Identifying, Preparing, and Supporting STEM Master Teachers

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# Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Roles of STEM Master Teachers in STEM Education Reform</strong></td>
<td>2</td>
</tr>
<tr>
<td>Supporting School/District STEM Improvements</td>
<td>2</td>
</tr>
<tr>
<td>Developing STEM Teaching Capacity</td>
<td>3</td>
</tr>
<tr>
<td><strong>Characteristics of Successful STEM Master Teachers</strong></td>
<td>5</td>
</tr>
<tr>
<td>The “Teacher” in STEM Master Teachers</td>
<td>5</td>
</tr>
<tr>
<td>Subject-Specific Knowledge</td>
<td>5</td>
</tr>
<tr>
<td>General Knowledge of Learning and Teaching</td>
<td>6</td>
</tr>
<tr>
<td>The “Leader” in STEM Master Teachers</td>
<td>7</td>
</tr>
<tr>
<td><strong>Selecting STEM Master Teachers</strong></td>
<td>8</td>
</tr>
<tr>
<td>Aligning the Evaluation System With Vision for STEM Instruction</td>
<td>8</td>
</tr>
<tr>
<td>Developing Selection Criteria for STEM Master Teachers</td>
<td>9</td>
</tr>
<tr>
<td>Applying Selection Criteria</td>
<td>10</td>
</tr>
<tr>
<td><strong>Preparing and Supporting STEM Master Teachers</strong></td>
<td>13</td>
</tr>
<tr>
<td>Preparing STEM Master Teachers</td>
<td>13</td>
</tr>
<tr>
<td>Providing Ongoing Support</td>
<td>14</td>
</tr>
<tr>
<td><strong>References</strong></td>
<td>17</td>
</tr>
<tr>
<td><strong>Appendix A. Selected Resources for Further Reading</strong></td>
<td>19</td>
</tr>
</tbody>
</table>
Introduction

National concerns about U.S. competitiveness in the fields of science, technology, engineering, and mathematics (STEM) have been well documented. Solutions toward addressing these concerns often point to improving STEM education in K–12 schools and teacher preparation for providing rigorous instruction in these areas. One strategy recommended by professionals in and outside of the field of education for improving STEM education is the development of a Master Teacher corps, recognizing and rewarding the most effective STEM educators. Multiple factors point to the importance of developing and supporting STEM Master Teachers. First, it is becoming increasingly apparent that expanding the definition of school leadership is sensible and productive. School administrators are challenged with numerous responsibilities and do not have sufficient time, and likely not all the needed expertise, to support teachers across multiple content areas. STEM Master Teachers can provide the STEM-education-specific instructional leadership that schools and districts need. Second, a large cadre of skilled and knowledgeable STEM teachers serving in leadership roles will be essential to STEM education improvement efforts across multiple schools. Finally, recognizing the expertise of STEM Master Teachers speaks to their professionalism and provides opportunities for career advancement, offering an incentive to attract and retain effective STEM teachers.

In 2012, as part of its Teacher Incentive Fund (TIF) program, the U.S. Department of Education funded six projects focused on improving STEM education by developing career ladders for STEM teachers. Known as the TIF STEM projects, these initiatives are charged with identifying, training, deploying, evaluating, and compensating STEM Master Teachers as part of their broader efforts to improve STEM education. This document was created to inform the work of grantees as they develop their STEM Master Teacher programs and is one component of the technical assistance being offered to the projects. The guide describes what is known about the knowledge and skills needed for STEM teachers to work successfully as STEM Master Teachers and the implications of this information for (1) their selection, preparation, and support and (2) the establishment of sustained preparation and support systems to ensure the continued development of teacher leaders.

... expanding the definition of school leadership is sensible and productive.

Although explicit efforts to develop teacher leaders can be traced back to the 1980s, available research provides little guidance for project leaders on how to design and implement a successful master teacher program in a particular context (Miller, 2008). This document draws on research and advice collected systematically from practitioners experienced in designing teacher leader programs (MSP Knowledge Management and Dissemination, 2007a), both of which have utility for leaders responsible for developing STEM Master Teacher programs.

The remainder of this document is divided into four chapters: Chapter 2 gives an overview of roles Master Teachers can play in a STEM education initiative. Chapter 3 describes the characteristics of successful STEM Master Teachers. Chapter 4 addresses issues related to the selection of STEM Master Teachers, and Chapter 5 explores the preparation and support of those teachers.
Roles of STEM Master Teachers in STEM Education Reform

Teacher leadership is generally defined as “actions by teachers outside of their own classroom which involve an explicit or implicit responsibility to provide professional development to their colleagues, to influence their communities’ or districts’ policies, or to act as adjunct district staff to support classroom changes among teachers” (Miller, Moon, & Elko, 2000). Leadership is not always a formally assigned position; it can also include informal leadership actions (Danielson, 2007; Muijs & Harris, 2006). A variety of titles are used for teachers in leadership positions (e.g., lead teacher, teacher leader, mentor teacher, peer teacher, coach, specialist, and master teacher), but there is no consensus on what duties any of the roles might entail.

The TIF STEM program uses “STEM Master Teacher” to describe effective STEM teachers in leadership roles, some of whom have some teaching responsibilities and others who serve as leaders full time. Individual TIF STEM projects have adopted different titles to distinguish between teachers in various places on their career ladders or with different types of leadership roles. For example, in one project, STEM coaches are responsible for mentoring, observing teachers, modeling instruction, and coaching teachers in STEM subjects. In another project, lead mentor teachers provide support to new STEM teachers. In this document, the term STEM Master Teachers is used to describe teachers who serve as recognized leaders in STEM education improvement efforts regardless of their specific duties.

STEM Master Teachers can have a variety of functions, which can be broadly sorted into two categories: supporting other school/district STEM improvements (i.e., beyond developing the capacity of the STEM teaching staff) and developing STEM teaching capacity (e.g., facilitating professional development programs, providing demonstration lessons, coaching). In this chapter, the roles they have in STEM education reforms will be explored.

Supporting School/District STEM Improvements

In supporting school/district STEM improvements, STEM Master Teachers can collaborate with district leaders to establish a common vision for effective STEM instruction, a critical and foundational aspect of STEM reform efforts. Once this vision is established, the knowledge and expertise of STEM Master Teachers can be used in a variety of ways to ensure that all parts of the STEM education system support the vision. STEM Master Teachers can be employed to ensure K–12 articulations, examining alignment of district curriculum to the vision for instructional change, and create pacing guides. Also, recognizing that student resources have a substantial influence on what is taught in STEM classrooms (Banilower et al., 2013; Weiss et al., 2003), STEM Master Teachers can be instrumental in analyzing resources for alignment with the project’s vision of effective STEM instruction. And, if gaps are found in examining alignment to the vision, STEM Master Teachers can identify learning experiences to fill these gaps. Also, during instructional materials adoptions, STEM Master Teachers could work to develop adoption criteria that ensure that new materials are aligned with the vision.

Further, STEM Master Teachers can be involved in identifying and highlighting educative materials (Davis & Krajcik, 2005) or infusing educative components to support teachers in using existing instructional materials.
Educative curriculum materials are designed to promote teacher learning about the substance or design of the activities in a set of instructional materials. These materials can (1) help teachers anticipate and interpret what learners may think about or do in response to instructional activities; (2) support teachers’ learning of subject matter addressed in the materials; (3) help teachers consider ways to make connections across units during the year; (4) provide teachers with the thinking behind particular instructional activities, i.e., how they are structured to develop understanding of a particular concept; and (5) develop teachers’ ability to make principled adaptations with fidelity to the purpose and goals of instruction, instead of making modification that might hinder student learning. Since instructional materials are used by teachers across districts, developing resources to make it more likely these materials are used well could be a critical role for STEM Master Teachers.

In addition to ensuring teachers have quality resources to support instruction, STEM Master Teachers can work for school/district STEM improvement by communicating the vision of effective STEM instruction and its implications to various stakeholders. STEM Master Teachers can coordinate with school and district administration in hiring new STEM teachers and procuring needed resources. They can work with school administration to examine and restructure school schedules to ensure there is time in the instructional day to support STEM instruction. In many areas, business communities are involved in STEM education improvement efforts, and STEM Master Teachers can play a critical role as liaisons to business/industry, working with them to determine collaborations (e.g., job shadowing opportunities for students) that will further STEM education improvement goals. Finally, STEM Master Teachers can work with parents to help them understand the vision of effective STEM instruction and how to support students in their learning and interest in these fields.

**Developing STEM Teaching Capacity**

STEM Master Teachers’ involvement in developing STEM teaching capacity entails various roles related to facilitating the professional learning of other teachers, both new and veteran. In this capacity, they can assess STEM teachers’ needs in relation to the project’s vision for effective STEM instruction using state/district data or teacher observation and then work with district leaders to develop a plan for teachers’ professional learning.

Professional development programs can use a number of different strategies (e.g., workshops, study groups, one-on-one coaching), and STEM Master Teachers can potentially have roles in each of these strategies. For example, they can design and facilitate workshops that are consistent with the broader vision for STEM instruction and utilize what is known about effective professional development for teachers. In initiatives that have outside experts provide workshops (e.g., local STEM higher education faculty offering content workshops), STEM Master Teachers can work with these experts to ensure that the workshops
provided are relevant to the teachers' instruction and are consistent with the vision for STEM improvement.

School-based professional learning is often facilitated by teachers in leadership roles. For example, STEM Master Teachers can design and facilitate professional learning communities (PLCs) focused on STEM teaching with groups of teachers and, possibly, administrators. They can also support teachers by providing demonstration lessons and modeling, planning lessons, helping teachers use assessment tasks and data for planning and reflection, and observing and giving feedback to individual teachers.

With the appropriate training, STEM Master Teachers could play any of these roles, but given time constraints, they cannot play all of them. It is important for leaders of STEM education improvement efforts to align the work of STEM Master Teachers with STEM instructional improvement goals and be strategic about how best to use STEM Master Teachers. Specifically, leaders should determine what roles STEM Master Teachers will play in support of the STEM education improvement efforts and what knowledge and skills they will need to be successful in these capacities. These foundational decisions will affect the selection and preparation of STEM Master Teachers, topics that will be explored in Chapters 4 and 5 of this document.
Characteristics of Successful STEM Master Teachers

Although some evidence exists of the positive influence of master teachers on instruction and student outcomes, research on the characteristics of successful STEM Master Teachers is limited. Few would argue that in order to be a successful master teacher, one must first be a good teacher with both an understanding of content and the skills to facilitate deep learning. These characteristics are necessary for teacher leader work but are not sufficient by themselves. Master teachers also need to possess or develop knowledge and skills related to their specific responsibilities, whether for working with other teachers or supporting other areas of the school/district STEM education improvements. This chapter explores the characteristics of successful STEM Master Teachers, drawing from research on teacher leadership, research on knowledge that is needed to be an effective STEM teacher, and practitioners’ advice on what makes a successful master teacher.

The “Teacher” in STEM Master Teachers

There is general agreement that teachers who serve in leadership roles should have significant experience in their teaching fields. They should have excellent teaching skills; extensive knowledge of teaching and learning, curriculum, and the content area; a clearly developed personal philosophy of education; a disposition toward lifelong learning; and enthusiasm for teaching (York-Barr & Duke, 2004). But what specifically are the knowledge and skills needed to be an effective STEM teacher?

Subject-Specific Knowledge

STEM teachers obviously need to know the content they teach. Research indicates that teachers’ content understanding has an impact on their teaching and their students. Still, there are multiple points of view on what it means to know content, or how teachers should know it. Three broad categories of content knowledge are typically considered as important for STEM teaching: (1) disciplinary content knowledge, (2) knowledge of the practices and applications of STEM disciplines, and (3) pedagogical content knowledge.

Disciplinary content knowledge includes understanding of the concepts in a subject area and how those concepts relate to each other to form the larger body of knowledge. Teachers clearly need to understand the content they are expected to teach at a particular grade level consistent with college and career readiness standards. In addition, teachers should understand the content beyond what is expected for students to learn, what some refer to as horizon knowledge (Ball, Thames, & Phelps, 2008). This advanced understanding of content is essential in choosing appropriate tasks, asking questions of students, interpreting students’ responses, and assessing students’ understanding.

Knowledge of practices and applications of STEM disciplines involves knowing how knowledge is formally established in a discipline, i.e., what it means “to know” something, and how that knowledge is generated. Although knowledge of this area has traditionally been recognized as necessary, the recent release of college and career readiness standards such as the Common Core State Standards for Mathematics (National Governors Association, 2011) and the Next Generation Science Standards (Achieve, 2013) has elevated its importance, as both documents recommend the teaching of important content through experiences that model the practices of the disciplines. Teacher knowledge of and facility with these practices will be essential in achieving that vision.
Identifying, Preparing, and Supporting STEM Master Teachers

Pedagogical content knowledge includes content-specific knowledge that is uniquely helpful in the work of teaching (Shulman, 1986; 1987). Teachers need to know which ideas in STEM are prerequisite or foundational for more sophisticated understandings. Teachers should understand how students think about particular STEM concepts and the how these ideas are typically developed so this information can be used as part of the teaching process. Pedagogical content knowledge also includes knowledge of curriculum/instructional materials. Specifically, teachers should understand how content ideas are sequenced in the materials, how connections among ideas are made, and how the various activities and their sequencing are intended to contribute to student learning of important STEM ideas. In addition, teachers need to understand a range of instructional strategies that are specific to STEM teaching, e.g., knowledge of different representations of mathematics and science concepts, how to assess STEM concepts and practices, and how to make instructional decisions based on assessment results.

General Knowledge of Learning and Teaching

In addition to subject-specific knowledge, STEM teachers need to have a strong understanding of how people learn and pedagogy that addresses the needs of learners. Research in the cognitive sciences has provided much knowledge about the mechanisms by which people learn (National Research Council 2003; 2005a; 2005b; 2005c). Teachers should understand the importance of placing heavy emphasis in their instruction on the ideas and understandings that students bring to the classroom, as students’ initial conceptions and skills affect how they process content and how they view the nature of the disciplines. In addition, STEM teachers need to understand and develop skill in supporting the processes by which students construct new knowledge. Students must be (1) motivated to learn, (2) intellectually engaged with appropriate phenomena in activities and/or discussions focused on what they already know, (3) encouraged to use evidence to support their claims, and (4) helped to make sense of new, developmentally appropriate ideas in the context of their prior thinking and their understanding of related concepts.

STEM teachers should also have knowledge of and facility with a range of differentiated pedagogical strategies for engaging all students with important STEM content. Knowing how to facilitate discussions or structure group work to substantively engage all students, manage materials and activities to maximize work time, and manage a classroom all fall into this category.

Even though the focus here has been on the knowledge STEM teachers need in order to be effective, it is important to recognize that other factors, including beliefs such as what the goals of instruction should be, whether and why certain topics are important, and what students can learn, will influence how teachers draw on their knowledge and ultimately what students experience in STEM classrooms. For example, one teacher may see the primary aim of instruction as developing conceptual understanding and draw on content knowledge to structure lessons that engage students with experiences that challenge their initial ideas. In contrast, a teacher who sees the purpose of instruction as transmitting the facts of a discipline is likely to structure lessons very differently, perhaps focusing on rote learning of vocabulary. Thus, it is important to recognize that defining effective teaching depends upon one’s vision for STEM instruction.
The “Leader” in STEM Master Teachers

Beyond deep understanding of one or more STEM disciplines and how to teach those disciplines, what STEM Master Teachers need to be a successful will depend largely on the roles they are assigned. For example, aside from having deep content knowledge, the knowledge and skills needed to be a mathematics coach are quite different from the knowledge and skills needed to design and facilitate professional development for teachers. At the same time, project leaders and researchers working with teacher leader programs agree on many of the characteristics that individuals serving in teacher leadership positions should possess (MSP Knowledge Management and Dissemination, 2007b; York-Barr & Duke, 2004), such as the following:

- Strong interpersonal skills/effective communicators;
- Ability to build trust with colleagues and support them;
- Ability to handle conflict, negotiate/mediate;
- Credibility with other teachers;
- Understanding of adult learners;
- Ability to assess, interpret, and prioritize district and teacher needs and concerns; and
- Solid understanding of the “big picture” issues in an organization, i.e., an ability to envision broader impact of decisions made by administrators and teachers.

STEM Master Teachers also need different knowledge and skills to be effective in specific functions (e.g., designing and implementing professional development, providing one-on-one coaching, structuring and facilitating PLCs, demonstrating lessons and debriefing with teachers, selecting/developing formative assessments, analyzing data, working with administrators and parents). For example, successful STEM Master Teachers who lead PLCs and workshops are able to facilitate discussions among groups of teachers, ensuring the discussion focuses on the designated goal and engages all participants. They also can design learning experiences for teachers, whether in PLCs or workshops, that are coherent, relevant, and likely to develop the intended understanding. STEM Master Teachers who are accomplished coaches are skilled at examining classroom practice, diagnosing areas that might limit student opportunity to learn important STEM content, and developing strategies to address designated needs.
Identifying, Preparing, and Supporting STEM Master Teachers

Selecting STEM Master Teachers

In preceding chapters, this document described what STEM Master Teachers do and the knowledge and skill they need for these roles. The remainder of the document explores implications of this knowledge for the selection, preparation, and support of STEM Master Teachers.

A STEM Master Teacher must be judged as an effective teacher based on the designated teacher evaluation system.

The selection of STEM Master Teachers in TIF STEM projects varies across projects but has some commonalities. A STEM Master Teacher must be judged as an effective teacher based on the designated teacher evaluation system. In all projects, a significant part of a teacher's effectiveness rating is based on the academic growth of his/her students during the school year. Teacher ratings are also based on two or more observations conducted by individuals in the school or district designated for that purpose (e.g., principal, STEM Master Teachers, district administrators). Other factors are taken into consideration in assigning teacher effectiveness ratings for teachers, but they vary across projects. For example, projects can include a school measure of student growth or surveys about a teacher's performance collected from students or parents. In addition, as part of the criteria specified by the Department of Education, TIF STEM projects must select STEM Master Teachers who are skilled at “modeling for peer teachers, pedagogical methods for teaching STEM skills and content at the appropriate grade level” and selected based on “criteria that are predictive of the ability to lead other teachers” (U.S. Department of Education, 2012).

This chapter explores the selection of STEM Master Teachers. It addresses implications of what is known about effective STEM teachers for the process of identifying STEM Master Teachers. In addition, it draws on the advice of experienced practitioners in STEM improvement projects. Specifically, the following topics are addressed:

- Aligning the evaluation system for identifying effective STEM teachers with the project’s vision for effective STEM instruction;
- Developing selection criteria for STEM Master Teachers; and
- Applying selection criteria.

Aligning the Evaluation System With Vision for STEM Instruction

As noted above, a key factor in the identification of STEM Master Teachers is identifying individuals who are effective STEM teachers. Results from teacher observations are one indicator of teacher effectiveness in evaluation systems being used by all TIF STEM projects. Given the centrality of observation systems in assessing teacher effectiveness, these systems communicate to teachers key aspects of instructional practice that are valued. Currently in these projects, common observation criteria are used across all subject areas, examining components of effective instruction more generally. They do not include STEM-specific indicators of effective instruction. Although using the same criteria for all subject areas provides a uniform framework for compensation decisions and facilitates building a common vision about effective practice, a “subject-neutral” system is limited in the extent to which it provides (1) sufficient information for identification of effective STEM teachers and (2) guidance for teachers about what is effective STEM instruction. In addition, as
data from observations are used to identify professional development needs, these subject-neutral criteria are likely inadequate for providing detailed information about needs specifically related to STEM instruction.

It is important, therefore, that teacher observations examine the extent to which instruction is aligned to the project’s vision of effective STEM instruction. For example, if the project’s vision is for mathematics or science concepts to be taught using strategies that model the practices in those disciplines, the observation should examine the extent and the quality with which this happens in a teacher’s instruction. If authentic, project-based learning is part of the vision, the observation should, for example, assess the extent to which the classroom projects in which students engage have clear STEM learning goals and lead to the learning of important content.

It should be noted that although components of the observation tools used in TIF STEM projects are consistent with what is known about effective STEM instruction, they do not explicitly address important areas of STEM teaching and learning. STEM content-specific issues will need attention in order to judge the quality of STEM instruction. For example, the current observation tools have indicators related to the nature of the tasks for students, examining the alignment of these tasks to instructional outcomes and the extent to which these tasks engage students with important and challenging content. All of these indicators require STEM-specific knowledge on the part of observers in order to judge quality.

In order to align the evaluation system with the vision of effective STEM instruction, it will be important to train observers in interpreting the observation tool consistently with the project’s vision of effective STEM instruction. Additional written guidance for observers (e.g., annotations for existing indicators, examples of existing indicators applied to STEM instruction) would be especially useful. Finally, since the evaluation system communicates to teachers what is valued in instruction, teachers also need professional development to understand the project’s vision of effective STEM instruction and how the evaluation system aligns with that vision.

Developing Selection Criteria for STEM Master Teachers

In TIF STEM projects, once a STEM teacher is designated as effective, those who are interested typically apply to serve in designated leadership roles. It is important that as part of the identification of STEM Master Teachers, clear selection criteria be established and a selection process put in place. In developing selection criteria, a number of factors should be considered. First, projects should establish what roles and functions STEM Master Teachers will have and then determine the necessary knowledge and skills. Selecting STEM Master Teachers without defining these roles may lead to general or vague selection criteria that result in hiring STEM Master Teachers without the requisite skills.

Second, in developing selection criteria, projects should consider the depth and kinds of disciplinary content knowledge necessary to carry out the work of the STEM Master Teacher. STEM Master Teachers need to have content expertise relevant to the particular role that they will be playing. For example, if a STEM Master Teacher will be coaching science at the middle school level, he/she ideally should have a science content background and experience teaching at the middle school level. It should be noted that teachers rarely have education background
in multiple STEM subjects or feel prepared to teach multiple STEM subjects (Banilower et al., 2013). Program leaders should consider how best to deploy STEM Master Teachers to ensure the appropriate expertise; e.g., instead of having one Master Teacher support both mathematics and science in a school, have one Master Teacher who supports mathematics and a second who supports science working across two schools.

Programs have used various mechanisms to try to ensure the necessary content knowledge: requiring a degree or secondary teaching certificate in the content area, asking interview questions about content knowledge in relation to classroom instruction, requesting professional references about a teacher’s level of content knowledge, and making classroom observations. Still, projects will inevitably need to strengthen the content knowledge of some STEM Master Teachers.

Third, in developing selection criteria, projects should consider the preparation program that will be provided for STEM Master Teachers and the implications for the knowledge and skills needed in Master Teacher candidates. Identifying STEM Master Teachers who are “ready to go” is unlikely—at least on a broad scale. Training will be needed, and the preparation that will be available should be considered in the development of selection criteria. For example, if STEM Master Teachers will provide workshops to elementary teachers on using an engineering curriculum and will be given training on how to facilitate these workshops, it will not be necessary to select for teachers who have background in that curriculum.

Fourth, projects should consider the credibility and interpersonal skills of candidates when selecting STEM Master Teachers. For example, primary teachers might be more receptive to a STEM Master Teacher who has taught science or mathematics to young children. In addition, STEM Master Teachers in all capacities will need to be able to communicate effectively, listen well to others, and be open minded in confronting and building on ideas counter to their own.

Fifth, selection criteria should take into account a Master Teacher candidate’s skill in working with adult learners such as other teachers. STEM Master Teachers need to understand the unique needs of adult learners and be able to apply this knowledge to their work. For example, adult learners are better able than K–12 students to identify their own needs. They are also capable of more independent learning.

Last, involving key stakeholders (e.g., school and district leaders, local business, faculty members, teachers) in the development of the selection criteria can provide an opportunity to build a common understanding of the nature of the work of STEM Master Teachers and how these stakeholders can contribute to the success of the teachers’ work. Various stakeholders can engage in considering what the work of STEM Master Teachers will entail, assist in developing criteria candidates need in order to do the work, and help determine the evidence that would be needed to know whether the criteria had been met. These discussions would provide an authentic and useful opportunity to build stakeholders’ understanding of the work of STEM Master Teachers and their role in the process.

Applying Selection Criteria

Once selection criteria have been established, processes should be put in place to apply the criteria. Although these processes can be structured in many ways, individuals who will be involved should have the knowledge and skills to apply the criteria consistently across candidates. For example, individuals interviewing candidates to gather evidence of disciplinary content understanding should have enough knowledge to assess the adequacy of a particular response. Similarly, if a candidate is providing evidence of his/her understanding of professional development design, the person assessing the quality of the response should understand best practices in professional development. Since any individual is unlikely to have all of
the requisite knowledge to assess STEM Master Teachers candidates, projects should consider a team approach to the selection process.

Another consideration in developing a process for STEM Master Teacher selection is gaining the involvement of key stakeholders in the selection process, e.g., a STEM department chair, a representative from a human resources department. Individuals in various roles can provide input through reviewing applications, interviewing, and conducting observations. Further, building-level administrators where STEM Master Teachers will be assigned should be involved in the selection process, as they will likely work closely together in the STEM improvement efforts.

In considering the selection process, projects should acknowledge that the identification of STEM Master Teachers is likely an ongoing process and not a one-time event. Turnover is inevitable in STEM education improvement programs involving teacher leaders. Program leaders should anticipate turnover and integrate into the program design opportunities to build leadership skills in teachers, ensuring that there will be experienced teachers in the pipeline. Some initiatives have used an apprentice model in which teachers shadow others in leadership positions and have the opportunity to try out their skills (e.g., as a facilitator of PLCs).

Further, it may be necessary to revisit the selection process and criteria either when it becomes evident that the process is not resulting in STEM Master Teachers with the necessary requisite skills or as the roles of STEM Master Teachers evolve, for example when there are shifting priorities in the STEM improvement efforts. Projects should periodically reflect on the selection process to ensure that it is resulting in STEM Master Teachers with the knowledge and skill needed to do their work. As part of this process, program leaders should consider what data to collect in order determine whether the selection process is working. For example, projects could survey teachers and interview principals regarding the utility of the STEM Master Teachers’ work. Project leaders should also regularly observe STEM Master Teachers in action, assessing the quality of their work.
Selecting STEM Master Teachers
Reflection Questions

In designing their systems for selecting STEM Master Teachers, projects should consider the following questions:

1. To what extent does our classroom observation system align with our vision of STEM instruction?

2. What roles and functions will STEM Master Teachers play in our STEM improvement efforts, and what knowledge and skills will they need to be successful in these roles?

3. What key stakeholders need to be involved in developing selection criteria for STEM Master Teachers?

4. In developing selection criteria:
   a. What level and kinds of disciplinary content knowledge will various STEM Master Teachers need to carry out their roles? What are the implications for our selection criteria?
   b. What preparation will we provide to STEM Master Teachers, and what are the implications for the selection criteria?
   c. How can our selection criteria take into account a candidate’s interpersonal skills, credibility with other teachers, and knowledge of and skill in working with adult learners?

5. In developing the selection process:
   a. Who needs to be involved in the selection process for STEM Master Teachers?
   b. How can we ensure that individuals who evaluate STEM teachers for STEM Master Teacher positions have the appropriate knowledge and skills?
   c. How do we cultivate other STEM teachers to serve as Master Teachers in the future?
   d. How will we know that our selection process is working? What evidence will we collect? When will we reexamine the process?
Preparing and Supporting STEM Master Teachers

Even though a thorough selection process is used, the STEM Master Teachers selected will probably not have all of the requisite knowledge and skills needed to assume the Master Teacher role. They will need specialized preparation in order to be successful. In addition, since working as a leader in the STEM education improvement effort will be a new experience for the majority of STEM Master Teachers, mechanisms for ongoing support should be instituted. This chapter provides guidance on (1) developing preparation programs for STEM Master Teachers, and (2) providing ongoing support to STEM Master Teachers.

Preparing STEM Master Teachers

Designing preparation programs for STEM Master Teachers is similar to designing any type of professional development program. It involves (1) clearly specifying the goals of the STEM Master Teachers’ development program and (2) designing learning experiences that are aligned to these goals. Specifying goals for the preparation is complex, as one not only must consider needs in relation to STEM Master Teachers’ knowledge of content and pedagogy, but also what else they will need to know and be able to do in relation to any number of leadership functions. For example, if STEM Master Teachers will provide one-on-one coaching, they will need to know about various coaching strategies. If they are to develop/identify formative assessments, they will need to understand principles of effective formative assessment. As time and resources for preparation are typically limited, projects must prioritize the needs for STEM Master Teachers’ preparation, considering both the functions they will have and the knowledge and skill they bring to the position.

Regardless of the priorities determined, preparation programs should ensure that all STEM Master Teachers develop a deep understanding of the project’s vision of effective STEM instruction and the implications for every component of the STEM education system, e.g., curriculum, instructional materials, assessment. As these individuals will be charged with applying the vision in support of school/district STEM improvements and developing STEM teaching capacity, this foundational understanding is critical. In addition, STEM Master Teachers’ preparation programs should explicitly state the development of a professional learning culture as an intended outcome and acknowledge that STEM Master Teachers are learners as well as leaders.

The structure of a preparation program for STEM Master Teachers will vary depending on the goals. Even when two programs address the same goals, the design of experiences can be quite different depending on the strategies selected, the time available for STEM Master Teacher preparation, and the expertise available to design and implement the program. For example, a preparation program aimed at deepening STEM Master Teachers’ understanding of mathematics concepts may choose to engage a local university in providing master’s-level coursework over several months or years, or alternatively, a series of workshops can be led by content experts.

Although detailed guidance on how to prepare STEM Master Teachers for all of their potential functions is beyond the scope of this document, several key design features of leadership preparation programs should be considered. First, projects should bear in mind that the preparation of STEM Master Teachers is a professional learning experience and, as such, should reflect best
Effective professional development programs for STEM teachers are based on a common vision of effective STEM instruction, are purposeful and based on student learning of specific disciplinary content, are coherent across time, and make use of effective facilitators and model effective practice (both classroom and leadership practice). In addition, effective professional development programs use assessment and evaluation for continuous improvement (Desimone, 2009; Elmore, 2002; Koellner, Jacobs, & Borko, 2011; Wilson & Berne, 1999).

STEM Master Teachers may have to deal with resistant teachers, administrators with different priorities, and limited time to do their work.

A number of designers of preparation programs also recommend the use of a variety of experiences/strategies in developing knowledge and skills for leadership work; e.g., content-deepening experiences led by STEM faculty, problem-solving activities, and opportunities to analyze instructional materials. Individuals who plan professional development run the risk of limiting professional development designs to those they know best or to what is available, whether or not they are the best fit for a particular context. Since STEM Master Teachers will have varying needs and bring with them a range of content understandings, interests, and experiences, it is not likely that any one approach will be successful in developing a particular set of skills. Projects should select strategies that are appropriate for the purposes of the preparation program, that address the needs of the STEM Master Teachers, and that are feasible to implement—i.e., the necessary resources and capacity are available.

Regardless of the strategies selected, experienced designers of STEM improvement initiatives recommend providing STEM Master Teachers with tools and protocols to scaffold their learning experiences. For example, when STEM Master Teachers are learning how to identify features of high-quality STEM instruction, either during observations or analysis of instructional materials, it is useful to provide a tool that is consistent with the project's vision of effective STEM instruction and that will guide their observations and the discussions that follow.

In addition, preparation programs should provide STEM Master Teachers with ongoing opportunities for practice and feedback, both initially and as their work progresses. Practice will allow STEM Master Teachers to try out what they learned in their own context and receive feedback on aspects of their implementation. For example, if one goal of the preparation program is to develop capacity to facilitate PLCs, STEM Master Teachers might initially share facilitation responsibilities with someone more experienced who can provide feedback. A similar strategy could be used when training STEM Master Teachers to assess the quality of STEM instruction. This iterative feedback will allow STEM Master Teachers opportunities to continually develop their skills.

Finally, preparation programs for STEM Master Teachers should be ongoing, not just occurring at the beginning of an initiative or at the start of a teacher’s role as a leader. Although the preparation that occurs before STEM Master Teachers assume their roles is essential, learning opportunities should also be planned as they are doing their work, both to build on their experiences (e.g., reflection on their work) and to address other needed areas of preparation that were not an initial priority of the STEM improvement initiative.

Providing Ongoing Support

The role of STEM Master Teachers will be challenging and will evolve over time. STEM Master Teachers may have to deal with resistant teachers, administrators with different priorities, and limited time to do their work. In order to be successful, they will need support at every step along the way. This support will involve both additional preparation and mechanisms that allow them to reflect on their work, share challenges, discuss solutions, and identify their continuing professional development needs.

A key aspect of support should come from school and district administrators. In order for administrators to provide appropriate support, they need to have an understanding of the vision for effective STEM education and the functions of STEM Master Teachers in their schools and districts. They also need to provide time and
potentially resources) for STEM Master Teachers to do their work. Setting this groundwork with administrators will contribute to early success. Various strategies can be used to engage administrators in the work of STEM Master Teachers. For example, as mentioned previously, they can be involved in developing selection criteria and in the selection process itself. They can also be invited to participate in professional development sessions for STEM Master Teachers. And, as the work of STEM Master Teachers progresses, administrators can provide important information on the successes and challenges of the teachers’ work and be a key participant in discussions about program improvements.

STEM Master Teachers themselves should create some of the opportunities for ongoing support. “Job-alike” opportunities for STEM Master Teachers to share their experiences, what is going well and not so well, their dilemmas, and the strategies they have found effective can be powerful. Although dedicated time for these exchanges on a monthly and even weekly basis reduces the time STEM Master Teachers spend in schools, these meetings, if well designed and focused on important issues, can be an important component of sustained preparation and support for STEM Master Teachers.

Finally, as STEM Master Teachers are deployed, projects should create mechanisms to allow them to communicate to project leaders any difficulties and/or critical issues related to their work or the STEM improvement efforts more broadly. Often it is these leaders who will be the best source of information on what is happening in the schools and district. In order to make ongoing improvements to the STEM education improvement efforts, an open line of communication for feedback will need to be established, along with clear procedures established for how these concerns will be addressed.

The preparation and support of STEM Master Teachers will be a continuing challenge for TIF STEM projects, but there many resources available to guide the way. There are a number of existing preparation programs for the professional development of STEM teachers and leaders. As design of preparation programs can be time intensive and involve considerable capacity, it would be useful for projects to investigate whether any of these are aligned to their program goals. A database of materials can be found at www.te-mat.org. In addition, it may be helpful to read about how others have structured their programs. Appendix A lists selected readings that are recommended for this purpose.
Preparing and Supporting STEM Master Teachers

Reflection Questions

1. What roles and functions will STEM Master Teachers have in our STEM improvement efforts?

2. What STEM content and pedagogy understandings will STEM Master Teachers need to be successful in these roles? What are the existing capacities of our selected STEM Master Teachers in these areas?

3. What leadership skills and strategies will STEM Master Teachers need to be successful in these roles? What are the existing capacities of our selected STEM Master Teachers in these areas?

4. What mix of strategies should we use that are appropriate for the purposes of the preparation program, address the needs of the STEM Master Teachers, and are feasible to implement, i.e., are the resources and capacity available? Are there existing professional development materials that could be used?

5. How can our preparation program be designed to incorporate what is known about effective professional development programs?

6. Are there personnel with the capacity, time, and resources to carry out the preparation and professional development programs for STEM Master Teachers?

7. How can we prepare school/district administrators to enable them to support the STEM education improvement efforts and the work of STEM Master Teachers?

8. How can we incorporate mechanisms for STEM Master Teachers to continue their professional learning and share information/concerns about their work and the broader STEM education improvement efforts? What process will we use to address any concerns that are shared?
References


Miller, B. (2008, January). *What do we know about teacher leaders’ practice and how well do we know it?* Presentation at the National Science Foundation Mathematics and Science Partnership Learning Network Conference, Washington, DC.


President’s Council of Advisors on Science and Technology (US). (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America’s future: Executive report*. Washington, DC: Executive Office of the President, President’s Council of Advisors on Science and Technology.


Appendix A. Selected Resources for Further Reading

Preparing Teacher Leaders to Facilitate Professional Learning Communities


http://hub.mspnet.org/index.cfm/20272

Some helpful suggestions for preparing teachers to effectively facilitate professional learning communities are presented in this brief and succinct guidance document. The lessons learned are derived from the experiences of educators operating a multi-district Math and Science Partnership (MSP) that started in 2003. Math and science coordinators, alongside institution of higher education (IHE) faculty, engaged in extensive discipline-focused training by “expert partners” in field-tested adult learning curricula. Using a train-the-trainer model, the MSP coordinators and IHE faculty develop district-appointed leaders who in turn guide their school colleagues in well-defined professional learning. Five key insights are presented using the acronym LEADS. L stands for Learning, rather than teaching, which must be at the core. This reflects the adage that you cannot teach what you do not know. E stands for making the learning goals and instructional activities Explicit. To become an effective leader, the learner needs to see the purpose of each activity and how the various concepts work together. A stands for Assessment and the need to develop a corresponding strategy for how learning will be assessed. The article references two assessment tools but does not describe them in any detail. D stands for the use of Debriefing to reflect on and refine practice. Learners who are becoming leaders must be helped to collaboratively make sense of their own learning and understand how assessing the learning of the learners will help refine facilitation. Last, S stands for Supporting the teacher leader through featured development materials. Key aspects of featured materials are described. Specific examples would make this resource more useful, but the overarching principles that support facilitation of professional learning communities would be of interest to districts establishing professional learning communities.
Building Middle-Level Mathematics Teachers’ Capacities as Teachers and Leaders


http://www.math.vcu.edu/g1/journal/Journal_11/1_Heaton_Lewis_Smith.pdf

This article describes the design and implementation of the Math in the Middle Institute Partnership (M2), a professional and leadership development program for middle school mathematics teachers designed and led by mathematicians and mathematics educators at the University of Nebraska, Lincoln. The program entails a 25-month curriculum of online and in-person courses leading to one of two mathematics education master’s degrees. A key aim of the program is to instill in teachers “mathematical habits of mind” that represent a deeper view of what it means to do mathematics, based on the unique disciplinary orientations mathematicians bring to their work. The authors share insights and success stories about their work in deepening content knowledge and habits of mind of middle grade teachers. This resource will be of most interest to TIF STEM leaders who are designing programs to develop middle grade master mathematics teachers and are interested in the kinds of instructional and organizational components that might be included in a mathematics teacher development program. The resource may also be of interest to TIF STEM leaders interested in online teacher professional development programs. In addition to a clearly written overview of the program and its components, the resource provides in-depth examples of three of the courses developed for the M2 Institute. Of the three example courses, the first two are designed to provide teachers with foundational skills and knowledge needed for mathematics instruction, while the third is aimed at introducing teachers to the theory and practice of teacher-led inquiry through action research. Included in the course descriptions are samples of teacher work and feedback statements from participating teachers, which are presented as anecdotal evidence of the program’s effectiveness and impacts.

Virginia Mathematics and Science Coalition Science Specialist Task Force Report


This easily readable 23-page report presents the findings and conclusions of a task force dedicated to making research-based recommendations for the design and implementation of a school-based science specialist position in Virginia public schools. The report provides a review of the literature related to professional development programs in education as well as important factors in effective science teaching practices. The authors present evidence that professional development can improve teacher efficacy, that successful professional development should come from teachers in a collaborative environment, and that school-based science specialists can help fill a gap in science teaching skills. The short report presents both evidence of the need for science specialists and evidence of effective, teacher-driven professional development programs in a format and language that can be readily understood by a nontechnical audience. The report makes the case that school-based, teacher-driven professional development programs have the largest effects on improving teacher content and pedagogical knowledge. The report states that science specialists attached to a school can focus on maintaining current knowledge of science content and pedagogical practices and use such knowledge to inform professional development design for other teachers in ways that are sensitive to the school’s contextual needs. The report then makes recommendations for science specialist preparation, certification requirements, competencies, and roles and responsibilities that would be relevant to implementation and design considerations.
Identifying, Preparing, and Supporting STEM Master Teachers

**Designing Professional Development for Teachers of Science and Mathematics**


No URL available

The second edition of *Designing Professional Development for Teachers of Science and Mathematics* provides extensive guidance to those managing and leading professional development for STEM teachers. The resource provides a general design framework for professional development (PD) in science and mathematics that is intended for use among professional developers ranging from teacher leaders to university faculty. In addition, the design framework can be used at any grade level and scale. The book summarizes the current knowledge regarding PD and dedicates chapters to various aspects of the design framework, such as strategies for professional learning and the context of the PD. In one chapter, the book describes the decision-making process in five case studies of professional developers working through the design process. Moreover, vignettes are provided to give readers a picture of how the authors’ vision of science and mathematics teaching and learning plays out in the classroom and in PD. Additionally, the book describes 18 strategies commonly used that could be helpful for teacher leaders as they design and conduct professional development in mathematics and science. The work that underlies this resource was supported by NSF; the five authors of the book were all members of the National Institute for Science Education (NISE) Professional Development team. Throughout the book, the authors offer recommendations for using parts of the resource and many practical suggestions that could be used by Master Teachers to design and lead small-scale study groups or larger-scale workshops for STEM teachers. The resource is thorough, very clear, and accessible to a nontechnical audience. This resource may be useful to those designing and/or leading any type of PD for STEM teachers.

**Coaching: A Strategy for Developing Instructional Capacity**


This report was the result of a longitudinal qualitative research study conducted by Education Matters, Inc., on behalf of the Aspen Institute Program on Education and the Annenberg Institute for School Reform. The resource provides a summary of the qualitative research and related literature about the development and implementation of a coaching program in a school system. The resource introduces the literature on student learning and learning in professional development, examines types of coaching programs and associated roles and responsibilities for coaches, and provides practical guidance for developing and implementing a coaching program in a school district. The 46-page resource, which is very accessible for a nontechnical audience, emphasizes that a successful coaching program will be grounded in inquiry, derived from teacher practices, collaborative, sustained, and connected with other district initiatives. While acknowledging there is no evidence tying coaching to student achievement gains, the resource points out that research has tied strong professional development programs with these features with improved teacher practices.
Building Coaching Capacity Through Lesson Study


This resource describes a strategy for implementing mathematics coaching in a large urban school district. The authors, who represent the perspectives of both researchers and practitioners, suggest that lesson study can be a useful way to train coaches and allow them to more effectively build relationships with the teachers they serve. The authors describe their modified lesson study approach as it was applied to the training of mathematics coaches in New York City and include examples of resources they developed, including a protocol designed to help coaches engage teachers in reflecting on student learning, a hallmark of lesson study. The guidance provided from lessons the authors have learned through their experiences is presented in the form of answers to questions other leaders and practitioners might ask about their work: “How does lesson study help coaches become skillful agents of change?” and “What foundation is needed for coaches to successfully, systemically improve teaching and learning in schools?” TIF STEM leaders may find this resource especially helpful when thinking about how to develop a corps of master teachers who will be involved in coaching or leading a lesson study process. The discussion of challenges that can face coaches, including isolation and resistance from teachers, may be of particular interest to leaders and STEM Master Teachers seeking information on potential pitfalls of this approach. The authors suggest that the lesson study approach helped them overcome these obstacles by encouraging the growth of professional learning communities both within the group of coaches and among teachers in the schools they serve. The evidence they present provides useful context and testimonial from coaches involved in the program.