Developing and Sustaining Elementary STEM Teacher Leadership Identities

Kristen Napolitano, *Mercy University*

Amanda M. Gunning, *Mercy University*

Meghan E. Marrero, *Mercy University*

Elena Nitecki, *Mercy University*

Abstract

Growing emphasis on elementary STEM education has pushed elementary teachers to face curriculum changes that focus on standards with which they are largely unfamiliar (Smith, 2020; Trygstad et al., 2013). As a result, elementary students are not always exposed to STEM subjects or integration and miss out on opportunities to access and enjoy the hands-on, inquiry-driven activities that accompany them. This deficit disproportionally impacts high-need, urban districts that serve Black and Brown children and families, thus perpetuating inequities in STEM education and careers (Tate et al., 2012).

To address these issues, we designed a Fellowship program that strengthened K-12 STEM teacher leadership in local, high-need, schools. In this paper, we take a closer look at how five elementary teachers took on STEM teacher leader identities and then sustained and strengthened those even as program supports reduced. We asked: How do elementary teachers develop and sustain STEM and leadership identities through participation in a Master Teacher Fellowship? Using positional identity and self-efficacy lenses, we interpreted focus group interviews, coursework, reflections, and Fellowship meeting notes. Findings suggest that elementary teachers developed their identities gradually—first, as they recognized themselves as STEM *teachers*; next, as they recognized themselves as STEM *leaders*; and then, as others recognized them as STEM teacher leaders and positioned them to enact change in their schools and to support their colleagues. Implications for teacher educators shed light on how elementary teachers can be best supported in increasing STEM learning for their students across grade levels to effect school change.

Keywords

STEM teacher leadership, positional identity, self-efficacy, elementary teacher education

Introduction

The increasing importance placed on elementary STEM education has compelled elementary educators to confront curriculum adjustments centered around standards that may be unfamiliar to them (Smith, 2020; Trygstad et al., 2013). Consequently, elementary students may not consistently encounter STEM subjects or integration, or experience the hands-on, inquiry-driven activities associated with these disciplines. Furthermore, these students may lose interest or motivation in pursuing STEM pathways as a result. These challenges disproportionately affect high-need urban districts catering to Black and Brown children and families, thereby perpetuating disparities in STEM education and career opportunities (Tate

Citation: Napolitano, Kristen, Gunning, Amanda M., Marrero, Meghan E., & Nitecki, Elena. (2023). Developing and Sustaining Elementary STEM Teacher Leadership Identities. *Global Education Review*, 10 (4), 37-55.

et al., 2012). We developed a Fellowship program to strengthen K-12 STEM teacher leadership in local, high-need schools to directly address these challenges. In this program, K-12 teachers collaborated and worked individually to build their STEM teacher leader identities while bringing more STEM engagement to their classrooms. Among the 14 teachers involved in this program, five elementary school teachers stood out as STEM leaders. In this paper, we take a closer look at how these elementary teachers took on STEM teacher leader identities and then sustained and strengthened those even as program supports reduced.

Through qualitative analysis, we asked: *How do elementary teachers develop and sustain STEM and leadership identities through participation in a Master Teacher Fellowship?* Using positional identity and self-efficacy framing, we interpreted focus group interviews, coursework, reflections, and Fellowship meeting notes. Here, we noticed that our participating elementary teachers developed their identities gradually over the course of the Fellowship—first, as they recognized themselves as STEM *teachers*; next, as they recognized themselves as STEM *leaders*; and then, as others recognized them as STEM teacher leaders and positioned them to enact change in their schools and to support their colleagues.

Conceptual Framing

Positional identity and self-efficacy framing offered perspectives that allowed us to see how teachers positioned themselves as STEM teachers, how others positioned them as STEM leaders, and how they gained confidence and strength in this evolving identity to support and encourage others to integrate STEM education into their schools and districts.

Positional and Professional Identity

A person can become or develop their identity depending on their participation in and recognition in discourses, institutions, and society (Gee, 2000). Identity can be shaped by many factors including shared experiences, upbringing, race, socioeconomic status, among numerous other visible and invisible sociopolitical, sociocultural factors (Mensah, 2016; Moore, 2008). In this paper we focused on professional and positional identity frameworks to guide our interpretation of teachers' experiences as STEM leaders.

Lave and Wenger (1991) explain that personal identity development occurs over "long-term, living relations between persons and their place and participation in communities of practice. Thus, identity, knowing, and social membership entail one another" (p. 52). When a person becomes a full participant in a particular community of practice, they are able to form an identity within that domain. This is often a change from lesser action to full action. For example, a teacher that first participates in a professional development may later identify as a leader in that area if they work to plan a professional development and then present it on their own. Working towards understanding how teacher leadership is developed to support STEM instruction is an important component of improving STEM education (Berg et al., 2014; Joswick-O'Connor, 2020).

STEM teacher leader positional identity development occurs as a person both recognizes themselves as a STEM leader and as others recognize them as STEM leaders (Chen & Mensah, 2018; Hazari et al., 2015; Holincheck & Galanti, 2023). A teacher with a strong STEM leader positional identity may describe themselves as such, offer guidance or support to others from the standpoint of a STEM leader, or pursue STEM leadership opportunities in their

schools and districts. In addition, teachers with strong STEM leader positional identities, may be positioned that way by others, including principals, colleagues, or students (Chen & Mensah, 2018; Hazari et al., 2015; Holincheck & Galanti, 2023). For example, a STEM teacher leader might be named as the "go-to" STEM person in the school, appointed to a STEM supervisor or coach job, or selected to serve on STEM committees in the school or district. As we sifted through the data, we noted these types of contributions to our teachers' STEM leader positional identities and described them in our findings below.

Self-Efficacy

Using self-efficacy as a lens, we examined participants' confidence in their STEM leadership development. Bandura's (1997) theory of self-efficacy has its origins in the field of psychology but has been used as a framework for studying teacher performance (Dembo & Gibson, 1985; Tschannen-Moran et al., 1998; Tschannen-Moran & Hoy, 2007) and has been used to study elementary teachers specifically (Gunning, 2010; Gunning & Moore Mensah, 2011; Deehan et al., 2019; Knaggs, & Sondergeld, 2015; Riggs & Enochs, 1990). The program of focus in this study, referred to in this paper as "the Fellowship," was created intentionally to build participant self-efficacy through particular elements including coursework, monthly meetings, and mentorship. Figure 1 illustrates how we envisioned these programmatic elements aligned to Bandura's framework.

Bandura's self-efficacy theory describes one's beliefs regarding their ability to achieve a specified goal. If an individual believes they will succeed in a given task or attainment, they are more likely to do so (Bandura, 1997). Teachers' perceived efficacy plays a role in leadership projects they undertake, and activities chosen for instruction. Because self-efficacy is a good predictor of future performance, it follows that improved teacher self-efficacy will result in improved student learning and may result in improved STEM instruction in the classroom and beyond (Gunning, 2010; Gunning & Moore Mensah, 2011; Bandura, 1997).

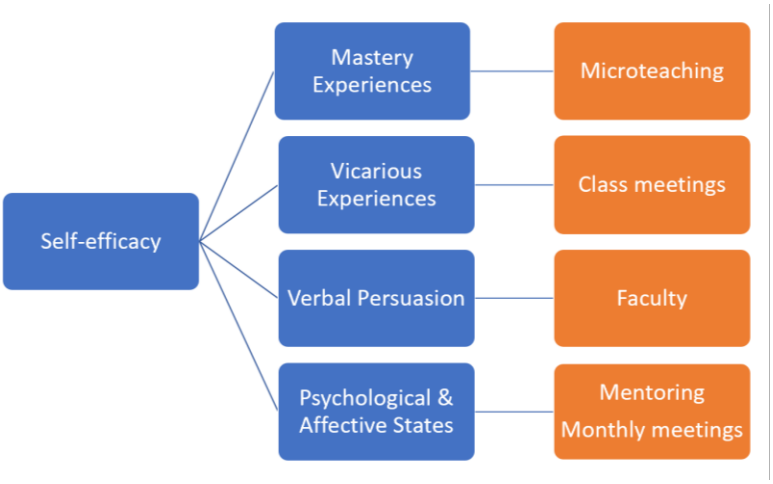

Figure 1: *Bandura's (1997) Self-Efficacy Framework Mapped to Fellowship Elements*

Bandura describes four ways of building self-efficacy: mastery experiences, verbal persuasion, vicarious experiences, and psychological and affective states. Mastery experiences are the most powerful way to develop self-efficacy and happen when an individual has the opportunity to enact the task being learned successfully, especially when witnessed by a trusted mentor. Mastery experiences were built into the Fellowship through microteaching assignments where teachers prepared STEM lessons and enacted them in their classrooms and with their cohort peers. When a trusted mentor, in this case the teachers' professor, encourages an individual that the task at hand can be successfully attained or provides actionable feedback, this is an element of verbal persuasion. Vicarious

experiences come from peers who are successful in the attainment and share their journey. The Fellowship embedded vicarious experiences into class meetings with opportunities for collaboration, peer feedback, and vertically articulated unit design projects (Gunning et al., 2020). Positive psychological and affective states support self-efficacy development because it means the given attainment can be developed in a less stressful environment. Mentoring and monthly meetings allowed these teachers to explore STEM education in safe spaces throughout the Fellowship. Over the course of the Fellowship, the components that supported STEM teacher leader self-efficacy adjusted to meet the needs and shifting identities of the teachers. These adjustments are shared below, especially as they pertain to Years 2-5, as part of the methodological framing for this study.

Professional Development Model

The Fellowship was designed using best practices for teacher professional development (PD), learned from both current literature and the research team's prior work (Hillman, et al, 2016; Gunning & Marrero, 2017; Gunning, et al, 2020). Darling-Hammond and Richardson (2009) find the most effective PD experiences for teachers are prolonged, promote insight into student learning, involve collaboration with other teachers, develop content understanding through hands-on work, and provide opportunities for classroom application. These elements were met through the Fellowship design which included two years of coursework that involved collaboration, lesson planning and studies, and engineering and STEM integration. All Fellows also received three additional years of mentoring, monthly meetings, and financial support.

Further, other hallmarks of strong professional development are characterized as: deeply embedded in subject matter (in this case, STEM); designed to involve active learning; able to connect teachers to their own practice (the Fellowship accomplished this by enacting microteaching and leadership projects and reflection); and part of a coherent system of support (provided through courses, seminar and personal relationships with faculty, and monthly meetings with their mentors and Cohort peers) (Ball, 1996; Garet et al., 1999; Weiss & Pasley, 2009).

In addition to these best practices, the Fellowship was structured with a gradual release model in mind. This model, which began in the reading and literacy field, focuses on how self-efficacy can be established through intentional, consistent shifting of responsibility from teacher to student (or in this case, faculty to Fellow). Gradual release as a strategy has since been studied as part of building teacher leadership identity and capacity (Osmond-Johnson, 2018; Pearson & Gallagher, 1983). At the beginning of the Fellowship, supports included activities and assignments that served as mastery experiences, such as microteaching lesson planning, collaborative vertically articulated STEM teaching presentations, and guided leadership projects. Additionally, teachers received weekly encouragement, actionable feedback, and time to reflect with peers. Over the course of the Fellowship, and as the coursework portion of the program came to an end, these explicit supports slowly decreased or became more implicit. Starting at the end of Year 2, the Fellows met monthly with their cohort peers and faculty to share vicarious experiences and continue to encourage one another. During these meetings, the Fellows had many opportunities to collaborate and socialize while also receiving direct support from their designated mentors, all of whom had been their professors at one point in their coursework. In the three years following, monthly meetings and mentorship continued even as Fellows largely initiated and conducted

their own leadership projects. Figure 2 maps out the Fellowship design as it relates to gradual release.

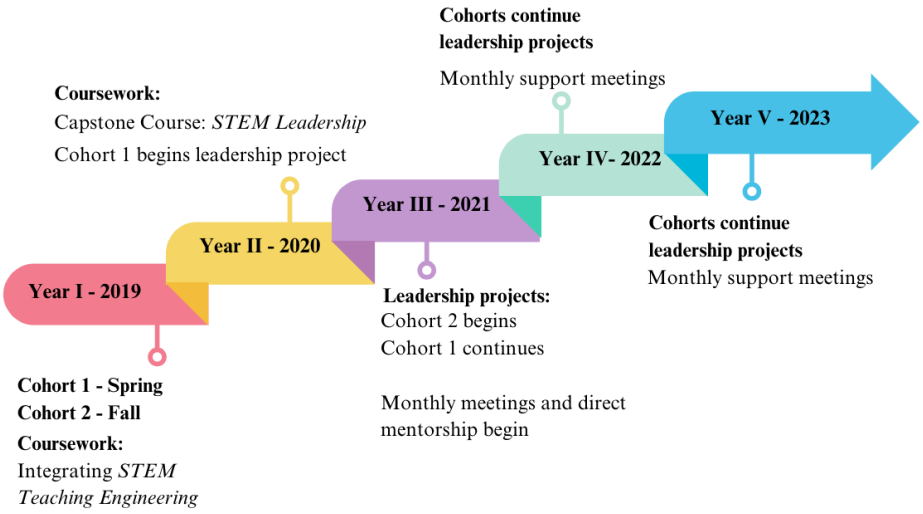

Figure 2: *Gradual Release Model within the Fellowship*

The program structure supported Fellows to develop self-efficacy and their leadership identities in low-stakes, safe environments designed to bolster their confidence and gradually increase their independence.

Methods

This study employed an interpretative case study method, which yielded rich, descriptive findings (Guba & Lincoln, 1989). Our qualitative approach provided detail and nuance to support possible future replication and learning from our findings. Through interpretation of data sources including focus groups, coursework, reflections, meeting notes, and observations, we asked: *How do elementary teachers develop and sustain STEM and leadership identities through participation in a Master Teacher Fellowship?*

Setting and Participants

This study took place during four years (2019-2023) of a five-year, grant-funded Master Teacher Fellowship that supported the professional development of 14 preK-12 teachers in STEM teacher leadership. The initial goal of the program was to increase K-12 STEM teacher leadership, thus improving STEM teaching in schools. The case study followed five in-service elementary teachers of grades preK-5 from high-need districts with at least three years' teaching experience who each participated in the Fellowship. These teachers were state certified (as elementary generalists) and each had earned a master's degree in education (as required for state teaching certification) and demonstrated exemplary teaching, based on transcripts and recommendations from supervisors and peers. Of these five teachers, all identified as female, two identified as White and three identified as racially White and Hispanic or Latino in ethnicity.

To participate in the grant-funded program, teachers had to apply and be accepted through a competitive process for a spot in one of two cohorts, each consisting of seven teachers. The Fellowship served teachers in four high-needs school districts in the New York metro area. The first two years for each cohort were intensive as they completed three graduate courses (see Table 1) while teaching full time and participated in co-curricular professional development. The professional development was provided through grant partners – an environmental organization and a local college of engineering – and was focused on STEM teaching and meaningful connections to the real world.

Table 1: *Course Descriptions for STEM Pedagogy Courses*

Course	Course Description
STEM Education	This course explores applying STEM education, for a compelling context for instruction in the classroom. The course will introduce theory and practice for teaching and assessing the integration of STEM. Participants will study STEM education in the context of the history of reform movements in mathematics and science education. This course includes elements of theory and practice for teaching, learning and assessing science, technology, engineering, and mathematics instruction, as well as issues of equity in STEM. Participants explore connections among reform-based and contemporary practices in teaching, while learning to use technology as a tool for promoting student understanding.
Teaching Engineering	In this course, teachers will become proficient with the engineering design cycle and Science and Engineering Practices, as outlined by the new (implemented Sept. 2017) NYS P-12 Science Standards. Teachers will learn how to apply engineering practices to integrated projects for secondary students, while raising awareness of careers and innovations in engineering. Students will demonstrate an understanding of history of engineering and its impact and shaping of society in the United States and globally.
STEM Leadership	This capstone course supports teachers in becoming leaders within their schools to assist other teachers and facilitate lesson study, professional learning communities, curriculum design, and peer feedback and coaching. Teachers use a model of vertical articulation in which they engage in a cycle of collaborative coaching, reflection, and action research, to improve teaching and learning in their classroom.

A major outcome of the program was to support Fellows to take on leadership roles connected to STEM in their schools and/or districts. Program leaders used self-efficacy development supports (Figure 1) and gradual release framing (Figure 2) to move toward this goal. Table 2 shows the timeframe of major program elements provided through the duration of teacher participation. Continuing self-efficacy supports are mapped in Figure 3 below that supported the gradual release approach. In addition, prior research on this Fellowship revealed additional elements of the program as supporting self-efficacy development for teachers in general and these were included in Figure 2 (Gunning et al., 2021). Figure 3 thus summarizes the connection of programmatic features to the modes of self-efficacy development, along with the gradual release elements in years 2-5.

Faculty members from the graduate school of education served as mentors for the Fellows. These faculty each taught one of the three courses listed in Table 1 and got to know the Fellows very well. Each faculty member also had all of a particular school district's Fellows for mentoring so that the nuances and challenges within the district could be understood across the site through each Fellow's experiences. Mentors were required to meet with each Fellow at least twice a semester by phone or Zoom and complete an electronic form summarizing the conversation. In many cases, mentors also worked with their mentee Fellows during the monthly meetings when the whole group broke out into smaller groups by district. This Fellowship program exists within a STEM education center run by graduate school of education faculty.

Figure 3: *Self-Efficacy Modes Mapped to Program Supports*

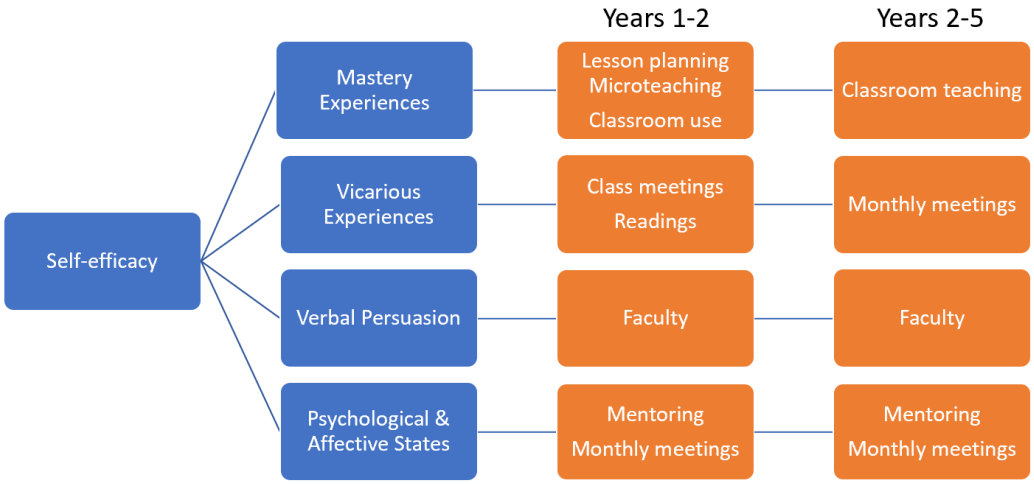

Table 2: *Timeline of Major Program Activities*

Activities	Years
Course instruction – two STEM pedagogical methods courses, one leadership in STEM course	1 & 2
Fellows enact leadership projects supported by grant funds, when needed	2-5
Mentoring of Fellows	1-5
Monthly Meetings	2-5

Data collection

Data was qualitative in nature to gain a detailed picture of how the Fellows experienced shifts in their self-efficacy and identities throughout the course of the program. These data sources were collected initially as program artifacts (either for evaluation of the program or as coursework). The data, ordered chronologically, represents many benchmarks that occurred across the span of the Fellowship, beginning with first semester reflections and ending with detailed meeting notes from faculty and staff in years 4 and 5 of the program. Below are more details regarding each data source:

Focus Groups

The research team conducted focus group interviews throughout the Fellows' first two years of the program, at the end of each semester of their coursework. These 45-minute, semi-structured interviews were initially intended for evaluation of the program but became an important part of this research as the teachers shared recurring ideas about their self-efficacy and leadership. Focus group transcripts were stored chronologically on a secure, cloud-based document sharing platform.

Coursework

Over the first two years of the Fellowship, the teachers completed coursework for the three required classes described above. The assignments in these courses were designed by faculty and members of the research team (three of whom taught the courses for the program). In the *STEM Education* course, their first of the program, teachers completed a STEM autobiography and course reflection. In *Teaching Engineering*, teachers completed microteaching lessons and unit plans. In *STEM Leadership*, teachers completed a vertically articulated lesson plan and a leadership initiative project. These course artifacts were reviewed as archival data to provide a sense of teachers' identities and self-efficacies from the beginning of the program to the end of the coursework component of the program.

Classroom observations

The research team observed each teacher each year of the program. These were done via video recording, video conferencing, and in-person depending on the mutual convenience for the participants and researchers. All observations conducted during the Covid-19 pandemic of 2020 and 2021 were done virtually even if classes were being held in person due to visitor restrictions at the time. Observers did not use an observation protocol – this may have limited the scope of what observers noticed in their visits.

Meeting notes

In Year 2 of the program, Fellows met monthly (as described in more detail above). During each of these meetings, members of the research team took notes to record observations and general ideas conveyed throughout the meeting. The meetings were not recorded, and researchers did not use a note-taking protocol. Notes were intended for program evaluation and planning. In this study, they shed light on the nuanced changes that occurred gradually over the years as Fellows shared monthly updates on their progress towards STEM teacher leadership.

Together, these data illuminated experiences, attitudes, and practices of participants in their own words. Their longitudinal scope allowed us to gain a fuller picture of how these Fellows experienced STEM teacher leadership and identified as STEM leaders over the course of their participation in the program.

Analysis and Trustworthiness

We used a comparative case study approach to analyze the data (Creswell & Poth, 2018; Yin, 2018). First, we sorted all electronic files of participant coursework and focus group interview transcripts and read through each, noticing broad categories and recurring comments, such as “collaboration” and “STEM-minded” (focus group and Fellow reflections). After several passes, we consolidated these broad categories to solidify themes described below. During analysis, researchers’ (some of whom are Fellowship faculty and/or mentors) experiences with each participant helped to inform and organize findings. Also, findings from classroom observations were summarized and shared with participants to member check, another element of rigor and validity (Lincoln & Guba, 1985). Because the data for this study is varied and multiple and collected over the course of several years, the study is characteristic of a rigorous qualitative study (Creswell, 2007). These facets of the study also allow for triangulation (Denzin, 1970; 1978), which may be drawn upon to increase rigor and assure validity. According to Denzin (1978), this study employs “methodological triangulation” and “data triangulation” by using different types of data collection (surveys, observations, written work from activities and teacher lesson plans) over time within different settings (coursework, PD setting, classroom) (p. 472).

Preliminary Findings and Discussion

As we interpreted data collected over the scope of the Fellowship, we noticed themes across data sources that illustrated how the teachers had developed and strengthened their STEM teacher self-efficacy and leader identities. These findings are categorized below into three themes: 1) Realizing STEM identity: Mitigating imposter syndrome; 2) Harnessing STEM leader identity: Advocating for more STEM in school, and; 3) As positioned by others: Sustaining as STEM teacher leaders beyond the Fellowship. Each of these themes helped us describe the stories of these Fellows' growth, development, and recognition as STEM teacher leaders in their schools and districts during and towards the end of their Fellowship program.

Realizing STEM identity: Mitigating imposter syndrome

One of the biggest hurdles that elementary school teachers need to clear in realizing themselves as STEM *leaders* is realizing themselves as STEM *teachers* (Holincheck & Galanti, 2023). Elementary teachers may not believe that they are masters of STEM content or prepared to effectively teach STEM. For many, they do not receive specific STEM pedagogy preparation in their teacher certification process and, therefore, feel unprepared and overwhelmed by STEM discourse and community (Corp et al., 2020; Holincheck & Galanti, 2023; Johnson et al., 2021). As we encountered this phenomenon in our work, we referred to it as STEM teacher "imposter syndrome," pulling from the idea that someone may experience a lack of belongingness or self-doubt as they try to adopt a new role or identity. It is worth noting that this phenomenon may be experienced more commonly by women, and disproportionately by women of color, especially in male-dominated fields, such as STEM (Collins et al., 2020). These feelings of self-doubt may be symptomatic of the oppressive male presence in STEM and lack of support or encouragement by colleagues.

This imposter syndrome was noticeable in the very first reflection the Fellows completed for their *STEM Education* course. In their reflections, the Fellows described their varied experiences, knowledges, and interests in teaching STEM, yet they felt as though they were not confident enough to be STEM leaders. One elementary math specialist, Evie (pseudonyms used here on out for each of the five participating Fellows) for instance, described years' worth of introducing engineering challenges to her students for an annual national event, entering the program with concrete mastery experiences in teaching STEM, but noted:

> I think I am just at the start of really understanding the approach of STEM education. I feel like I have implemented activities in my classroom that are STEM-like, but the actual STEM approach is not consistently there…I still feel that I need further growth in understanding STEM education in depth and consistently teaching in that mindset (reflection, 2019).

Even with several prior experiences and an institutional identity as math specialist, Evie perceived these years of success in teaching STEM as "just the start." With that said, all of the elementary teachers were already contemplating and taking on roles as STEM teachers in their schools. They exhibited an eagerness to enact STEM teaching right away and moved more quickly into deeper understanding and application. Participants exhibited positive self-efficacy for integrating content areas, implemented STEM lessons immediately, and moved into thinking about leadership roles (instructor reflections).

For instance, one P-3rd grade teacher, Maeve, wrote in her reflection that, before the program, she had kept her distance from STEM education. She wrote of her shifting perspectives on teaching STEM:

> STEM was always a wonder to me…Over the years I have looked into learning more about STEM but never pursued it, probably due to my poor academic history in science and math classes. As a teacher in a school where the population is 100% culturally and economically disadvantaged, I am now driven to expose my students to a challenging STEM learning environment that engages their inquiry (course reflection, 2019).

Maeve went on to explain that when she first saw the advertisement for the Fellowship,

she did not apply because she did not see herself as a STEM teacher. As she looked more into the program, she was drawn to the leadership component and decided to try out the STEM that went along with it. Through her coursework, Maeve saw areas of her own practice that could lend themselves to more STEM integration. While she expressed nervousness about introducing more STEM, she was feeling more confident in her STEM identity and in her ability to justify why doing more STEM would be beneficial to her practice.

As the Fellowship continued, the elementary teachers became increasingly confident with the STEM content. They began to realize that they were already masters of STEM teaching. As one 1st-3rd grade teacher, Elise, noted: "I am struck by how much I knew without realizing I knew [STEM] before [the program]" (reflection, 2020).

As Year 1 of the Fellowship unfolded, classroom observations of these teachers illustrated how they were beginning to realize their mastery of STEM teaching. One 4th grade teacher, Corrine, who initially described her experience with integrating STEM as "uncomfortable," designed an engineering design challenge that engaged students in creating water filters to address issues of accessibility to potable water (observation, December 2019). This lesson made space for conversations about drinking water and engaged students in working collaboratively to design methods for cleaning water to make it safe. Corrine not only pushed herself out of her comfort zone, but also demonstrated her clear mastery of STEM integration after just one semester in the program.

The other four teachers also designed engaging, inquiry-driven STEM lessons, including building and testing ramps in kindergarten, building towers in a math class, making butter in a 3rd grade social studies class, and exploring magnets as part of a materials engineering investigation (observations, 2019). In addition, in their focus group interview at the end of their first year in the program, the elementary teachers noted ways that they felt their STEM identities expanding. For instance, Cohort 2 Fellows noted how engaging in STEM lesson planning during the program pushed them further. Maeve explained this noticeable growth:

> It was the first time I learned about 5E [a STEM lesson planning tool] and so that was [a] productive struggle and I had never heard about that and yet it was a productive struggle and going through it together was comforting. Knowing that it was the way of the future prepared us for what lessons we can use, and I did in fact try mine out with my children and it was useful that way. I loved the feedback (focus group, Fall 2019).

Maeve's description of this productive struggle illuminated her growing confidence as a STEM teacher and the ways that lesson planning served as a mastery experience in the program by providing her both time to explore STEM with her students and get feedback on the lesson from her peers and mentors.

As the five elementary teachers moved into the 2020-2021 school year, they fearlessly took STEM beyond their classrooms and began to harness their STEM leader identities.

Harnessing STEM leader identity: Silent leaders to vocal STEM advocates

As the elementary teachers strengthened their STEM identities, they also bolstered their identities as leaders. For these teachers, this meant shifting their roles as "silent" leaders to more vocal leaders, putting themselves in front of colleagues and administrators to advocate for more STEM instruction and integration in their

schools. They expanded their reach beyond their own classrooms to increase STEM opportunities for children after school, in other classrooms, and in the summer.

All five of the elementary teachers shared that the program helped bolster their self-confidence and ability to be an advocate for STEM teaching approaches. For instance, Corrine explained that her experience in the program made her feel more comfortable approaching her principal to increase STEM opportunities for her students. She said:

> It's made me want to be more vocal in school and I have a supportive principal, but I just feel like for the first time in 13 years, I have a voice and I speak up. (Fall 2019, focus group)

Corrine showed that, even though many of the teachers in the Fellowship already had an interest in leadership and in STEM, they did not know how to take an active role in advocating for more STEM in their buildings. Over time, these elementary teachers took STEM beyond their classroom walls to engage others in STEM. Elise, a 1st-4th grade science specialist shared a similar experience:

> I also think in ways, I've been a silent leader. Does that make sense? So, like I push into some of my classes and I'll do something and they'll say, 'Oh, I've never thought of teaching a lesson in this way' […] so I think I've silently been a leader in people seeing the way that I teach. (Fall 2019, focus group).

As Elise continued through the program, she decided to launch an afterschool STEM enrichment program that enrolled several cohorts of students. This leadership initiative went far beyond her initial silent leadership at the beginning of the program. Similarly, the other elementary teachers made note of the effect that their teaching was having on their colleagues. For instance, in the same Fall 2019 focus group, Evie explained how, prior to her integrating STEM teaching, other elementary teachers in her school typically skipped STEM in their day because they didn't feel as though they had time to introduce it, but once they saw her doing it, she noticed them spending more time trying to implement STEM activities across their curriculum. In this way, she expressed a sense of being a role model for her colleagues in STEM. These were encouraging mindset shifts and offered an insight into how their experiences in the program supported them in becoming STEM teacher leaders.

This was particularly noticeable in the ways that Fellows described their leadership roles to us in their Year 2 focus groups and year-end surveys. In the December 2020 focus group, a 3rd grade teacher, Ava, explained that:

> I have always been interested in science and things like that, but I never really knew what my next steps could be to bring across that passion and bring across what I know in science and to inspire others. I think this course…helped prepare…that mindset that "ok I can do this and what I do know this is valuable regardless of how many years I have been teaching or not been teaching." It prepared me for the idea that I could be a leader not just within my school, but within the community, within the science teaching community.

Ava's growing confidence as a leader in teaching STEM was supported through the coursework, in particular a vertically articulated unit plan design, she completed in the Year 2 *Leadership* course. As a result, Ava felt that she could lead within her school district and with her colleagues and she felt that she was establishing a place as a leader in the community as well.

Even with noticeable growth among the teachers in their leadership identities, in 2021, Fellows were still hesitant to describe themselves as leaders. When asked whether they had done any leadership activities over the course of the year, many initially said they had not (survey, 2021). Nonetheless, in a February 2021 monthly meeting, the Fellows shared the varied ways that they were enacting leadership throughout their districts. For example, Ava was leading the development of a schoolwide pollinator garden and aligned ecology curriculum to support STEM instruction, Corrine and Evie were launching a bilingual family STEM workshop series at their school, and Elise was designing a STEM integrated literacy unit to support her English Language Learners. This sparked the research team to create a new survey tool that provided specific examples of leadership activities, such as leading professional development, attending or presenting at a conference, etc. When provided with this list, the teachers realized that they had in fact completed many of the activities. On average, the five Fellows identified that they had each completed eight of the twenty-one listed activities over the course of the 2020-21 school year. This was even more impressive to us given how the pandemic contextualized much of this time and could have limited their accessibility to leadership roles.

The following year, in 2022, Fellows more readily identified themselves as leaders without extra prompting. They explained how they were running professional development for their districts, joining STEM committees in their schools, attending and/or presenting at professional conferences, and facilitating clubs or afterschool family STEM programs. In an October 2022 monthly meeting, Ava explained how she was now part of three grant-funded leadership programs and working on expanding a bilingual family STEM workshop to new grade levels at her school; Elise was conducting training for teachers interested in facilitating a districtwide STEM program she had launched the previous year and; Evie had joined an additional leadership program where she was working with a team of teachers in her school to expand STEM integration across the third grade (monthly meeting notes). A 2023 survey showed similar results, with each teacher reporting eight leadership activities on average. These results were compelling considering all of the program supports that had existed during the 2020-21 school year had lessened or ended completely as part of the gradual release design.

As positioned by others: Sustaining STEM teacher leadership beyond the Fellowship

As the Fellows progressed through the program, they experienced new positioning as leaders as their peers, mentors, and administrators turned to them as STEM experts. This positional identity was reinforced early on by the fact that one of the lead faculty and mentors in the program was an early childhood education professor. At the same time, an unanticipated factor that shaped elementary STEM leader identity was the way that their peers, secondary teachers, positioned them as leaders. This was evident in the Fellows' *Leadership* course where they worked together in vertically articulated professional learning groups (VPLCs). This approach was designed to model previous iterations of vertical alignment in our other STEM leadership programming (Gunning et al., 2020). While working in VPLCs allowed the elementary teachers to gain confidence in STEM and in their teaching, it also shifted secondary teachers' perspectives of their peers. For instance, in focus groups, secondary teachers cited the VPLCs and peer feedback as important components of the course and of their professional development. The elementary

school teachers were positioned by the secondary school teachers as STEM integration experts. Ava recognized this positioning as she explained:

> [We] really [saw] the strengths that an elementary, middle school, [and] high school…teacher bring in…as an elementary school teacher I needed resources that, if I were to google when I was teaching, would seem like, "this is all for high school, I can't use this," but [a middle school science teacher] said "look at this one and do this." We all brought our strengths to the table. (focus group, Fall 2019)

During the VPLC activities, the secondary teachers helped the elementary teachers troubleshoot as they searched for STEM resources that could be aligned to their grade levels. In this case, Ava and a middle school teacher collaborated and realized each other's challenges and strengths. This developed a symbiotic relationship where, when designing activities, the elementary teachers guided their peers away from their content silos and through the process of weaving STEM into their curriculum while the secondary teachers helped navigate the barriers that pervade online STEM education resource platforms. This relationship continued throughout the scope of the program. In a February 2023 meeting, Elise offered to help the middle school and high school Fellows from another district in running vertically aligned professional development for their teachers. This seemed to be a significant shift from the beginning of the program when conducting professional development, even for grade level colleagues, may have seemed daunting for Elise:

> As I look into the future, I continue to have goals not only for myself as a STEM educator but also for my district. I hope that through these classes, I am able to find ways to not only turnkey professional development to my colleagues but come up with a district plan of implementation. Through this course, I have realized that I cannot do this alone and need support from administrators, parents, and teachers to make a real shift in mentality and teaching. (reflection, 2019)

This intention set at the very start of Elise's journey towards STEM leadership was becoming a part of her identity as she volunteered to share her STEM expertise with the secondary Fellows nearly four years later.

Throughout the Fellowship, it was important that Fellows gained positional identity in their schools and districts. While the teachers were beginning to recognize themselves as leaders towards the end of their coursework in 2020, they were finding that their principals and other administrators were not acknowledging them as leaders. For instance, in a November 2020 meeting, Fellows described how their principals were not taking them or their concerns seriously and how the time they were promised to conduct professional development with their colleagues was being taken away for other programming. While the Fellows were prepared to take on leadership roles, their administrators held them back. We speculated at the time that this might have been due to issues caused by the pandemic and new administrative priorities that came to a head as a result.

A common issue among grant funded programs is the fact that once program funding, support, and professional development ends, so do all the achievements and changes that the program brought about (Flint, 2017). In many situations, once the championing program concludes, the participating teachers lose steam, administrative support, and even some of their positional identity as others forget their accomplishments in the program. This was a big

fear of ours as the bulk of the program supports began to abate in 2022. The only remaining supports were stipends, mentor relationships, and monthly meetings. The coursework and weekly meetings ended in 2021, yet the Fellows' STEM leadership identities continued to grow.

In monthly meetings Fellows shared their updates with us on their leadership initiatives. Many departed from their guided leadership projects that started in their courses to take on even bigger roles in their schools and districts. For instance, Fellows initiated STEAM fairs or other events in their schools, created family math initiatives, and were asked to present their work at School Board meetings (monthly meeting notes, 2022;2023). While the implicit positioning by the program facilitators remained, other people in the Fellows' lives began to explicitly position them as leaders. This was evident in the way that Fellows were brought onto STEM committees at their schools, consulted as STEM experts for curriculum and professional development for other teachers, or named as district-wide STEM representatives (monthly meeting notes 2022;23). In the February 2023 meeting, Fellows overwhelming noted the principal supports that they were receiving. For example, Elise, who was running a large afterschool STEM program that began earlier in the Fellowship, reported that she had received additional funding from her school to expand the program. Corrine, who had been running a bilingual family STEM workshop series, was granted funding to run a coding club and to train six teachers to help her with implementation. At the same school, Evie had received support to conduct a full-day professional development to expand STEM programming across the school. She said this was the first time her principal had dedicated this much professional development time to STEM (monthly meeting notes, February 2023). These shifts were significant given how little Fellows had mentioned principal or administrator support in the past. This administrative support provided Fellows with funding, time, and recognition that they otherwise would not have gotten in the past.

Discussion

Studies have long shown that elementary teachers generally do not feel prepared to teach science and engineering, and frequently feel apprehensive about STEM content (Corp et al., 2020; Holincheck & Galanti, 2023; Johnson et al., 2021). However, over the course of the program, elementary teacher Fellows in this study evolved as STEM leaders, taking on STEM identities, growing as STEM advocates, and finally being recognized by others as STEM teacher leaders. This gradual transformation is powerful and seems to have led to sustained growth and shifts in identity, demonstrating that targeted professional development designed to improve teachers' self-efficacy and leadership skills can be effective (Catalano et al., 2019; Cervato & Kerton, 2007; Manner, 1998; Yasar et al., 2006; Yesilyurt et al., 2021).

It is worth noting that secondary teacher Fellows continued to hit roadblocks in their leadership goals throughout the program. In particular, a high school Fellow was continuously met with challenges, including a major lack of administrative support, consistency, or funding (monthly meeting notes, 2022;23). Another high school Fellow was ignored as a leader in her district and felt forced to leave teaching altogether after many years of persisting through countless defeats (monthly meeting notes, 2022). This is to say that the Fellowship program supports can only float Fellows so far. Without the administrative scaffolds to bolster their positional identities, Fellows cannot sustain their roles as leaders, silent or otherwise. We find it interesting that

this lack of support seemed to be even more oppressive at the secondary education level. We wonder what other factors at the elementary school level have allowed our elementary teacher Fellows to persist even amidst the pressures of standardized testing and a heavy focus on English language arts and math skills.

The Fellowship program has shown these Fellows that they can be and should be leaders in their districts, it has allowed them to recognize themselves as leaders and seek that recognition from their administrators. With continued recognition, we expect that these Fellows will continue to grow and strengthen their STEM leadership identities.

As we continue to analyze the data from years 5 and 6, we see these teachers blossoming into full-fledged leaders in their schools and districts. Since inception, two have become coaches for their elementary school (one STEM and one math); one has been awarded a grant to start an afterschool STEM program for elementary that was so successful she was asked to expand it for more grade levels; three have worked to lead a family STEM engagement program across their district; one has been accepted to another computer science for elementary Fellowship; and all of the participants have improved STEM instruction, particularly in the areas of technology and engineering (monthly meeting notes, 2022, 2023).

Conclusion and Implications

As leaders in the field of STEM education considers how to support STEM for all learners, strong *teacher* leaders can help push change from within schools. Elementary STEM education continues to shift as policy shifts emphasize Next Generation Science Standards in curriculum and assessment. In the instance of this study, New York State has already fully integrated the New York State Science Learning Standards (NYSSLS) and, just this year, the Board of Regents released preparation materials for the newly NYSSLS-aligned 5th grade state exams which have a distinct focus on science and engineering practices (https://www.nysed.gov/curriculum-instruction/science-standards-implementation-resources). The Fellows in this study were well positioned to pivot with these policy changes and to help others in their adjustment to a new scope and sequence. In fact, anecdotally all five of these Fellows have shared the ways that their administrators have turned to them for guidance as these changes unfold in the 2023-24 school year. Their STEM leadership identities persist and grow as they are comfortable now with taking on professional development initiatives, STEM enrichment programming, and family and community outreach.

Implications for elementary and childhood educators suggest that programming such as this is critical in developing STEM teacher leadership skills and identities. Collaborative, vertically articulated, and leadership-focused elementary STEM leadership programming is necessary in preparing teachers for a growing and everchanging STEM education landscape.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant #1758317.

References

Ball, D. L. (1996). Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *Phi Delta Kappan*, 77(7), 500-508.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman and Company.

Berg, J., Carver, C., Mangin, M. (2014). Teacher leader model standards: Implications for preparation, policy, and practice. *Journal of Research on Leadership Education*, 9, 195-217. http://doi.org/10.1177/1942775113507714

Catalano, A., Asselta, L., & Durkin, A. (2019). Exploring the relationship between science content knowledge and science teaching self-efficacy among elementary teachers. *IAFOR Journal of Education*, 7(1), 57-70. https://files.eric.ed.gov/fulltext/EJ1217961.pdf

Cervato, C., & Kerton, C. (2017). Improving the science teaching self-efficacy of preservice elementary teachers: A multiyear study of a hybrid geoscience course. *Journal of College Science Teaching*, 47(2), 83-91. https://my.nsta.org/resource/?id=10.2505/4/jcst17_047_02_83

Chen, J. L., & Mensah, F. M. (2018). Teaching contexts that influence elementary preservice teachers' teacher and science teacher identity development. *Journal of Science Teacher Education*, 29(5), 420-439. http://doi.org/1-46560X.2018.1469187

Collins, K. H., Price, E. F., Hanson, L., & Neaves, D. (2020). Consequences of stereotype threat and imposter syndrome: The personal journey from STEM-practitioner to STEM-educator for four women of color. *Taboo: The Journal of Culture and Education*, 19(4), 161-178. https://digitalscholarship.unlv.edu/taboo/vol19/iss4/10

Corp, A., Fields, M., & Naizer, G. (2020). Elementary STEM teacher education: Recent practices to prepare general elementary teachers for STEM. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), *Handbook of research on STEM education*. Routledge. https://doi.org/10.4324/9780429021381

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Sage.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches*. Sage.

Darling-Hammond, L. & Richardson, N. (2009). Teacher learning: What matters? *Educational Leadership*, 66(5), 46-53.

Deehan, J., McKinnon, D. H., & Danaia, L. (2019). A long-term investigation of the science teaching efficacy beliefs of multiple cohorts of preservice elementary teachers. *Journal of Science Teacher Education*, 30(8), 923-945.

Dembo, M. H., & Gibson, S. (1985). Teachers' sense of efficacy: An important factor in school improvement. *The Elementary School Journal*, 86(2), 173-184.

Denzin, N. K. (1970). *The research act: A theoretical introduction to sociological methods*. Aldine Publishing Company.

Denzin, N. K. (1978). *The research act: A theoretical introduction to sociological methods*. McGraw-Hill.

Flint, V. (2017, October 25). Don't let your projects die when grant funding runs out [Blog]. *EdSurge*. https://www.edsurge.com/news/2017-10-25-don-t-let-your-projects-die-when-grant-funding-runs-out

Garet, M., Birman, B., Porter, A., Desimone, L., & Herman, B. (with Suk Yoon, K.). (1999). *Designing effective professional development: Lessons from the Eisenhower Program*. U.S. Department of Education.

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, 25. 99-125. https://www.jstor.org/stable/1167322

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Sage.

Gunning, A. M. (2010). *Exploring the development of physical science self-efficacy in preservice elementary school teachers participating in a science education methods course* [Doctoral dissertation], Teachers College, Columbia University. ProQuest.

Gunning, A. M. & Moore Mensah, F. (2011). One preservice elementary teacher's development of self-efficacy and confidence to teach science: A case study. *Journal of Elementary Science Education*, 22, 171-185.

Gunning, A. M. & Marrero, M. E. (2017). Examining inservice teachers' mental models on teaching science through online learning. *The Online Journal of New Horizons in Education*, 7(1).

Gunning, A. M., Marrero, M. E., & Larson, K. V. (2021, July). Studying In-service Teacher Professional Development on Purposeful Integration of Engineering into K-12 STEM Teaching (Research to Practice). In *2021 ASEE Virtual Annual Conference Content Access*. https://peer.asee.org/37778

Hazari, Z. Cass, C., Beattie, C. (2015). Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development. *Journal of Research in Science Teaching*, 52(6). 733-762. http://doi.org/10.1002/tea.21214

Hillman, P., Coddett, A., Gunning, A. & Marrero, M. (2016) Vertically Articulated Professional Learning Communities: Building Collaboration and Practice amongst K-12 Science Teachers. *Open Online Journal for Research and Education*, (5).

Holincheck, N., & Galanti, T. M. (2023). Applying a model of interated STEM teacher identity to understand change in elementary teachers' STEM self-efficacy and career awareness. *School Science and Mathematics*, 1-15. http://doi.org/10.1111/ssm.12610

Johnson, T. M., Byrd, K. O., & Allison, E. R. (2021). The impact of integrated STEM modeling on elementary preservice teachers' self-efficacy for integrated STEM instruction: A co-teaching approach. *School Science and Mathematics*, 121, 25-35. http://doi.org/10.1111/ssm.12443

Joswick-O'Connor, C. (2020). *A longitudinal developmentally intentional leadership institute for teacher leaders: A case study of the experiences of 13 teacher leaders*. Columbia University.

Knaggs, C. M., & Sondergeld, T. A. (2015). Science as a learner and as a teacher: Measuring science self-efficacy of elementary preservice teachers. *School Science and Mathematics*, 115(3), 117-128.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lincoln, Y. G., & Guba, E. (1985). *Naturalistic inquiry*. Sage Publications.

Manner, B. M. (1998). Academic preparation and confidence level of elementary school science teachers. *Journal of Geoscience Education*, 46(1), 28–29. https://doi.org/10.5408/1089-9995-46.1.28

Mensah, F. M. (2016). Positional identity as a framework to studying science teacher identity: Looking at the experiences of teachers of color. In L. Avraamidou (Ed.), *Studying science teacher identity: Theoretical perspectives, methodological approaches and empirical findings*, 49-69. Sense Publishers.

Moore, F.M. (2008). Agency, identity, and social justice education: Preservice teachers' thoughts on becoming agents of change in urban elementary science classrooms. *Research in Science Education*, 38(5), 589-610. http://www.doi.org/10.1007/s11165-007-9065-6

Osmond-Johnson, P. (2019). Becoming a teacher leader: Building social capital through gradual release. *Journal of Professional Capital and Community*, 4(1), 66-80. http://www.doi.org/10.1108/jpcc-05-2018-0016

Pearson, P. D., & Gallagher, M. C. (1983). The instruction of reading comprehension. *Contemporary Educational Psychology*, 8(3), 317-344.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74(6), 625-637.

Smith, P.S. (2020). *2018 NSSME+: Trends in U.S. Science Education From 2012 to 2018* [Report]. The National Survey of Science & Mathematics Education. Horizon Research. https://www.horizon-research.com/horizonresearchwp/wp-content/uploads/2020/04/Science-Trend-Report.pdf

Tate, W. F., Jones, B. D., Thorne-Wallington, E. & Hogrebe, M. C. (2012). Science and the city: Thinking geospatially about opportunity to learn. *Urban Education*, 47, 399-433.

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, 68, 202-248.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and teacher Education*, 23(6), 944-956.

Trygstad, P. J., Smith, P. S., Banilower, E. R., & Nelson, M. M. (2013). *The status of elementary science education: Are we ready for the Next Generation Science Standards?* Horizon Research, Inc.

Weiss, I. R. & Pasley, J. D. (2009). *Mathematics and science for a change: How to design, implement, and sustain high-quality professional development*. Heinemann.

Yasar, S., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education*, 95(3), 205–216. https://doi.org/10.1002/j.2168-9830.2006.tb00893.x

Yesilyurt, E., Deniz, H., & Kaya, E. (2021). Exploring sources of engineering teaching self-efficacy for pre-service elementary teachers. *International Journal of STEM Education*,

8(1), 1-15. https://doi.org/10.1186/s40594-021-00299-8

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th edition). SAGE.