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Advocacy Interrupted: Exploring K-12 STEM Teacher Leaders' Conceptions of STEM Education Advocacy Before and During COVID-19

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ABSTRACT

This phenomenographical study examined 10 American science, technology, engineering, and mathematics (STEM) teacher leaders' (TL) conceptions of and activities in STEM education advocacy before and during the coronavirus disease 2019 (COVID-19) pandemic. Data collection consisted of semi-structured interviews conducted via online conferencing before the onset of the pandemic and responses to an online questionnaire completed during the pandemic. The outcome space emerging from the participants' conceptions of STEM education advocacy were: (1) identity, (2) communication, and (3) movement. Communication was a priority of advocacy activities before COVID-19 interruptions, whereas movement was thematically transformed due to participants' experiences (challenges and successes) in transferring their advocacy activities to online modalities. This study addresses gaps in STEM teacher and teacher advocacy literature by qualifying TLs' conceptions of and activities in education advocacy.

Keywords: COVID-19, phenomenography, STEMMaTe, STEM teacher leader, STEM teacher advocacy, teacher leadership

Introduction

To stymie the spread of the coronavirus disease 2019 (COVID-19) during the first quarter of 2020, public and private K-12 schools ceased face-to-face classes and K-12 teachers rapidly transitioned to fully remote (primarily online) instruction (Kaden, 2020). The lion's share of attention has been focused on student outcomes due to this shift in instruction and how students are differentially navigating this sudden change. Other changes may be impacting students, such as their teachers' conceptions of how able they are to advocate for their students, fellow teachers, and local communities. "Teacher advocacy [is] both a practice of teacher leadership, as well as teaching and leading for social justice," performed through activities that ensure teachers and students have adequate, accessible, and equitable resources both in and out of school (Bradley-Levine, 2018, p. 47). In particular, teacher advocacy in the science, technology, engineering, and mathematics (STEM) disciplines is vitally important to ensure students receive the equipment and supplies needed for generative experiences (National Research Council [NRC], 2012), provide their fellow teachers the professional development (PD) and support needed to provide rich K-12 STEM experiences (Fulton & Britton, 2011), engage their communities by facilitating family-centered STEM activities, and promote social justice in STEM (Sondel et al., 2017). Because of the technological resources needed

to access online learning platforms, the pandemic has disproportionately impacted vulnerable, under-resourced students (Armitage & Nellums, 2020). Therefore, it is important to concurrently examine how the pandemic has augmented K-12 STEM teachers' conceptions of planning and engagement in advocacy work, to improve equity and access to STEM education when it is most threatened. Thus, we explored how STEM teacher leaders (TL) conceptualized STEM education advocacy before and during the COVID-19 pandemic. This study was guided by the following research question: *how have STEM TLs' conceptions of advocacy (through their advocacy activities) changed since the onset of COVID-19?*

Purpose and Theoretical Framework

In this study, we sought to describe conceptions of K-12 STEM education advocacy among 10 community-vetted and advocacy-trained TLs both before and during the COVID-19 pandemic. We examined how the pandemic augmented thinking (conceptions) and outcomes (advocacy) among these STEM education teacher-advocates. We focused on the type of "teacher leadership [that] occurs within and outside classrooms to influence school-wide instructional practice" that impacts students (Cooper at al., 2016, p. 87). These STEM TLs were trained in policy advocacy work through the National Science Foundation's STEM Teacher Ambassador (STA) program (NSF, 2019). The program consists of learning modules and experiences in basic STEM education policy knowledge, crafting effective policy briefs, speaking to local and national media, and using social media (Twitter) as a digital advocacy space.

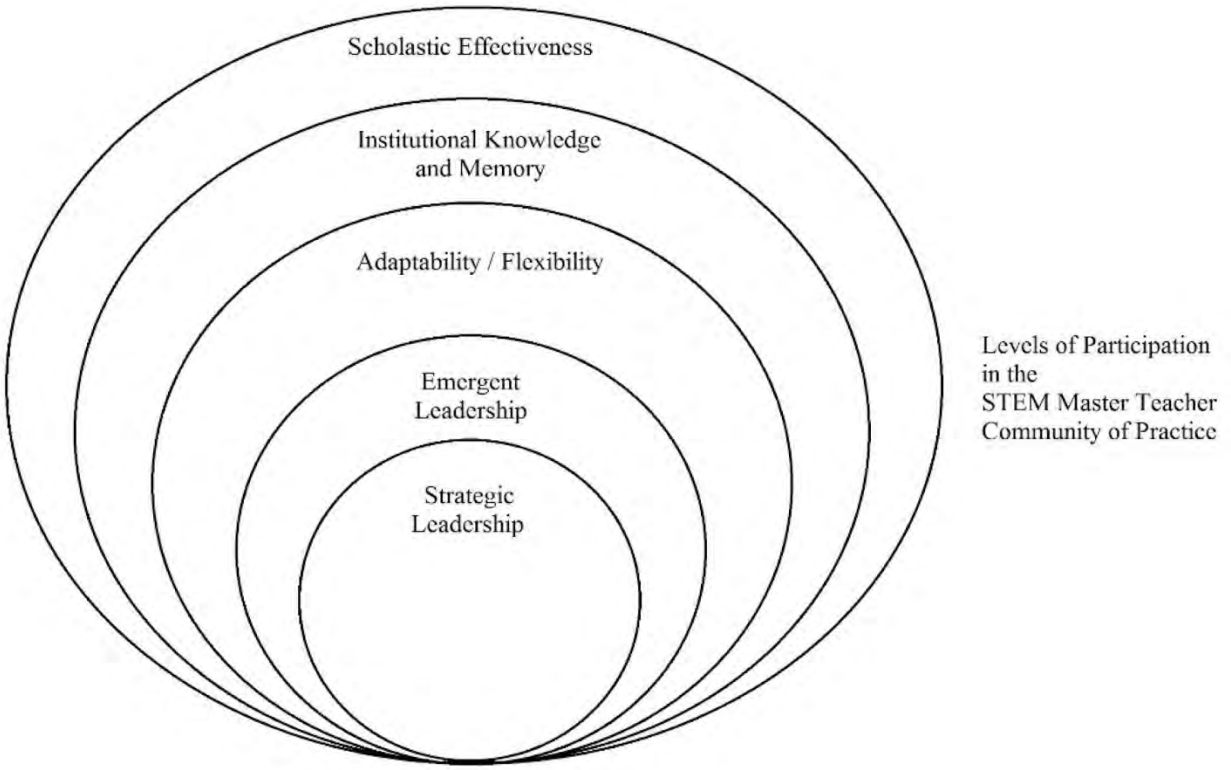
This study applies the *STEM Master Teacher (STEMMaTe)* framework of teacher-leadership development in advocacy (Hite & Milbourne, 2018) to explore how STEM TLs progress in their participation in advocacy-based leadership. STEM teachers progress through five stages of generative developmental experiences with respective communities of practice, which is reflective of Lave and Wenger's (1991) legitimate peripheral participation (LPP) concept. Lave and Wenger (1991, p. 29) defined LPP as providing "a way to speak about the relations between newcomers and old-timers, about the activities, identities, artifacts, and communities of knowledge and practices. It concerns the process by which newcomers become part of a community of practice." Thus, LPP can be explored as the process in which novices within a new domain engage in ample and appropriate opportunities to develop necessary knowledge, skill, and disposition of that domain (i.e., expertise). This process occurs within legitimate experiences assisted by experts. LPP experiences for the novice in the framework of teacher leadership in policy (STEMMaTe) describes LPP related to the individual's development first within STEM teaching by developing their scholastic effectiveness in content knowledge and pedagogical expertise and their understanding of how their local school and district functions (institutional knowledge and memory, Figure 1). Within these opportunities, STEM TLs gain knowledge, skills and dispositions from instructional leadership to strategic leadership through high-impact policy and advocacy activities among experts in those arenas.

The STEMMaTe model asserts that development as an advocate requires opportunities for acquiring experiences within each of the five sequential domains. *Scholastic effectiveness* requires a solid knowledge of STEM teaching. For example, appropriate LPP at the scholastic effectiveness level would be high-quality classroom teaching guided by a mentor teacher. *Institutional knowledge and memory* is the ability to (recognize) practice and policy issues within STEM education outside their own professional context (Hite et al., 2020). Appropriate LPP at this level could be sourced from participation on district or school committees with administrators to garner a greater understanding of the school's policies and politics. *Adaptability and flexibility* refer to gaining experience and knowledge of policy development and implementation to become an effective policy agent (Good et al., 2017). With these new experiences, TLs may begin to problematize issues in STEM education and learn the 'culture' of policy spaces, so they can understand issues within a policy context. Adaptability and flexibility are known for specific PD, training and programs that bring effective teachers and emergent

leaders to novel contexts in which they are able to obtain new knowledge and skills beyond scholastic effectiveness. Examples include participating in a Research Experiences for Teachers (RET) program, Albert Einstein Distinguished Educator Fellowship Program, or CDC Science Ambassador Fellowship. Leadership opportunities comprise *emergent leadership*, leading to full engagement (*strategic leadership*), in leadership work that influences or creates STEM education policy from local to international levels. Emergent leadership might include assisting with implementation of an RET program; strategic leadership would include concept and design of the RET program.

Figure 1

The STEMMaTe Model of STEM Teacher Growth in Policy-Advocacy and Leadership



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The STEMMaTe framework is useful to this study as it both justifies the examination of STEM TLs who have vetted LPP experiences that mirror the STEMMaTe model and how COVID-19 interruptions created new needs for LPP to reengage in the modified advocacy landscapes. Working and advocating in virtual versus physical environments warrants a new phase of adaptability and flexibility to lead online versus in person. This *adaptive expertise* (NRC, 2000) enables people to "remain flexible and adaptive to new situations" (p. 33). Termed within a dichotomy of expertise as artisan and virtuoso, individuals with virtuosity are able to identify the knowledge and skills needed in a new environment. In this case, STEM TLs who are able to garner the knowledge, skills, and disposition need to re-engage with leading in the now-changed policy advocacy spaces for STEM education. In studying STEM TLs, we may understand how their advocacy-based leadership, as viewed through their conceptions of STEM advocacy and subsequent advocacy activities, are impacted by sudden changes due to COVID-19. Using the STEMMaTe model, we can examine how changes to their situated expertise may have pushed them back into the adaptability and flexibility level of the framework. This is based upon how they perceived themselves as advocates or changed their advocacy

activities entirely due to the larger societal interruptions from the pandemic (e.g., needing to learn how to engage in remote teaching and learning, learning how to advocate for different types of resources). Moreover, this framework helps to ensure that what participants are reporting vis-a-vis changes in their advocacy activities are not due to a lack of understanding of STEM teaching (i.e., scholastic effectiveness), how schools operate (i.e. institutional knowledge and memory), or a lack of experience working in policy spaces (i.e. emergent or strategic leadership). Rather, we can study changes in participants' conceptions of STEM education advocacy and their activities due to the pandemic. Engaging in adaptability and flexibility to garner the knowledge and skills needed to re-conceptualize and re-engage in policy-leadership activities provides vital insight to how these STEM TLs are differentially advocating for their colleagues and students.

Literature Review

Much of the literature on teacher advocacy focuses on general teacher leadership (e.g., Bradley-Levine, 2018; Nguyen et al., 2020; Pantic, 2017; Wenner & Campbell, 2017) or teacher advocacy in specific contexts, such as teacher advocates for English language learners (e.g., Dubetz & de Jong, 2011; Haneda & Alexander, 2015) and teacher advocates in special education (e.g., Burke et al., 2016; West & Shepherd, 2016). While there are extant studies on conceptions of STEM education by STEM teachers (e.g., Dare et al., 2019; Radloff & Guzey, 2016), we have not found studies that explore how STEM TLs conceptualize specifically STEM education *advocacy*. Such a study would provide insight to the ways in which STEM teachers practice and enact advocacy, a critical aspect of STEM teacher leadership (Bradley-Levine, 2018). We sought to address these gaps in both the STEM teacher and teacher leadership literature, by qualifying how this sampled group of STEM TLs conceptualized STEM education advocacy before and during the pandemic. Such insights are also crucial at a time when the COVID-19 pandemic, in the U.S., has stymied face-to-face education, creating both obstacles and opportunities in STEM education as well as its advocacy. Herein we review recent literature on STEM education, teacher leadership, and teacher's activities in policy advocacy, through the currently known (empirical) impacts of COVID-19 on American K-12 STEM education.

STEM Education, Teacher Leadership, and Teacher Policy Advocacy

Before discussing *how* K-12 STEM teachers advocate for K-12 STEM education, it is important to first understand *why* STEM education advocacy is necessary. On a broader scale, research in the field has suggested several reasons why STEM education is beneficial for economic prosperity (Langdon et al., 2011; Xie et al., 2015) and global competitiveness (Breiner et al., 2012) by providing content-savvy graduates to fill the growing number of positions in emerging STEM jobs and careers (Hira, 2019; Noonan, 2017) and by fostering students' problem-solving and critical thinking skills both in STEM and real-life (Brophy et al., 2008). It would follow logically if teacher advocacy is seen as "a practice of activism external to the school and a practice of educational leadership" (Bradley-Levine, 2018, p. 47), then advocating for STEM education, especially by instructionally proficient STEM teachers like STEM TLs (Hess, 2015), is vitally important and beneficial for students short-term and for society long-term.

While many states and districts have recognized the importance of a high-quality and equitable STEM education, there is a lack of consensus in the decentralized American school system as to how STEM is applied in schools (Brown et al., 2011; Chalmers et al., 2017; Hite & Milbourne, 2021; Reimann, 2020). Largely, the key stakeholders that STEM education policies would impact—students and teachers—are absent in the policymaking process (Pennington, 2013). Yet, study after study has evidenced the importance of the teacher voice in crafting effective and efficient education-focused policies and the impacts of school effects (e.g., negative administrators or colleagues) on teachers'

abilities to promote policies with fidelity (Fairman & Mackenzie, 2015; Olsen & Buchanan, 2019; Sunderman et al., 2004). One study showcased that specifically involving special education teachers in the evaluation of special education policy provided insight to what actually occurs within special education classrooms (Bourke et al., 2004). Benefits included teachers helping to clarify academic language and curricula specific to special education classrooms, as well as special education teachers gaining new skills in policy through their participation in the policymaking process. This situation is not unique to special education teachers, however, as similar results were evidenced in a study of bilingual teachers (Dubetz & de Jong, 2011).

These studies suggest that teachers lack opportunities for experiences in the policymaking process (required for knowledge and skill development) as well as engaging in activities related to policy advocacy (Cohen, 2008; Dever, 2006) as LPP. Bond (2019) amplified this notion by stating that teacher advocates of any discipline need these specific experiences in policy leadership, especially those actively engaged in advocacy. This need is significant because teacher advocates who gain this experience may lend an influential voice in policy decisions that affect students and fellow teachers. Similarly, a case can be made for STEM TLs who wish to advocate for STEM education. For STEM specifically, many policymakers lack backgrounds in education (Dever, 2006), therefore, involving STEM TLs in the decision- and policy-making process, showcasing their instructional and educational expertise, as well as leadership skills (per STEMMaTe) is a vital act of advocacy that would contribute to student success (Pennington, 2013; Wayman, 2005).

Cooper et al. (2016) describe teacher leadership as a dichotomy of the actions that occur within and outside of schools, both of which affect schooling outcomes. This study furthers that notion by utilizing what Wenner and Campbell (2018) referred to as 'thick' and 'thin' teacher leadership. Thick leadership is described as teachers' leadership activities that extend beyond school walls (e.g. policy advocacy via conversation with STEM education policymakers), whereas thin leadership refers to leadership activities at the school level (e.g. math department chairperson modeling implementation of STEM integration in the math classroom). While the latter form of leadership is typically mastered in *instructional knowledge and memory*, opportunities for LPP in policy advocacy are vital for STEM teachers to be effective as advocates. There are extant STEM educator policy training programs (i.e., STA) that provide LPP opportunities for STEM TLs to engage and be trained in policy advocacy.

COVID-19 Impact on STEM Education

The COVID-19 pandemic suddenly and dramatically changed K-12 education in the U.S. by abruptly shifting face-to-face instruction to virtual formats (Kaden, 2020). Two notable studies have reported projected effects of the pandemic on STEM education: one study forecasts a decrease in pass percentage rates among secondary students in science and mathematics due to the lack of technology resources available to students at home (Sintema, 2020). The second projects that school closures and shifts to distance teaching and learning will facilitate a significant decrease in K-12 student academic performance, specifically in mathematics (Kuhfeld et al., 2020). Most notably, a consensus study report from the National Academies Press predicts the STEM education equity gap to widen profoundly, especially for disadvantaged populations such as Black and Hispanic minority groups, due to the abrupt change in instructional delivery (Bond et al., 2020).

In regard to institutional challenges, a report from the Albert Shanker Institute stated that "the revenue that funds public K-12 schools--almost 90 percent of which comes from state and local sources--will see large decreases," due to the economic recession as a result of COVID-19 (Baker & Di Carlo, 2020, p. 1). Baker and Di Carlo further explained that many states are still recovering from the last recession in late 2007. Thus, budget cuts that have been set in place endanger school initiatives and programs, including those involving STEM. It is then important for STEM TLs to keep abreast of these pandemic-induced education obstacles in student academic losses, widening equity gaps, and

ongoing budget costs, to leverage their knowledge and skills of STEM education and advocacy practices in sustaining effective STEM education curriculum and programming during the pandemic. Further, without the tight constraints school environments exert that inhibit teacher leadership (Fairman & Mackenzie, 2015), it is unknown to what degree STEM TLs are advocating (more or less) without hindrance, or how they are advocating (new or adapted advocacy activities).

Per the STEMMaTe model, LPP at each of the five levels relate to face-to-face means of obtaining LPP, such as school, district, and programmatic supports. In STEM, this has meant many schools and districts closed or went online for emergent leaders, shifting or reducing their support networks. For those STEM leaders who were engaging in LPP for adaptability and flexibility, STEM educator policy leadership programs went online (e.g., the AEF) or on hiatus (e.g., RET programs with deferred NSF grants). Emergent and strategic STEM teacher leaders had previously exercised their policy leadership in communities with stakeholders and one another in-person, such as designing and delivering professional development experiences for other STEM teachers at practitioner conferences. Due to the pandemic, much of this PD was either cancelled or migrated to webinars.

At each of the five STEMMaTe levels, LPP supports for policy leadership development among STEM teachers were impacted by the interruptions caused by COVID-19. Per Lave and Wenger (1991), a lack of LPP opportunities fosters a dearth of social interactions to comprehend, develop and refine the knowledge, skills, and dispositions to affirm and extend activities within a chosen domain, such as policy-advocacy activities for STEM education among STEM teachers. Therefore, it is unknown how STEM TLs understood, obtained, leveraged, abstained from, or provided LPP in the fewer and socially different online modality of policy leadership LPP during the pandemic. Maintaining effective and equitable STEM education programming may be explored through STEM TLs' conceptions of and activities in STEM education advocacy prior and during the COVID-19 pandemic.

Methods

This study employed phenomenography, defined as a qualitative research approach that "aims at description, analysis, and understanding of experiences" (Marton, 1981, p. 180). Phenomenography is often confused with, and erroneously compared directly to, phenomenology as both relate to phenomenon-based research (Cibangu & Hepworth, 2016; Hasselgren & Beach, 1997). A critical difference is how these qualitative approaches problematize the purpose or the intention of the study, which in this case was to understand and describe the phenomenon of STEM advocacy as conceptualized by STEM teacher advocates, rather than lived experiences (of phenomenology). Instead, phenomenography allows for the description of a phenomenon as it is *conceptualized* by a group of participants (Alsop & Tompsett, 2006), which is why Han and Ellis (2019) have ascribed phenomenography as an ideal methodology for STEM education research.

Therefore, in phenomenography, descriptions of experiences of a phenomenon (engaging in STEM advocacy activities) as provided by participants (STEM TLs who are engaged in advocacy) are grouped together to form what is known as *categories of description* (Marton, 1986). These categories are established through a robust analysis of the relationships between and variations among participants' *utterances*, their descriptions of experiences, which serve as this method's units of analysis. Notably, utterances can be whole sentences, segments of sentences, or a cluster of sentences that are placed into a specific category after multiple rounds of coding. Final categories of description are commonly structured hierarchically, to provide explicit descriptions of how categories differ. Collectively, these categories comprise the *outcome space* of categories established from utterances of sampled participants (Marton & Pong, 2005). Given the understudied phenomena related to conceptions of and activities in STEM advocacy among STEM TLs, and the novel effects of the pandemic in the sphere of education, phenomenography provided the means to ascertain variations among and relationships between elicited conceptions uttered by STEM TLs on advocacy at two levels (Marton & Pang, 2008):

through STEM education advocates as processed by the researcher (*first-order perspective*) and as described by utterances reflective of the experiences of STEM education advocates (*second-order perspective*) (Marton, 1986). This, in part, is what made phenomenography the most appropriate methodological approach for this study: STEM advocacy was occurring before and during an unprecedented time, completely altering the thick and thin leadership in which STEM TL advocacy would normally take place and perhaps the purpose (e.g., greater focus on procuring technology resources) of their advocacy activities.

Participants

Purposeful sampling is customary for phenomenographical research due to its strictly empirical and inductive nature in analysis (Åkerlind, 2005). In order to capture conceptions of STEM advocacy, we recruited STEM TLs specifically trained and experienced in advocacy. Based on the STEMMaTe model, these sampled individuals constitute teachers at the emergent leadership phase, participating in leadership (advocating) for STEM education. The LPP experiences of these participants occurred in the NSF's STA (2019) program, jointly facilitated by the National Science Teaching Association (NSTA) and the National Council of Teachers of Mathematics (NCTM). An important criterion for participation in the STA program was that teachers had to be past recipients of the Presidential Award of Excellence in Mathematics and Science Teaching (PAEMST), a national-level award for K-12 STEM teachers who have demonstrated excellence in STEM classroom teaching and leadership. Programmatic criteria provide vetting of the scholastic effectiveness and institutional knowledge and memory (Figure 1) to effectively participate in the LPP experiences (adaptability and flexibility) within the STA program to become an effective STEM education advocate.

In the two years of the program's existence, a total of 20 STEM teacher advocates (10 per year) completed the advocacy training fellowship. The STA program consisted of learning modules and experiences (LPP) in basic STEM education policy knowledge, crafting effective policy briefs, speaking to local and national media, and using social media (Twitter) as a digital advocacy space. Fifty percent (10/20) of all STA alumni participated in this study; they comprise a diverse demographic in terms of gender, grade level taught (and STEM discipline, if they taught at the secondary level), and number of years of teaching experience (Table 1). It is important to note that while this study had a small sample size, the focus of phenomenographic research and analysis is driven by the presentation of variations of conceptions described by participants, not by the number of participants itself (Mullet et al., 2018). Thus, both the sampling and sample are appropriate for a phenomenographic study (Bruce et al., 2004; Mullet et al., 2018; Trigwell, 2006).

Data Sources and Collection

Interviews and a follow-up questionnaire provided the data on how these 10 STA alumni conceptualized and problematized STEM education, and how their advocacy priorities and/or activities have shifted as a result of COVID-19. Data collection for this study occurred in two phases: (1) pre-COVID-19 in the summer of 2019 and (2) during COVID-19 in the spring of 2020. While the original intent of this study was to analyze and describe STEM teacher advocates' conceptions of STEM advocacy in a more general manner, the onset of COVID-19 allowed us to not only analyze their conceptions of STEM advocacy, but also to do so within a pandemic. Given the abrupt shift in moving teaching and learning to hybrid or fully-online teaching modalities was a novel situation for math and science teachers (Bloom et al., 2020), that may too have had impacts on these specific STEM TLs' conceptions of advocacy and resultant activities.

Table 1

Study Participants

Pseudonym	Sex	Grade Level Band (and STEM Discipline)	No. of Years of STEM Educator Experience	Notes
Jane	F	Elementary	21	
Ben	M	Elementary	27	District STEM teacher
Dave	M	Middle School Science	33	
Lou	F	High School Science	31	Held teacher educator role concurrently
Mark	M	Middle School Math	13	
Lisa	F	Elementary	35	Retired at the time of interview
Mary	F	Elementary	22	State curriculum coordinator for science
Anne	F	High School Math	26	Held administrative role concurrently
Paul	M	High School Science	20	
Beth	F	High School Math	28	Held administrative role concurrently

Individual semi-structured interviews were conducted as an extension of a previous study on how alumni of the STA program conceptualized and engaged in STEM TL advocacy (Velasco et al., 2021) during July and August of 2019. Audio data was transcribed using qualitative analysis transcription software (Otter, 2020). Interviews were video-recorded via Zoom (2016) and lasted no longer than one hour. Interview questions focused on participants' conceptions of and experiences in STEM advocacy, such as: How have you come to understand what advocating for STEM education entails? How has your experience as an STA influenced your role as an advocate for STEM education in your classroom? What are you doing now for STEM education, regarding advocacy, after the STA program? How has your teaching changed since STA as an education advocate?

Phase two of the data collection process occurred during the COVID-19 pandemic (April 2020) and at a time when most K-12 schools and universities across the U.S. had fully transitioned to online or hybrid instructional platforms (Tull et al., 2020). During this phase, a five-item open-ended questionnaire (Edwards, 2007) was developed based upon the most cogent responses from the interview data. Items asked participants to reflect and describe: the extent to which they have advocated, or plan to advocate, for STEM education during the COVID-19 pandemic; how their thinking (conceptualization) or advocacy (activities) for STEM education have changed since the onset of the COVID-19 pandemic, including how they network with other TL advocates; how they think their advocacy for STEM education will change after the end of the COVID-19 pandemic. A Google Form with an online link was directly emailed to all 10 participants during the first week of April 2020. All participants were able to fully complete the questionnaire within two weeks.

Analysis

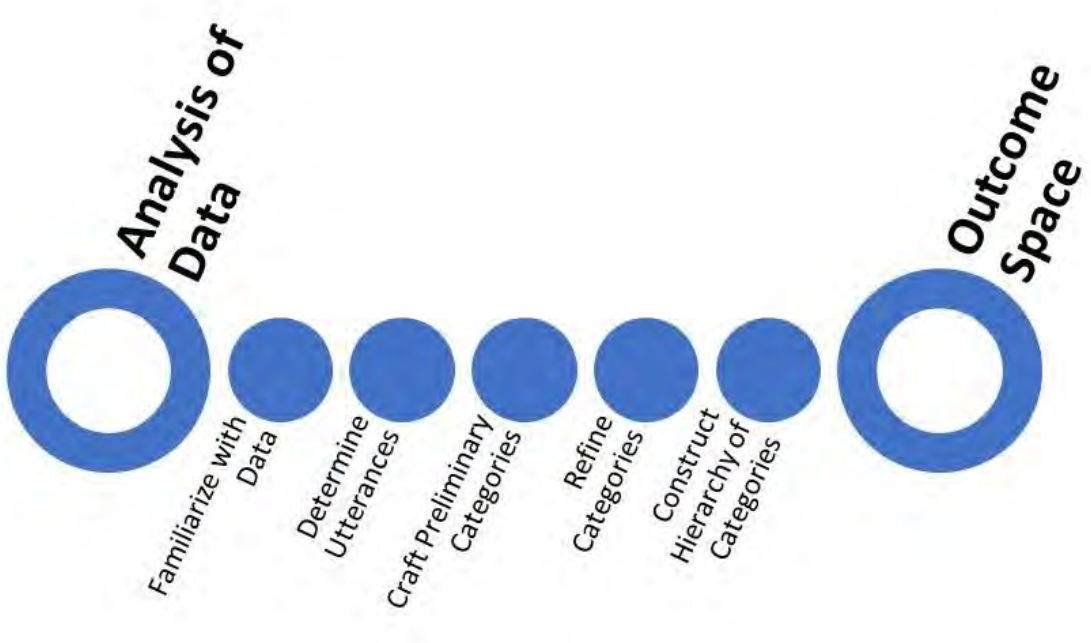
The analytic approach to phenomenography is both empirical and inductive (Marton, 1986), focusing on description of participants' conceptions of a phenomenon underscored by how said phenomena is actively experienced by the participant. While there is no specific prescribed technique in the analytical process of phenomenography (Ashworth & Lucas, 2000), we utilized the five-step formula offered by Sandberg (1997) for both sets of data collected (before and during COVID-19; Figure 2). First, we familiarized ourselves with the 10 previously de-identified transcripts by reviewing the data, correcting software-based errors, and establishing the audit trail. Second, we inductively identified and selected utterances from the transcripts by making sure to focus primarily on the utterance as its own unit of analysis, independent of the participant. We first conducted this second step of the analysis separately to ensure an unbiased selection of utterances, then compared and discussed notes to come to an agreement in final use of utterance as data. A third senior researcher was consulted to help resolve disagreements. Third in the analytical process, we conducted preliminary categorizations of the utterances, where utterances were grouped based on similarities and collective meanings across the set of data, unbounded by linking specific utterances to participants. Fourth, we refined categories by shifting utterances to expand and/or collapse categories until we reached consensus on the final categories of description. This refining process is vital to reduce categories of meaning into developing the outcome space because "these categories of description are the logically related [yet] qualitatively distinct ways of experiencing the phenomenon" (Åkerlind, 2005 as cited in Daniel, 2021, p. 4). Last, we reviewed the outcome space (i.e., the collection of categories of description) and explicitly described differences among categories, but also their relationship to the phenomena of study. Per Han and Ellis (2019) the phenomenographic outcome space "contains two essential elements: descriptions of each category and selections of illustrative statements accompanying each category" (p. 6). Thus, once categories of the outcome space are established, readers are given an understanding of how many illustrative statements were made by participants to substantiate the categorical descriptions. Han and Ellis (2019) elaborated that "the outcome space can also be arranged chronically (temporal ordering), which denote the evolution of the participants' experience" (p. 6). Given that the research inquiry is punctuated by COVID-19 interruptions, marking the shift from face-to-face to online LPP for learning and exercising expertise in STEM education policy advocacy, bifurcating the data is logical to understand how this shift impacted participants' experiences or activities in STEM education policy advocacy.

Researchers' Positionality

Both authors were former K-12 STEM TLs who have had experience in STEM policy advocacy training and are current STEM education researchers at large research institutions in the Midwestern and Southern regions of the U.S. Both researchers leveraged their classroom and policy knowledge, advocacy training, and scholarly experiences to develop the interview protocol and questionnaire used in the study. The first author is an alumnus of the second (and final) STA cohort, collecting all data from participants given this relationship to the program and participants. The second author has had deep involvement in K-12 STEM TL advocacy and prior scholarship in this space.

Figure 2

The Five Step Phenomenographic Progress



Note. Adapted from Sandberg (1997).

Trustworthiness

To maintain the degree of confidence and rigor of analysis employed in this phenomenographical approach to research, we strove to meet the four criteria of trustworthiness offered by Lincoln and Guba (1985). Credibility of the data was established since the participants of this study were community-vetted STEM teacher advocates, per the theoretical frame of the STEMMaTe model, who shared and provided thick descriptions of their advocacy experiences after being trained in advocacy. Dependability measures were taken as we kept an audit trail of participants' transcription data. Both researchers worked collaboratively to code all data of the present study, discuss the data over multiple time periods, and construct final categories of description to account for confirmability of data. For transferability purposes, we provided a detailed description of the study's context (conceptions of STEM advocacy), setting (pre-COVID-19 and during), and participants (STEM teacher advocates).

Results

We reviewed a total of 224 pages of transcribed data from all 10 interviews and an additional 21 pages extracted from the questionnaire responses. For our initial analysis, we identified and selected 304 relevant utterances from the interview data and 73 relevant utterances from the questionnaire data for a total of 377 units of analysis for the data pool. We began with the utterances in the transcribed data collected pre-pandemic, grouping similar utterances inductively, producing a total of 44 preliminary categories. We completed the same process for questionnaire data and found that utterances in this data set fit into 16 of the preliminary categories derived from the transcript data. This process of categorical refinement (i.e., from 44 to 16) is integral to the development of the

phenomenographic outcome space. Data from questionnaires were highlighted in a different color to distinguish them from interview data; these preliminary categories are summarized in Table 2.

Table 2

Preliminary Categories in Alphabetical Order

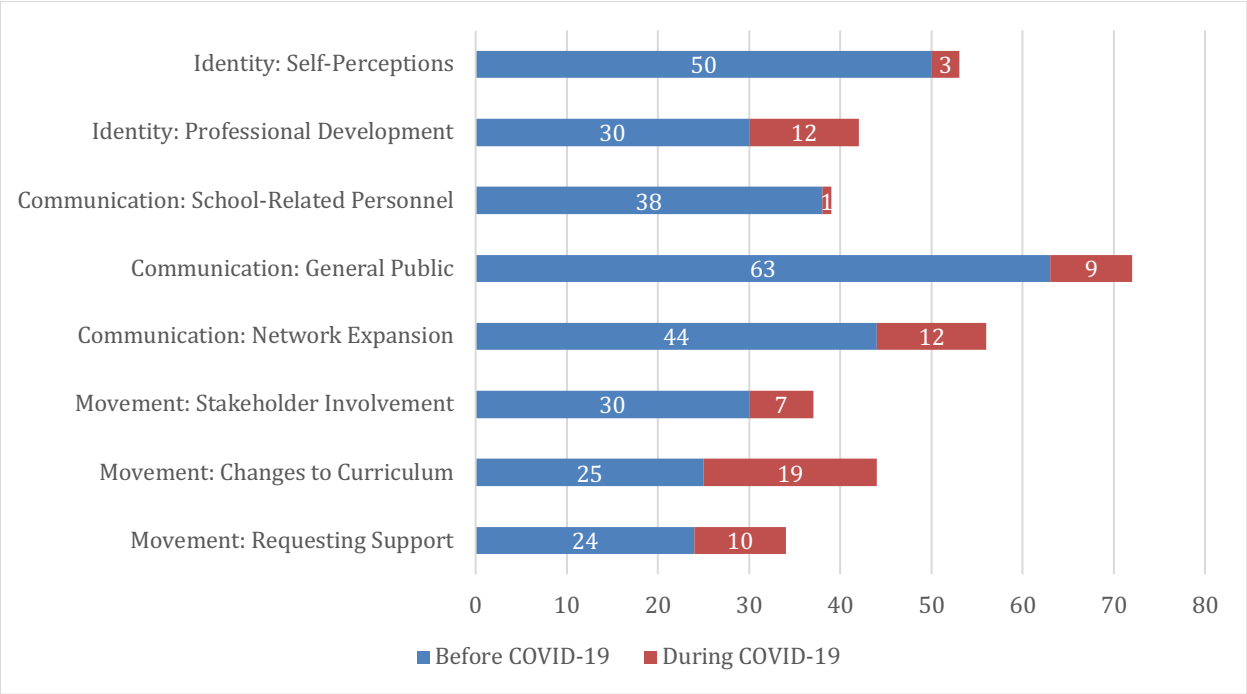
Advocacy as a passion	Involvement with STEM education community*
Advocacy training	Making connections with other STEM teachers
Advocate identity*	More advocacy needed*
Advocating for funds for STEM*	Political awareness
Advocacy as a calling	Presentations at professional organizations
Applying for grants and awards	Providing support
Being a STEM person	Push for math
Constantly learning for professional growth	Responding to questions about STEM
Conversations with government officials*	Responding to STEM opportunities
Convincing other STEM TL to advocate	Speaking with the school board*
Creating school STEM programs	Spreading awareness: what advocacy looks like*
Curriculum changes*	STEM activity in the community*
Deciding on how funds should be spent for STEM	STEM advocacy using social media*
Disseminating STEM info. to stakeholders*	STEM awareness
Engaging with a broader audience	STEM in a problem-based learning environment
Helping pre-service teachers	STEM night for parents
Highlighting STEM in casual conversation	Talking with administrators
Incorporate STEM into teaching	Talking with district supervisors or leaders
Increasing in STEM knowledge*	Teaching other teachers to become advocates
Increasing networks*	Teaching style is constantly changing
Integration of STEM into other disciplines*	Teaching workshops to other teachers*
Inviting STEM professionals to class	Writing an op-ed*

*Preliminary categories that include utterances from survey data.

Upon further examination, we then reassigned, regrouped, and rearranged utterances to different categories and eliminated categories. For example, the preliminary categories 'advocacy is a passion,' 'advocate identity,' 'advocacy as a calling,' and 'being a STEM person,' all shared common utterances that referenced STEM TLs' perceptions of their identities as STEM teachers and advocates. Thus, the utterances in these preliminary categories were regrouped to form the 'Self-perceptions' subcategory. Further refinement of categories led to a final set of three overarching categories, each containing a set of subcategories: (1) *identity*, (2) *communication,* and (3) *movement* (Table 3). Findings indicated that STEM TLs' conceptions of advocacy were tied to their STEM teacher and advocate identities. In order to advocate for STEM, one must be knowledgeable and skilled in their discipline and advocacy. Furthermore, STEM TLs' conceptions of advocacy were manifested in some form of communication. STEM TLs made references to conversations with education leaders, voicing the importance of STEM with the general public, or collaborating with professional networks. Finally, STEM TLs' conceptions of advocacy went beyond voicing concerns and were more action-oriented (hence the category, 'movement'), resulting in training or creating a document. Figure 3 illustrates the frequencies of utterances per subcategory before and during the COVID-19 pandemic.

Figure 3

Frequency of Utterances Per Subcategory in Outcome Space



Findings reveal that prior to the COVID-19 pandemic, STEM TLs' conceptions of STEM education advocacy were largely in the form of constant communication. During the pandemic, participants primarily conceptualized STEM education advocacy as immediate movement (i.e. advocacy that requires action beyond communication). The sections that follow further explicate the thick descriptions within each of the three overarching categories and their subcategories formed in the outcome space. In addition to these descriptions supported by direct quotations from participants, we report the sum number of utterances as well as the final number of utterances assigned from both the interview and questionnaire. We report percentages of increase to illuminate how data changed in the categories of description from the time before the onset of pandemic to the time questionnaire data was collected.

Category 1: Identity

Ninety-five descriptions of identity were uttered in STEM TLs' conceptions of STEM education advocacy, comprising the least amount of data in the outcome space. Eighty utterances were extracted from interviews conducted pre-pandemic and 15 utterances were added from questionnaires answered during the pandemic, indicating an 18.8% increase in utterance frequency. Within this category of identity, sampled STEM TLs' conceptions of STEM education advocacy were dependent upon their self-perceived roles and their reception of received PD.

Self-perceptions

According to sampled STEM TLs, STEM education advocacy was a result of self-identifying as a STEM educator and an advocate. Many utterances related to respondents' exemplary teaching of a STEM discipline (i.e. science or math), and from that expertise, they felt compelled to be advocates

Table 3

Overarching Categories, Subcategories, and Utterance Examples Prior to and During COVID-19 Pandemic

Subcategory	Examples of Utterances Pre-Pandemic	Examples of Utterances During Pandemic
Category 1: Identity		
Description: STEM teacher leaders' conceptions of advocacy were tied to their STEM teacher and advocate identities. In order to advocate for STEM, one must be knowledgeable and skilled in their discipline and advocacy.		
A. Self-perceptions	Jane: "I was advocate for it in my district, and in my school, pretty much limited to that level, it was I didn't do a lot of calling legislators I didn't do a lot of you know, that type of advocacy, writing articles or anything like that, I just was just active and doing it in my classroom and at the school level, and kind of leading it that way." Ben: "I've always been kind of a STEM person." Mark: "The research on advocacy is my proudest moment."	Mary: "It has shown me that my work is essential. We have got to do better so that we have a more informed public who can understand basic health issues, understand math and science models, and grapple with data and basic stats. Our future as a nation depends on it. I'm even more fired up." Dave: "I feel STEM ed may be less of a priority in the short term due to extreme budget cuts happening to local education agencies everywhere, but in the long term, I think interest may increase as we will need STEM educated citizens to solve these complex world problems." Anne: "COVID-19 has made me think about how to continue to push for STEM as we enter the online world."
B. Professional development	Dave: "The [STEM teacher ambassador] training was focused on the state level, how to navigate state politics, which was very helpful." Beth: "I wanted to learn more about STEM, kind of on the ground roots and also figure out how to do more collaboration between our science and math staff at the high school."	Jane: "I think the pandemic will bring a greater respect for STEM and educators in general which will hopefully allow us to do more for our students." Lou: "STEM knowledge is so important to dispel the many myths and misunderstandings."

Category 2: Communication		
Description: STEM teacher leaders' conceptions of advocacy were manifested in some form of communication, be it conversations with education leaders, voicing the importance of STEM with the general public, or collaborating with professional networks.		
A. School-related personnel	Lisa: "I'm serving on a board right now, where we're bringing the new standards into schools. And I know that they're coming with some resistance, because it's not that easy, you know, give this test, teach these facts." Anne: "I'm trying to get the other teachers to buy in, because some of them don't even understand [STEM]." Lou: "[Administrators] pretend like they want our opinions, but they already have theirs."	Dave: "My work—advocating for NGSS—continues during COVID and is actually doing well. Tomorrow, our state board of education is having its first ever live Zoom that will, in part, discuss the standards revision process."
B. General public	Ben: "I think I have a bigger platform now because now when I meet people, I don't just share my ideas. I share my ideas and say, I'm a STEM ambassador. And, you know, it's a platform." Anne: "Whenever you get a chance and sometimes I can run into people where you're not planning to run into and you have an opportunity or an opportunity presented [to talk about STEM]. Paul: "I've been a moderator before, so I felt like I was I am I've got some skills in that area, some background in that area. And then but also, you know, I'm very excited for what everybody else is bringing to the table."	Mark: "For the past couple of months, I've tweeted a few topics on STEM education to help educators with some STEM-at-home ideas, such as reading news articles." Lou: "I have posted instructional ideas via Facebook and Twitter. I have tried to explain COVID things and posted videos and tutorials." Jane: "In addition I have created a Facebook page called Science Sleuths dedicated to science instruction and a platform for students to share their experiments and investigations."
C. Network expansion	Paul: "So, I have not yet reached out to the new representative or so that's also something that I've learned is like some of these relationships that you maybe want to try to build." Beth: "My purpose of that is to then provide it to the governor as more think piece. We need to be better and stabilize." Anne: "Further the dissemination of the information and, and how advocacy is important to get more teachers and politicians and in general just everybody realizing how important [STEM] is in education and how and why it is so important."	Mary: "I hope to partner with my state leaders to provide quality science experiences for my colleagues in my state. We are working on if that can happen." Dave: "There will now be connections and networks to ramp up my advocacy to a global level." Lisa: "I am reaching out to my network to support them with resources, helping with ideas for trainings, and offering classes myself in STEM."

Category 3: Movement Description: STEM teacher leaders' conceptions of advocacy went beyond voicing concerns and were more action-oriented, resulting in training or creating a document.		
A. Stakeholder involvement	Anne: "The classroom sharing with the teachers, because a lot of the teachers don't understand, you know, the elementary because they're not really trained in science." Mark: "That's at least where I see myself like in the future and take advocacy another level that goes beyond the classroom in terms of being more active."	Beth: "I've also recruited teachers for the upcoming science committee. Unfortunately, our district does not have a STEM committee. I have also worked with our counseling department to set schedule for next year to include Tech Pathways course." Mary: "I'll include family and communities more. STEM is a social endeavor. No better place to start than the home and community." Lisa: "As a STEM advocate, I found myself "coaching" others through the process to brainstorm, create solutions, and design a plan that retains the best of STEM."
B. Changes to curriculum	Paul: "I've had a leadership role in transitioning the district to [my state's] new science standards, which are modeled after the next generation science standards." Ben: "I think teaching in a STEM platform in a problem-based learning environment. I created our STEM program." Dave: "So I am teaching in a way that is 180 degrees different than I think how I've taught prior to this, I mean teaching more for divergent thinking, instead of teaching to the test, more for project-based learning, problem solving, authentic learning real world application, whereas before it was test focused."	Mary: "I worked with my district task force of teachers to create 6 weeks of home learning K-5 science lessons that were true to our vision of phenomenon-based, three-dimensional learning. These lessons included on and offline resources/activities and families were encouraged to participate in the learning." Paul: "I have led my district in preparing distance learning opportunities for our high school science classes." Anne: "I am also continuing to help develop/teach online science in summer school for this coming session. I make sure activities are selected that represent STEM and inquiry processes." Beth: "And of course I taught my only foundations of algebra and geometry class via Canvas and Zoom where I integrated technology to support the class."
C. Requesting support	Lisa: "But our task was to go and share about STEM education and getting more funding for that." Jane: "I would think the thing I would need to do that I haven't done and really put off is writing articles and op-eds."	Ben: "Fighting to keep as much of it [budgets] intact as possible." Mark: "It's made me more lethargic and anxious thinking what the future would hold... during this time that has made me think, it's going to get better and life will go on and we shouldn't stop advocating for STEM education, but that it is okay if we need to take a pause for a moment."

within and for the profession. For instance, Ben (all participant names are pseudonyms), an elementary STEM teacher TL described, "I would say I've always been an advocate. I think I've always been since early on. I'm an advocate for STEM, because I'm a STEM teacher." Lisa, a retired elementary teacher with over 35 years of educator experience, echoed the same sentiment,: "So I feel like just being a science teacher, [advocacy] was just a natural part of who I am and who I was. I always think of it as fighting for what's right, fighting for what's good." Where STEM TLs identified as STEM teacher advocates, there was also a passion for advocacy and in certain instances, advocacy was a calling. Mary, a former elementary teacher and currently her state's science curriculum coordinator explained about advocacy, "I have a passion, and I'm putting in the work. I felt if no one else is doing it, then I'll do it because our kids deserve the time, they deserve the learning."

Respondents' passions and calls to advocacy did not wane during the pandemic. Mary expressed how the pandemic has given a greater purpose to her advocacy activities, "My work is essential. We have to do better so that we have a more informed public who can understand basic health issues, understand math and science models, and grapple with data and basic stats. I'm even more fired up!" There were also pandemic challenges in advocating for STEM education, such as the shift to online learning. For example, Lisa vented, "I have become an advocate for hands-on learning. It is frustrating when I hear teachers saying, 'I can't do hands-on when it's online.'" Middle school math teacher Mark shared how quarantining posed challenges to his advocacy: "Because I have been in self-isolation for most of this time during the pandemic, it has been quite difficult to advocate for STEM education in some capacity."

Professional Development

The majority of utterances that increased over time (between the data sets) in the category of identity were in relation to STEM TLs' descriptions of a continual need for PD; so teachers could learn more about STEM education and receive training for advocacy work. Prior to the pandemic, participants felt that STEM education meant continuous learning of STEM in general. For example, high school science teacher Paul indicated, "I want to learn more about STEM and some of the ins and outs of it, from a policy standpoint or even from a historical standpoint." Beth, a high school math teacher and administrator, also elaborated, "I wanted to learn more about STEM, kind of on the ground roots. What our nation needs are highly competent people in the areas of science, technology, engineering, and math, and we're falling behind." To further illustrate the importance of explicit educative experiences in advocacy, middle school science teacher Dave spoke to experiences and training he received in the STA program, describing that "their [advocacy] training was focused on the state level, how to navigate state politics, which was very helpful."

During the pandemic, STEM TLs acknowledged that advocating for STEM education would help mitigate misconceptions and misunderstanding associated with the COVID-19 global crisis. Lou, a high school science teacher and teacher educator, articulated, "I feel that [advocacy] gives us a voice to promote STEM as something that will help bring this pandemic under control. STEM knowledge is so important to dispel the many myths and misunderstandings." Participants discussed what the pandemic meant for the future of STEM education initiatives and policies. As Mary observed, "I saw that during this time many used this health crisis to manipulate STEM initiatives. I think we as a community need to be concise and make sure we are champions for equitable STEM learning for ALL rather than novel activities disconnected from authentic learning or what is cute on Instagram. And we need to be clearer on what STEM is and what STEM isn't."

Category 2: Communication

The category of communication consisted of 167 utterances, marking the largest amount of data in the outcome space. However, this category had the smallest percentage increase of utterances at 15.2% with 145 utterances coming from pre-pandemic data and 22 during pandemic data. Similar utterances assigned in preliminary categories were grouped together into subcategories. Specifically, STEM TLs had conceptualized STEM education advocacy as conversations with school-related personnel about STEM, informing the general public about the importance of STEM, and calling upon or being recruited by external organizations to expand their STEM education networks.

School-related Personnel

Respondents' described STEM education advocacy as being more successful when co-workers are educated and involved. Anne, a math teacher and school administrator mentioned, "I'm trying to get other teachers to buy in, [but finding trouble] because some of them don't even understand it." Dave shared the same sentiments in regard to spearheading his own state's STEM advocacy program, expressing that advocacy "would be an awesome thing to continue and to get more teachers involved with." For elementary teacher Jane, effective advocacy means involving school administration, "My response to the definition [of advocacy] was different. I felt like advocacy was where I was with teachers, with principals, with administrators." She suggested that her administration's involvement led to her school district reaching out to her as a STEM TL, "My district gave me more attention for being an ambassador, and for being a presidential awardee." Paul articulated a similar experience having been recruited by his school board to be a part of his district's STEM advisory board, "I am part of my district's STEM advisory board. This is a new role for me. I don't think I would have been invited had I not been named [as] a STEM advocate." Other participants commented on how they leveraged their networks to extend their advocacy beyond the school's walls, as STEM TLs referenced contacting district leaders to enact change. As an example, Lou declared, "If I really believe something, and I have some strong views, I'm talking to my superintendent, I'm emailing, I'm talking to my principal now." However, STEM TLs cautioned that this approach was not always effective. Ben indicated that, in trying to incorporate a more integrative STEM curriculum at his middle school, persistence was also necessary, "And I kept pushing. It's the same old thing, like people don't want to be bothered, like, change is different." Beth described another example of disappointment by stating, "I was able to insert things like, 'Well, I think we need to do this because it will prepare kids for these types of careers.' But, a lot of my suggestions fell on deaf ears." Other than a statement provided by Dave regarding meeting with his school board via Zoom (Table 3), notably no other utterances from the questionnaire data collected during the pandemic were assigned to this subcategory.

General Public

Another conceptualization of STEM education advocacy among respondents was promoting and communicating the significance and importance of STEM education to the general community. For example, Dave uses his TL voice to advocate to the community about STEM education's importance to a thriving economy, "I try to convince people that STEM is all about competing globally, for jobs, for the economy." Ben described experiences that aided him in elevating his voice and more effectively communicating the importance of STEM education, "I think the STEM ambassadors was a platform to bring [STEM] to a bigger audience, to talk about it to a bigger audience." Leveraging social media was also referenced by STEM TLs as a means to advocate for and communicate STEM education to the general public. Reflecting upon her experiences of using social media for advocacy (prior to the pandemic), Jane shared that, "I did become a lot more active on

Twitter, connecting and retweeting, you know, just trying to get [STEM] out there, to the people that I connect with or that follow me." Mary indicated that social media was her avenue to have her voice heard: "I very quickly found out that Twitter was a great space for not just learning, but networking and sharing my voice in a way that I felt could also improve the things I had to say." However, some STEM TLs indicated that they were apprehensive about sharing advocacy on social media. Paul talked about his trepidation, yet shared nonetheless that he uses social media to promote his STEM interests, "I am very cautious about what I put on social media still. I seem to advocate NASA. I love NASA. And so, I find it easiest to retweet, or like and mention, respond to amazing things NASA is doing." Lou added her thoughts on the need for more training before STEM TLs use social media for advocacy: "I still don't use it. There could be more training on how to really utilize and expand your reach if you do choose to use social media."

The following utterances on social media represent the data added to this subcategory from questionnaire responses collected during the pandemic. Shifts to hybrid and virtual learning prompted STEM TLs to leverage the internet and social media to advocate for STEM. For instance, Dave shared that "Zoom and [Microsoft] Teams have been great resources for advocacy." And from Mark, "I have been retweeting STEM resources that I find to be helpful or particularly useful for parents to help their kids at home." However, Mark also noted obstacles for students without access to technology and/or the internet, "I definitely want to be more active in advocating for STEM using social media, but I also have to think about ways to reach populations that do not have social media. I think reaching out to communities and seeing what their needs are based on this pandemic and being able to relate the notion of STEM and what STEM is all about is very important." Further, technology can be a lifeline for teachers and students. As Lisa described, "I worry about the isolation of the students and their teachers. Education is such a collaboration and we need each other. Using Zoom type platforms to create interactions has been increasingly important."

Network Expansion

STEM TLs' conceptions of STEM education advocacy entailed communicating with external STEM organizations, government officials and lawmakers to expand their own professional networks in education policy. Speaking on STEM organizations, Lisa ascribed success in advocacy to working diplomatically with those who may exhibit opposition, "A big thing that was a revelation for me was making yourself available to some of those key players in the STEM world, so that they know you're on their side, even though they might kind of potentially be against you to work with them, to continue to build that relationship and that common understanding."

In regard to government officials and lawmakers, Dave shared that advocating for changes in STEM education policy begins with his state-level policymakers, "I feel like [advocacy] is getting a conversation going in [my state], to rethink what schools could be as far as STEM education." Further, respondents also felt an important part of their advocacy conversations with policymakers was to keep them abreast of the reality of K-12 STEM in today's classrooms. An example of this sentiment was shared by Lisa, "Advocacy is talking to your senators and representatives to share that this is from the classroom, this is from the heart of the classroom. They're in this fantasy world of what STEM education is." In order to have those often tough conversations, STEM TLs stressed the importance of establishing a professional relationship first with their local and state policymakers. Paul shared, "I have not yet reached out to the new representative. That's also something that I've learned is like some of these relationships that you maybe want to try to build." Ben shared he made a point to develop a professional relationship with one of his state's lawmakers, "I live 30 minutes from our state capitol. So, I think that [proximity] has really helped the cause, because a lot of these lawmakers, policymakers, and their staffers, live in my community. So, the relationship has already started." Establishing and maintaining relationships afforded the STEM TLs new and different opportunities, even at the

national level, to advocate for STEM education. Jane recalled, "I feel like my name is more out there at the national level than it is in my own state or district."

With the exception of one utterance making reference to partnering with other state leaders, all utterances collected during the pandemic were assigned to this subcategory of increasing networks. Having shifted to virtual modalities for teaching and working from home, Jane put it explicitly, "Increased time at home during the pandemic has given me the opportunity to further build my network." All other utterances shared in terms of network expansion described how the shift to virtual work benefited their STEM education advocacy. Support from now virtual networks helped connect STEM TLs with resources. Mary shared, "I used [my networks] for guidance and support. We were overwhelmingly provided with resources. My networks helped. It was humbling how we were there for each other." Lisa stated, "I feel I am discovering ways to use the virtual classroom as a powerful way to reach teachers across the country in addition to the area teachers. I think this could really extend the outreach of my STEM training."

Category 3: Movement

The final category of movement had the lowest number of utterances from the transcribed interview data collected, with 79 utterances. However, questionnaire data collected early into the pandemic added 36 more utterances to this category, bringing the total number of utterances to 115, which is the second highest number of utterances among the three categories. These additional utterances increased 45.6%, marking this category with the largest increase among the three overarching categories in the outcome space. In terms of movement, this category describes STEM TLs conceptions of STEM education advocacy involving actions beyond communication. These actions included garnering community stakeholder involvement, carrying out changes to curriculum, and requesting funding for STEM education by crafting letters and memos.

Stakeholder Involvement

As described by STEM TLs, training was a common conceptualization in terms of involving stakeholders for movement in STEM education advocacy. STEM TLs felt it was important to train other teachers how to integrate STEM into their curriculum or advocate for better STEM education policies. Ben said, "I have been teaching workshops to other teachers on how to do hands-on science labs, instead of just reading something from a book." And Lou wishes to train all teachers in education policy, not just TLs such to "get them involved in legislation, and let them know about it. Train them to share their ideas in conferences, so they can build their network outside of their school." Anne's advocacy activities focused on parents in her community, "We had a STEM night and did activities with the parents and their kids and saw how engaged they were." From that experience, Anne described she next wanted to similarly engage pre-service teachers, focusing on training "future teachers how to be an advocate for STEM." Mark's advocacy activities progressed beyond the school because he "wants to take advocacy to another level that goes beyond the classroom. I want to be more active and have districts work with local universities."

Conceptions of STEM education advocacy during the pandemic involving stakeholders included continuing work mainly with teacher groups, but in a virtual setting. Lisa shared, "I have been working with teacher groups…on making their online more interactive and more hands-on." With her teacher colleagues, Lou was able to share STEM activities that can be done at home, "I have given other content area teachers ideas for remote learning that also include STEM (e.g., kite making, hydro dipping, disc golf)." For Beth, it seemed to have been business as usual: "I've also recruited teachers for the upcoming science committee. Unfortunately, our district does not have a STEM committee…[so] I have also worked with our counseling department to set a schedule for next year

to include a Tech Pathways course." Initial or small-scale advocacy experiences at the local level led to increasingly larger scale advocacy activities to serve a larger and/or wider audience of STEM education stakeholders.

Changes to Curriculum

Of all subcategories in the outcome space, the most utterances from questionnaires referred to curriculum changes. When STEM TLs advocated for STEM education, there was a focus on making needed changes to K-12 STEM curriculum. These changes were mostly targeted at the classroom level, as Anne stated, "I incorporated more of what's going on with STEM and into that course." Beth, discussed how it was important to better integrate STEM, especially in math courses, "I was a proponent of revamping that [STEM] course and turning it into a financial algebra course." For Mary, it was elementary engineering, "But literally it is sharing, what is engineering? Can we integrate technology and then here are some activities that we can do? And so, when I was in the classroom, that's pretty much what I focused on." As for Lou, doing STEM education advocacy work during the pandemic afforded her the opportunity to integrate STEM with art, "I have been the voice for STEM and the NGSS with the Innovation Collaborative which seeks to promote STEAM. This has involved helping with their position statement and STEAM integration activities development." Therefore, STEM advocacy meant advocates had to take bold steps in establishing new initiatives at the school and/or district levels. Ben announced that he had single-handedly "created our STEM program." Other utterances were for curriculum change at the state level as they perceived helping states' standards transition to national (the NGSS) standards, was important advocacy work. Paul expressed, "for the past few years specifically, I've had a leadership role in transitioning the district to [my state's] new science standards, which are modeled after the next generation science standards."

The most prominent theme among desired changes to curriculum were due to the abrupt shift to virtual learning and learning from home. For example, Jane replied, "This has caused me to think how to deliver hands-on instruction through a virtual platform." Lisa experienced pushback in delivering PD online, whereas Anne described how her new foray into online advocacy has reaped benefits for an online STEM curriculum, "I am working with my school system (Teaching and Learning Department) in creating online STEM related activities. I am incorporating STEM activities into my own lessons within the online world. I am also continuing to help develop/teach online science in summer school for this coming session. I make sure activities are selected that represent STEM and inquiry processes. I will have developed a better collection of online activities/modeling investigations that can still be used as we re-enter school settings. I will continue to push for more inquiry and STEM activities that integrate cross-disciplinary activities. Online experiences can augment classroom activities and discussions."

Requesting Support

Finally, STEM TLs' conceptions of STEM education advocacy encompassed formally requesting funding or monetary support for STEM programs and curriculum creation and sustainment. This subcategory is distinguished from communication because certain steps were taken to advocate for funding explicitly, such as writing an op-ed or an email to a lawmaker or lobbying them directly, instead of talking with another individual or organizing body. As an example, Ben took the necessary steps to apply for a grant such that he "got a…$10,000 grant to start an after-school STEM program." Mary was recruited as her state's science curriculum coordinator due to her advocacy activities, "They selected me because I wrote grants [and] I went for fellowships." A few STEM TLs described that writing memos and op-eds were important from an advocate standpoint, but doing so was the task that was always set aside. Jane, just like a few other STEM TLs, shared, "I would think

the thing I would need to do that I haven't done and really put off is writing articles and op-eds." Paul felt that he was unsure about what to write about, "Through the course of the year, there were a number of topics that I thought I kind of wanted to maybe blog about or write about. I wasn't ever convinced that it was big enough or hefty enough to write about. And then I definitely never carved out the time to think it through and do it."

Dave mentioned that STA advocacy training initially "helped a lot, you know, like helping me figure out how to write [op-eds]. I felt like the first one or two that I did, they helped a lot" giving him the LPP experience so he could "figure it out and just can do it [on my own]." Little was mentioned in regard to this subcategory from questionnaire data collected during the pandemic as funding priorities shifted. Beth stressed that she had her hands full with other tasks that took priority during the pandemic, "There were so many logistical tasks to complete the last eight weeks so advocacy was not at the forefront." However, one sampled STEM TL mentioned that during the pandemic, moving was needed to ensure that funding for STEM programs would continue. Ben shared that he had been "Fighting to keep as much of our budgets intact as possible. I've been lobbying within my district for funding for STEM, as with COVID causing a drop in [my state's] revenue. Our budget and my program are being slashed."

Discussion

The purpose of this study was to describe STEM TLs' conceptions of STEM advocacy before the onset of COVID-19 and to what extent these conceptions changed during the early months of the pandemic as LPP shifted from largely in-person interactions to solely online. The driving research question for the study was: *How have STEM TLs' conceptions of advocacy and their advocacy activities changed with the onset of COVID-19 interruptions?* To address this research question, we employed a phenomenographical approach, underpinned by the STEMMaTe conceptual framework (Hite & Milbourne, 2018; Hite et al., 2020) of STEM TL in advocacy, with STEM TLs who had participated in an LPP program for STEM education advocacy and have participated in advocacy activities for STEM education. Table 4 correlates our findings to the STEMMaTe conceptual framework. Overall, our study suggests a considerable shift in priorities in STEM TLs' conceptualizations of and activities in advocacy related to the onset educational interruptions caused by the COVID-19 pandemic. Whereas communication was a priority of advocacy before the onset of the pandemic, movement was a dominating theme at the start of the pandemic, affirming prior research that teacher advocates are "often spurred to action after experiencing a crisis" (Bond, 2019, p. 86). We discuss each of the three themes in the outcome space (i.e., identity, communication, and movement) in detail by first presenting implications of STEM TLs' conceptions of STEM education advocacy prior to the pandemic, then provide a discussion regarding the implications of a conceptual shift during the pandemic, framing these discussions within the STEMMaTe conceptual framework. Finally, we conclude with a discussion on limitations and areas for future research.

Table 4

STEM TLs' Conceptions of Advocacy as it Relates to the STEMMaTe Framework

Category	Level of Participation
1. Identity	Scholastic Effectiveness Institutional Knowledge and Memory Adaptability/Flexibility
2. Communication	Emergent Leadership
3. Movement	Strategic Leadership

Reaffirming STEM and Advocate Identity

In the STEMMaTe model, the levels of *scholastic effectiveness*, *institutional knowledge and memory*, and *adaptability and flexibility* are identity-forming areas (Hite & Milbourne, 2018). It was vital for STEM TLs to secure opportunities for LPP (*scholastic effectiveness*) as they navigated changes (*institutional knowledge and memory*) in STEM advocate identity (category 1). This undertaking was evidenced by utterances in the subcategories of self-perceptions and continued PD (*institutional knowledge and memory*). Prior to the pandemic, STEM TLs had sourced their STEM TL advocate identities from their expertise in grade-level STEM content and pedagogy with a heightened interest in publicly promoting STEM. Their desire to provide a more interdisciplinary STEM experience for their students coupled with their understanding of the overall significance of STEM supports findings from literature on STEM teacher identity being the result of the intersection between professional traits and personal beliefs (El Nagdi et al., 2018). This grounding of their STEM teacher identity provides STEM TLs the cognitive foundation to apply their advocacy by assessing their foundational professional expertise, as evidenced in several utterances (Table 3). Furthermore, STEM TLs who had an interest in advocating for STEM education sought additional opportunities for LPP in advocacy, so they could become adaptable and flexible in refining their advocate identity (Servage, 2009).

From LPP sought during the pandemic, STEM TLs learned more about how they could advocate for STEM education effectively and creatively in an online environment, given that most U.S. school districts shifted to online learning. These amplifying experiences suggest a building of advocacy-based self-efficacy, such that positive advocacy experiences led to persistence in advocacy regardless of context (Velasco, 2020) and despite pandemic-facilitated challenges. Recognizing their own obstacles and challenges (professional and/or personal) during the pandemic caused respondents to self-assess how they would continue to advocate for STEM education in an online environment. A tenet of identity formation is that it is dynamic, requiring one to continually evaluate and assess their profession within a given situation (El Nagdi et al., 2018). Given the stress upon teachers due to the pandemic (MacIntyre et al., 2020), it was understandable that some STEM TLs did not resume or adapt their advocacy activities as quickly as others when instruction shifted online. Even so, they did indicate interest (through plans or ideas for advocacy), showcasing their resiliency in adapting and being flexible in the new advocacy landscape.

Communication for STEM Awareness and Network Connections

Before the pandemic, STEM TLs prioritized communication with stakeholders to bring STEM awareness and its importance in education as well as to build and strengthen network connections. This sense of prioritization (*emergent leadership*) is typified by policy messaging and stakeholder engagement, taking on the responsibility to be the voice for STEM students and teachers impacted by these policies. Other studies have supported this notion of teacher advocates being the voice for the voiceless (Burke et al., 2013; Dubetz & de Jong, 2011; Pennington, 2013). To achieve this, STEM TLs conceptualized STEM education advocacy as engaging in discussion with relevant STEM education stakeholders, such as fellow teachers, administrators, district leaders, and parents. Involving education personnel and stakeholders in conversation, conceptions of STEM education become more enlightened and aligned with the needs of the students and the community (Harris & Jones, 2019). As emergent leaders, many STEM TLs emphasized the importance of cultivating positive professional relationships with STEM organizations and policymakers, whether or not they share similar views (Bond, 2019). Diplomatic conversations allow STEM TLs to leverage their experiences and expertise to effectively advocate for STEM education in schools and districts.

An interesting finding from the study was that while communication was conceptualized as a priority in terms of STEM education advocacy, STEM TLs shared little in regard to communication

with stakeholders during the pandemic. Still, many expressed the importance of accurate messaging, honing in on the importance of trusted media sources (Donovan, 2020). STEM TLs nonetheless had direct communication with their current networks to discuss strategies on virtual STEM instruction, especially for teachers. In addition to emails and video conferences, social media (specifically Twitter) emerged as an advocacy tactic to communicate information during the rapid transition to virtual learning during the pandemic (Cruickshank & Carley, 2020). STEM TLs described that the hashtag feature in Twitter was ideal to obtain information and attention. Given the ubiquity of Twitter, STEM TLs used tweets to share STEM resources publicly. In essence, while there wasn't as much direct communication between STEM TLs and stakeholders during the pandemic as before, communication technologies and social media afforded a communication space to voice messages indirectly.

Increased Movement in the Time of Crisis

STEM TLs conceptualized STEM education advocacy in terms of movement (*strategic leadership*), in which STEM TLs engage in the most robust advocacy activities and at scale. STEM education advocacy involved training other teachers, both STEM and non-STEM. To achieve their conceptualization, STEM TLs designed and led PD opportunities (LPP) for other teachers by modeling ways to integrate STEM activities into the classroom, providing strategies in closing the equity gap, or training other STEM teachers in advocacy. Fittingly, training other teachers in advocacy work is a signature activity of teacher advocates (Bradley-Levine, 2018; Pennington, 2013; Weiner & Lamb, 2020).

One last and significant finding is how movement was conceptualized by STEM TLs as the greatest priority in advocating for STEM education during the pandemic. A majority of these utterances were specifically in reference to needed changes in STEM curriculum. This finding was especially significant as the pandemic brought about the abrupt shift to virtual learning—a shift for which most educators were not prepared (MacIntyre et al., 2020). While STEM TLs spoke to the notion that they too were unprepared for this shift, they rallied quickly to develop strategies and materials to help students, teachers, and administrators transition to virtual learning. Because of the swiftness of the shift, many of the resources that STEM TLs provided were pulled from various resources from their teaching experiences and networks with other STEM TLs. Yet, because of the limited resources in online STEM instructional delivery, some STEM TLs took the initiative to create and demonstrate how STEM can be delivered in an online setting. Some STEM TLs were moved to write op-eds and letters to policymakers, requesting financial support to make virtual learning possible for all students. These STEM TLs took it upon themselves to advocate on behalf of their schools and/or districts for virtual learning to take place, namely computer devices and widespread internet access. This movement affirms reports on the effectiveness of crafting messages to policymakers to magnify the issue and relay the seriousness (Bond, 2019; Bradley-Levine, 2018). It is indeed possible for STEM TLs to engage in policy by leveraging emails and other tools to craft messages to policymakers to sustain the quality of STEM education throughout the pandemic.

Conclusion

Data from this study revealed significant findings in STEM TLs' conceptualizations of STEM education advocacy related to interruptions in their advocacy activities due to the COVID-19 pandemic. There was a considerable shift in STEM TLs' conceptualizations of advocacy related to a social shift from in-person to online LPP supporting activities caused by the COVID-19 pandemic. Communication was a priority of advocacy activities before the onset of COVID-19, whereas movement emerged as a dominating theme during the pandemic, primarily due to the transition to and domination of virtual social interactions. This shift from voice- to action-oriented advocacy

implies a need for STEM TL preparedness in a time of crisis in terms of providing instructional resources and support for students and fellow teachers. From these findings, we recommend that STEM TLs be adequately prepared for engaging with digital technology as a new domain of knowledge, skills and dispositions and provided LPP with experts for adaptability and flexibility per the STEMMaTe model. With targeted and robust LPP, these STEM teacher leaders may engage in advocacy for and activities in assisting STEM teachers for readiness in online instruction and social interactions. We suggest that STEM TLs be provided advocacy-based PD that helps strengthen skills in finding and allocating resources for teachers and students. Although the pandemic is waning, we are confident that LPP experiences and social interaction will be permanently changed (i.e., less reliance on in-person interaction in favor of hybrid experiences or remain online). For example, some practitioner conferences are currently considering hybrid or online-only activities, for the practicality that online PD delivery offers after the pandemic ends. Given that online interaction will likely only scale up, it is important to understand how STEM TLs adapted to and overcame these challenges. Through this exploration of STEM TLs conceptions of STEM education advocacy before and during the pandemic, we have learned that immediate movement is necessary to sustain equitable STEM education for all students in a time of crisis. Vitally important were keeping communication lines open, as well as continual self-assessment of one's STEM advocate identity. STEM TLs are vital in developing online STEM curriculum learning models (Aliyyah et al., 2020), supporting other teachers through STEM materials and/or demonstrations (MacIntyre et al., 2020), and crafting messages to policymakers that communicate school/district needs (Bond, 2019).

Limitations and Recommendations for Future Research

Limitations relate to the change in data collection modality (interviews prior to and questionnaires during the pandemic). Because of the numerous challenges that the participants were juggling during the pandemic, we took steps to ensure that questionnaire data was aligned to the other data set and was a more efficient, and still robust, means to capture participants' thoughts. Second, we purposively selected STEM TLs for this study who received formal training in STEM teacher advocacy and expert advice on how to carry out advocacy practices. Hence, the experiences shared here may not be reflective of all STEM TLs, especially those who have not had formal advocacy training experiences, or even for those who have had similar training in policy-advocacy programs. Thus, further studies are warranted in examining these groups of STEM TLs and their conceptions of STEM education advocacy. Finally, the second data time point was in April 2020, at the beginning of the COVID-19 pandemic; a third data collection is warranted to explore conceptions about how continued pandemic impacts have influenced conceptions of and activities in STEM education advocacy.

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