activity which is the improvement of learning outcomes. Of particular interest is the nature and role of professional learning communities, the resources for teaching, and the development of the teachers' self-understandings of their work and their roles.

5.2   Aligning with the Next Generation Science Standards

The Next Generation Science Standards are designed to create a context for learning in three dimensions. These are (1) science and engineering practices (2) disciplinary core ideas; (3) crosscutting concepts (ways of linking the different domains of science). The objective is to provide for contexts of instruction where students understand how science is done (practice) and its practical value (applications), along with mastering content.

The consensus among teachers has been that the enacting the NGSS curriculum in the classroom is challenging. As noted, the program has used MI-STAR curriculum materials. Teachers saw the MI-STAR curriculum as a critical resource for guidance. Students were challenged to question and to think. A case in point is teacher Knack who reflected on the uses of the MI-STAR curriculum and the mentoring he has received. "I would say my understanding of the Next Generation Science standards is leagues ahead of where it was when I started. Before I would say I was a very content, driven teacher." He described his experience as "absolutely phenomenal." Other teachers also reported building their repertoire of abilities for teaching. Among these were modeling, and phenomenon-based learning.

Classroom observations of nine classrooms provided evidence that leachers were making progress towards NGSS alignment of their classroom instruction but not consistently with fidelity. The most cited challenge was time to plan lessons. Additionally, teachers from the large urban schools saw the curriculum resources as not consistently attuned to teaching English language learners, and students with deficiencies in reading skills.

5.3   Peer networks as mediators of teacher leadership development

Building professional teacher networks has been a core feature of the professional development program. All respondents had established close collaboration with at least one other professional peer. Three had been in collaboration with 1-4 others; seven were in collaboration with 5-9 others; and two teachers had collaborated with more than 10 others. Additionally, 12 of the respondents had established collaborations that included peer professionals from outside their school district. The activities conducted in the networks focused on curriculum planning, instruction, and professional development. A case in point was teacher Knack. "There's a lot of value being derived from just being in a network of professionals that are also in that kind of a learning mindset" he said. He added, "we talk about the content. But we also talk about careers and opportunities, and what's working great." More recently, he had collaborated on Lesson Study. "The Lesson Study, I thought turned out really well with the project that we chose. I wasn't sure what to expect of it. I am using what I learned now in the classroom."
Participation gave teacher Knack a new level of confidence to assume leadership in his school. "I spend a lot of time communicating with other teachers in my building in my district, working with them specifically at my grade level, though I haven't done a lot outside of the curriculum I teach." In the past, he would not have done that, but he now felt the need to share and use what he had learned. "I guess I would say I feel like I have a mandate or a degree of authority, to take some of the leadership positions and to try and push some things we can do. I guess to be a little bit more active or proactive in my building, and the district level. That's not necessarily something I would have volunteered to do without my experiences on the program."
Teacher Dean described another example of a collaborative experience with teachers from other school districts.

> "One project I have been working on is on STEM careers. It is website resource that connects careers to each unit lesson. Through that project I have come to know some teachers really well. We can look at things from a different perspective. I am   doing the seventh-grade units, and another person is doing sixth grade. We have a team that works together really well."

In summary, networks have created opportunities for sharing and gaining expertise among teachers, bringing teachers from across the state together.

5.4 The role of technology

Internet technologies have expanded the opportunities for professional development across the state using video conferencing platforms. Teachers were able to create documents and share materials. Teachers have been able to virtually "visit" other classrooms and observe the enactment of lesson plans. The uses of the technologies have broken down the distance barriers, allowing teachers working hundreds of miles apart to actively engage. The COVID pandemic accelerated the trend to go online. Teacher Kahler talked about this experience:

> "COVID brought more collaboration. Everybody had to learn how to be virtual with technology. We were forced into that. It really allowed Laura, Ashley, Yonee [her colleagues] and I to work some lesson ideas. Some teachers were just putting a whole bunch of worksheets into Google classroom. With science you've got to have a lab, you've got to discover. We could figure it."

5.5.   Teachers' Growth as Leaders

MTP teachers   have become a critical resource for professional development in their school districts. A survey of all the participants indicated most of their teacher leadership work to be focused on developing and providing professional development in their districts (16 teachers). Other related activities reported by teachers were selecting and adapting instructional materials (13 teachers); using research to inform curriculum development and/or learning strategies (12 teachers); and mentoring new teachers (8 teachers).

Teacher Kahler is among those who are certified to coach on the NGSS aligned MI-STAR curriculum. **"**I got to write curriculum materials for a couple of years which I think gave me a benefit because I started to see what the cycle of a lesson was, what went into the thinking, and really looking into NGSS too."

Thirteen teachers with at least 3 years on the program self-rated their gains on eight dimensions associated with teacher leadership. Four items on the survey focused on instruction, and the other four were related to wider school improvement beyond their classroom, for example fostering a collaborative culture. Participants were directed that their only point of reference was the MTP program and they were to rate their gains in capabilities on each item on a 7-point Likert scale. The average are indicated in table 1.

Table 1: Average Self-Reported Teacher Ratings on Dimensions of Teacher Leadership (N=13)

Teacher Self-Assessed Abilities	M	SD
*Accessing and using research to improve practice, student learning	6.09	0.58
*Facilitating improvements in instruction and student learning	6.18	0.75
*Implementing NGSS aligned lessons	6.20	0.94

*Developing lessons that support learning for all students	6.08	0.86
+Promoting a shared school vision, mission, and goals of learning	5.55	1.07
+Fostering a collaborative culture to support educator development and student learning	6.18	0.62
+Improving outreach and collaboration with families and community	5.09	0.97
+Promoting professional learning for continuous improvement	6.27	0.49

Based on a 7-point scale (1=Strongly Disagree ; 4= Neutral; 7=Strongly Agree)

*Items related to instruction   + Items related to wider school improvement

The teachers also rated their understanding of what it meant to be a teacher leader when compared to where they were when they started. One of the 13 respondents believed they were at about the same level as when they started. Another indicated that their understanding was 'a bit more' than when they started. Five teachers rated their understanding as 'more than' and another six as 'much more' than when they started. Teachers were also asked to explain their responses. One strand of responses focused on gains in understanding the nature of teacher leadership and the ways in which they could express it. A teacher cast this as a "vision" for teacher leadership, and another saw this in terms of learning "what it takes to lead." Gaining confidence was another theme, this occurring as teachers were provided opportunities to learn and participate at multiple levels, within and beyond   their school districts.

5.6   Tensions and contradictions
The discussion focuses on four issues: (1) assessment and evaluation; (2) managing the wide diversity of student needs; and (3) norms and rules and associated statutory regulations.

5.6.1   Issues with student assessment

Public Act 173 governs educator evaluations for teachers and administrators in the State of Michigan. Beginning with the 2019-2020 school year, 40% of the annual year-end evaluation of teachers has been based on student growth and assessment. Students in the state of Michigan must take the state mandated M-STEP assessment. They also take other school district-selected benchmark assessments, such as the Northwest Educational Progress Assessment (NWEA). The statutory testing requirements have raised the stakes for the work of teachers, a situation compounded by the fact that they have no control over the content of the assessments and how the results should be interpreted. As teacher Knack put it, the data are not "actionable." In that sense, he sees the assessments as "getting in the way" of his teaching because of the time taken to prepare and take the tests. He also observed that "a lot of the kids just don't care. They're not really trying to show what their ability level is." Knack and his PLC have been engaged in a formative assessment project to that helps them to gain a better understanding of student learning and how to improve instruction.

5.6.2   Teacher evaluations as busy work

Measurements of student growth are one component of teacher evaluation. In one school, this was a weekly requirement. Teachers do not understand how this is beneficial to their work. When asked, they had no idea what happened to the materials periodically created and submitted. "I don't particularly think that they're being read," one teacher surmised. "I know what I'm doing," they added. "I have a plan. Why am I going through the extra steps of making it available to somebody that doesn't understand it and doesn't seem to care." "They force you to use your time in different ways, than you would," remarked another teacher. "I feel like this is a waste of time because I don't even know if they're going to read it or it's just one of those boxes I have to check."   Teacher- Kahler concurred with these sentiments.

> "One of the things that just feels silly to me are the teacher evaluations. When you have teachers that are doing well, and they are reaching students and it shows in their work, it seems ridiculous to me to keep assessing those teachers every year and trying to make the principal come in and evaluate them. There are hoops that you have to jump through when that time can be spent so much more wisely with your students. It takes time away from doing something much richer and more productive.

In summary, the requirements for assessment and evaluation meet bureaucratic statutory requirements but appear to be in contradiction with the overall objective of supporting innovative and autonomous teacher work.

5.6.3   Teaching science to all students

The diversity of the student population posed challenges. For example, teachers in the larger urban districts have above average proportions of children with special needs. Teachers have cited the challenge of teaching English language learners. Interview data indicated that districts had budgets to employ paraprofessionals to provide support in reading comprehension. However, recruitment was a challenge because of uncompetitive salaries. A teacher informant talked about his surprise when he found out what the school district was offering. "All I remember is taking a look at it and being absolutely horrified. That's what we were paying! No wonder we are having problems." Teachers have also expressed a need for support with students with mental health challenges. The recent COVID pandemic had compounded the problem, leaving some teachers feeling unsupported and stranded with severe cases.

Some schools were clearly stretched in terms of resources. Classroom observations have indicated class sizes ranging from 16 to 50 for the middle school science classes. The sizes were skewed towards the large size, and most class sizes were in the mid-thirties. One science lesson observed had 33 students and the room was "very full." The room was not properly equipped for science, with just one sink. Another room in a different school was clearly "not a

science room." There were no sinks. Another teacher reported limited funds and insufficient technology.

Nevertheless, teachers were committed to continually innovate.   Teacher Kahler, among others, had embraced the "challenge" of working with her student population.Teacher Knack had been surprised at how well some of his students had turned out. "It's nice to see when they are doing well. The middle school is not a shining moment for a lot of them. Some of them don't turn out so well. It's mixed. Some of the ones you thought were going to do very poorly have done just fine."

6   Conclusion

The work of teachers occurs in complex environments. The concept of activity as described in this work provides a framework for analyzing the contexts of the work of science teachers and the ways in which an intervention such as the MTP program can support teacher leadership development. The emerging leadership identities of teachers may be understood in terms of three elements. These were (1) an emerging commitment to re-conceptualize and adapt instructional practices in alignment with the NGSS vision of science education reform; (2) a commitment to develop and provide professional development support to other teachers; and (3) an interest in wider professional networks for the development of their professional knowledge.

The analysis has revealed significant tensions and contradictions that to not align with the objective (motive) of the activity. Teachers work in environments where professional autonomy and expertise are not always properly recognized; standards and procedures for assessment and evaluation are in tension with learning goals; resources are often in adequate; the routines, norms, and statutory regulations do not add value to teachers' work; and the range of student needs is often beyond the teachers' ability to manage. Teachers who have persisted have been motivated by a belief that they can find pathways to some success

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