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Implementation of Immersive Classroom Simulation Activities in a Mathematics Methods Course and a Life and Environmental Science Course

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Abstract

This study investigated the influence of immersive classroom simulation activities on the development of elementary pre-service teachers in two separate mathematics and science education courses that simultaneously focus on pedagogy and content. Participants submitted written personal reflections about their teaching experiences using the immersive classroom simulation activities. These reflections were analyzed for common emergent themes within and across courses. The participants discussed the benefits of the immersive classroom simulation activities in their written personal reflections. They viewed the experience as helpful in developing their skills as a practicing teacher in mathematics and science. Specifically, participants identified three sub-themes including: (a) the immersive classroom simulation activities as being beneficial by providing more authentic real-life teaching experiences than those experienced during peer-group teaching activities; (b) the importance of holding complete and appropriate understandings of content when teaching mathematics and science; and (c) the role of deep content knowledge in the process of developing high quality questions for students. This study has shown immersive classroom simulation activities to be a viable alternative for teacher education programs to engage elementary pre-service teachers in developing skills regarding classroom mathematics and science discourse.

Keywords: *Immersive classroom simulation, Math, Life and Environmental Science*

INTRODUCTION

Ambitious teaching is necessary to ensure learning for all students and pedagogies of elementary teacher education have been re-conceptualized to engage elementary pre-service teachers (EPSTs) in ambitious teaching early in their preparation (Lampert et al., 2013). One vital aspect of ambitious teaching is eliciting and responding to student thinking. However, the majority of classroom interactions reflect a teacher-centered approach with little opportunity for students to share their thinking (Michaels & O'Connor, 2015). The U.S. educational communities have achieved a national consensus that instructional subject areas for K-12 grade levels should promote academic talk as a critical component. The National Research Council, along with the major teacher organizations, report the need to emphasize active discourse with students when discussing investigations to involve thinking about using evidence to support their claims, conjectures, predictions, and explanations (NCTM, NSTA, NRC reports). To prepare teachers to facilitate productive discussion, strategies for eliciting and responding to students' ideas are supported by research (Michaels & O'Connor, 2015; Kovalaninen & Kumpulainen, 2005), emphasized in standards (NGSS, 2013; CCSSO, 2010; NCTM, 2000), and centralized in methods and field experiences (Esmonde, 2009).

Educational research has focused on the tools and structures necessary to successfully engage elementary preservice teachers (EPSTs) in the intricacies of eliciting and responding to student thinking (Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010; Thompson, Windschitl, & Braaten, 2013; Kazemi, Franke, & Lampert, 2009). Within this work, pedagogies of teacher education have been examined (Lampert & Graziani, 2009; Ghousseni & Herbst, 2016) and structures such as Cycles of Enactment and Investigation (Lampert et al., 2013) have been designed to engage EPSTs in opportunities to deliberately practice specific teaching episodes and enact those episodes in classroom settings. These rehearsals allow for concentrated feedback on teaching to build the skills and conceptual understanding to truly develop ambitious teaching. Just as a chess player will repeatedly practice a series of moves in order to become an expert, novice teachers can benefit from practicing or rehearsing certain teaching episodes to develop their skills and conceptualization of pedagogical elements. However, the human resources needed to employ an iterative, practice-based process within teacher preparation are often unavailable at institutions with large programs.

One innovative technology to facilitate such iterative practice is virtual simulation software, such as that available from Mursion® (developed as TLE TeachLivE™), that allows for the simulation of various classroom scenarios and provides a platform for EPSTs to practice interaction with students. These virtual environments provide immersive, interactive learning through practice-based teacher development (Dieker, et al., 2014). During each immersive classroom simulation activity (ICSA), pre-service teachers can engage with a classroom of five student avatars on a large computer screen. A simulation specialist operates the avatars and uses a simulation scenario to guide the interactions. In this article, we describe the utilization of ICSAs within a mathematics methods course and a science course to develop EPSTs' facilitation of effective classroom discussions. In addition to a delineation of the implementation, we also examined EPSTs' perceptions of the rehearsals to better understand the impact.

RELATED POLICY AND RESEARCH

Mathematics and Science Standards

Ambitious teaching and use of appropriate pedagogy are necessary to ensure all students are making progress towards appropriate learning benchmarks and standards. Recently adopted standards for both math and science education serve as a foundation for instruction and are used to inform how educators and students interact with each other while discussing math and science topics. These standards are aimed at refining how students learn and encourage the fostering of a deeper understanding of underlying principles and the relationship between topics. The Next Generation of Science Standards (Lead States, 2013) emphasizes the need for students to construct their own explanations of scientific phenomena that incorporate current understandings of science. This critical component of discourse should be incorporated into every lesson, allowing students the opportunity to examine essential academic content by discussing alternative ideas and clarifying understanding. To accomplish this task, students need explicit experiences in discourse by creating their own explanations with evidence from investigations that emulate the actual practices of scientists (Sandoval and Morrison, 2003). These classroom experiences need to be structured by experienced classroom teachers skilled in facilitating appropriate discourse opportunities.

The Common Core Mathematics Standards (CCMS) emphasize the context of mathematical concepts, for example, in kindergarten students are expected not only to be able to count up to 100, but they should also understand that each successive number represents the addition of one to the previous number. At each level, the students must engage in discourse surrounding topics in order to engage with the mathematics using the appropriate terms used in the field and to demonstrate their understanding of the concepts involved in the use of mathematical communication. The Standards for Mathematical Practice outline the ways in which students should do mathematics, including constructing arguments and critiquing the reasoning of others (CCSSO, 2010). The content and practice standards require that students express understanding through explanations and justifications and not merely regurgitation of procedures.

Importance of Discourse in Mathematics and Science Instruction

Discourse is at the heart of expressing understanding of mathematics and science.. Mathematics educators have described learning mathematics as a sociocultural process that allows learners to become participants in discourse (Esmonde, 2009). Discourse in mathematics learning has been divided into several categories including conjecturing, supporting claims with evidence, representing mathematical concepts, and using specialized language and symbols accurately (Moschkovich, 2002). In order to present any meaningful conclusion from the solution to a problem or the analysis of data, one must be able to engage with others in a discussion using the appropriate jargon and must be able to communicate both orally and in written form regarding their understanding of the problem. The use of discourse is particularly important in group work situations in order for students to communicate with other students about their work and to ensure all students are building a better understanding. Discourse also helps to identify and correct student misconceptions. A wrong answer to a math problem illustrates misunderstanding, but the use of discourse helps to identify the thinking behind the wrong answer and gives the instructor the opportunity to remediate (Sfard, 2001).

Learning science also requires students to be engaged with others in a social context while constructing meaning and building an understanding of scientific concepts (Duit & Treagust, 1998). In an attempt to advance scientific reasoning and understanding in science classrooms, science education researchers have been investigating how classroom discourse occurs among teachers and students and more importantly, the interactions between students and their peers (Candela, 2005; Chin, 2007; Cornelius & Herrenkohl, 2004; Erdogan & Campbell, 2008; Moje et al., 2001; Roth & Lucas, 1997; Scott et al., 2006; van Zee et al., 2001). A majority of classrooms do not provide students with opportunities for negotiating their own ideas or time to talk with others in order to incorporate new and old ideas into their own conceptual framework (Alexander, 2008; Lyle, 2008). The process of leading discourse requires pedagogical skills and strategies that science teachers need for engaging students in the process of knowledge building (Duschl, 2008). Kovalaninen and Kumpulainen (2005) observed and described elementary classroom discourse as teacher-initiated talks that were information-driven with the teacher delivering information with limited interactions between students discussing evidence about investigations. This common method of classroom discourse typically results in students offering brief comments, which requires limited student reasoning or critical explanations.

Scientific and mathematics knowledge is constructed through engaging in a social process through negotiation and consensus building (Candela, 2005; Michaels & O'Connor, 2015). Understanding how to facilitate these types of discussions with students is a skill that is nationally recognized as essential (Mercer, 2008) and complex. The complexity of leading discourse for teachers involves two important aspects understanding the conceptualization of classroom discourse and negotiating the sequencing of the talk while also managing the engagement of students (Lehesvouri, Viiri, & Rasku-Puttonen, 2011). To help elementary pre-service teachers (EPSTs) learn about the complexity of discourse and build competence facilitating it, they need explicit experiences with planning and implementing effective classroom discourse in both math and science.

Interactive Classroom Simulation Activities-Mursion

This article reports on initial findings from a three-year, National Science Foundation (NSF) funded effort entitled Project INTERSECT. The purpose of Project INTERSECT is to determine whether integration of ICSAs into mathematics and science education pre-service teacher candidate curriculum improves teacher candidate performance with respect to both teacher and student discourse. Project INTERSECT is engaged in: (a) developing a curricular model for math and science pre-service teacher education that expands opportunities to master teacher discourse, (b) measuring the effects of curriculum change and increased discourse engagement on pre-service teachers' use of discourse including anxiety and confidence in the classroom, and (c) disseminating the study results. Project INTERSECT seeks to advance knowledge regarding design for learning, particularly in math and science undergraduate teacher preparation by contributing an innovative, replicable research design that expands the metaphor of the teacher's toolkit to include a series of discourse tools or Teacher Moves (Chapin, O'Connor, & Anderson, 2013) that pre-service teachers can analyze, practice, reflect upon, and improve upon to develop confidence and competence in both using and facilitating effective STEM- oriented discourse.

For decades, teacher educators have recognized the disparity between pre-service teachers' knowledge of content and their ability to apply essential instructional and management skills (Pretti-Fontczak et al., 2005). In order to overcome this disparity, some teacher preparation programs have attempted to restructure coursework with alternative field experiences (Allsopp et al., 2006; Brownellet al., 2005). Educational researchers have documented the impact of field experiences on novice teachers' beliefs about teaching and learning, but there is a limited amount of research on how field experiences affect their instructional practices (Clift & Brady, 2005; Maheady et al., 2014), due to the inability of educators to align conceptual understandings of practice with the range of complexity of actual classrooms (Clift & Brady, 2005). This complexity of classrooms requires pre-service teachers to try and figure out what to concentrate on in their lessons, especially when they are not experienced with numerous instructional strategies and classroom management skills (Girod & Girod, 2006).

Teacher preparation programs have recently begun investigating virtual simulations as a way to represent the complexities of actual classrooms for practicing teaching (Dieker et al., 2008; Dieker, Rodriquez, Lignugaris/Kraft, Hynes, & Hughes, 2014). The theory of situated learning (J.S. Brown et al., 1989) supports that training in a virtual environment should transfer to practice in actual classroom settings. The Murison laboratory can be used as a sophisticated classroom simulation with full immersion teaching experiences representing countless situations and complexities that exist in a real classroom (Dieker et al., 2008; Dieker et al., 2014). Mursion® is an immersive classroom learning experience that provides education candidates with a managed space in which they can practice teaching skills and receive direct feedback from virtual students, peers, and their professor. The concept and technology was developed at the University of Central Florida (UCF) as TLE TeachLive™ but is now commercially marketed as Mursion®. During the interactive classroom simulation, participants interrelate with a classroom of five student avatars on a large computer screen. The avatars are operated by a specifically trained actor, or simulation specialist, who portrays the avatars as typical and/or atypical students within the classroom as determined by the specific simulation scenario. The power of Mursion is having pre-service teachers practice their instructional skills with life-size avatars that engage them with immediate verbal responses (Dieker et al., 2014; Elford, 2013). The benefit of Mursion as an effective teaching platform for educational instructors is the ability to control the complexity of the teaching environment for pre-service teachers to practice management skills and more complex instructional strategies.

CONTEXT OF ICSA IMPLEMENTATION

This study investigated the influence of ICSAs on the development of elementary preservice teachers (EPSTs) in two separate mathematics and science education courses that simultaneously focus on pedagogy and content. Each course will be described to provide context for the implementation of the of ICSAs.

Intermediate Elementary Mathematics Methods Course

Elementary education majors are required to take a course series of two mathematics methods courses; the first focusing on primary grades (K-2) and the second concentrating on intermediate grades (3-6). Each course includes instruction on content and methods for teaching in the specified grade bands and a practicum experience parallels the courses. In the intermediate methods course, the content focus is rational numbers and the pedagogical focus is the implementation of effective discourse. One of the key instructional activities designed to help ESPTs develop in both of these areas is the design and implementation of Number Talks (Chapin, O'Connor & Anderson, 2013).

Number Talk Assignment. The Number Talk Assignment involved each EPST planning and implementing one number talk in which they lead the entire class of their peers. As a part of the planning process, each EPST utilized a graphic organizer to record anticipated strategies and misconceptions, possible questions to guide discussion, and a closure to their number talk. They then lead the class in their number talk on one assigned day throughout the semester which was recorded by the EPST on their personal device. The content of the number talk varied based on the topic of the week. During the number talk, the instructor utilized elements of coaching, by interacting as a student, posing questions, and taking notes. Notes focused on mathematical accuracy, talk moves, and student engagement. Talk moves are pedagogical tools used by teachers to help navigate discourse among students (Michaels & O'Connor, 2015). Notes were used in a debriefing session directly after the number talk in which key talk moves and strategies were highlighted by the instructor.

The complete Number Talk Analysis involves components that deconstruct the mathematics and pedagogy. To account for the mathematics, EPSTs selected two peer strategies and described student thinking, pinpointed mathematical properties underlying the strategy, and created examples and non-examples of effective use of the strategy. To reflect on pedagogy, EPSTs responded to the prompt, "How did the use of Talk Moves influence your number talk?" and "Discuss the experience of teaching a number talk. What did you learn about teaching mathematics?" EPSTs used their recorded number talk to assist in this analysis.

Life and Environmental Science Course

At our university, all elementary education majors are required to choose an eighteen-hour concentration in an academic discipline as part of their undergraduate program. There is a subset of elementary majors that have chosen to concentrate in science. The Elementary Science Concentration (ESC) includes courses that focus on specific science content and methods for teaching K-6 science. Science education professors teach five of the courses within the College of Education. The ESC courses include Life and Environmental Science, Earth Science, Physical Science, Elementary Science Methods, and Informal Science Methods.

For this study, we will discuss the implementation of an assignment called Science Talks within the Life and Environmental Science course. The Life and Environmental Science course is divided into four modules that align with the disciplinary core ideas of life science within the Next Generation of Science Standards (Lead States, 2013). The four life science disciplinary core ideas are: 1) From Molecules to Organisms: Structure and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, and 4) Biological Evolution: Unity and Diversity. During the semester, each EPST is required to plan and implement a science talk that focuses on the content within each of the life science disciplinary core ideas.

Science Talk Assignment. Each semester, EPSTs complete an assignment called Science Talks within each of the content courses of the ESC. The Science Talk assignment was initially designed to provide experiences for EPSTs to rehearse their skills at leading discourse in science. In each ESC content course, each EPST plans, conducts, and reflects on one Science Talk. In addition, EPSTs also participated in three talks led by their peers. To prepare their science talk plan, EPSTs use a Page Keeley assessment probe (Keeley et al., 2005). Selected probes are aligned with each disciplinary core idea of the content courses. The probes include a scenario focused on the disciplinary core idea, related student misconceptions, and preconceptions. EPSTs use the "Teacher Notes" provided to learn the background information and suggestions for implementation of the probe.

Each EPST completes a plan for conducting his/her/their Science Talk, which includes research on the content, a discussion map of questions to ask, and designated times to implement talk moves. This initial Science Talk assignment was conducted only with a peer group during one class meeting which was videotaped for the purpose of reflection.

METHODS

Participants

Elementary Mathematics Methods Participants. Thirty-eight EPSTs completed the number talk assignment within the Intermediate Mathematics Methods Course. The undergraduates were in the junior year of coursework and ranged in age from 20-22 years except for one non-traditional student who was 36 years old. All participants were female (thirty-six Caucasian and two Black).

Elementary Science Concentrators. Forty-two EPSTs were in enrolled in two sections of the Life and Environmental Science Course and participated in the science talk assignment. All participants were undergraduate students ranging in age from 18-22. Participates ranged in college status from two freshmen, twenty-two sophomores, twelve juniors, and six seniors. There were forty-two females (forty Caucasian and two Latino).

Implementation of ICSA

Number Talks. The initial Number Talk assignment was redesigned to include the ICSA. The assignment was expanded to include two rehearsals in the ICSA with a third implementation in an elementary classroom. The mathematical content was connected to multi-digit multiplication problems to allow for a specific focus within an iterative cycle. For each of the three implementations, ESPTs planned their assigned problem in groups. For example, for the first implementations, the number strand was 12x6, 12x8, 12x15, or 12x24. As a part of the planning process, EPSTs had to utilize a graphic organizer to record anticipated strategies and misconceptions, possible questions to guide discussion, and a closure to their number talk. Then ESPTs individually led their number talk within the ICSA with three to four peers, building in complexity (i.e., 12x6 first and then 12x8). That is, ESPTs led their number talk and observed others within their group lead their assigned problem.

During the ICSA, the instructor took notes on talk moves, mathematical accuracy in explanations, student engagement, and then also stepped in at key points. After each ICSA, the instructor facilitated a debrief based on notes. In addition to the debrief session, the instructor viewed the recorded session via GoReact (video software) and provided timestamped comments that EPSTs reviewed as a part of their analysis of their teaching. The completed Number Talk Analysis involves components that deconstructed the mathematics and pedagogy. To account for the mathematics, EPSTs selected two student strategies and described student thinking, pinpointed mathematical properties underlying the strategy, and created examples and non-examples of effective use of the strategy. To deconstruct the pedagogy, EPSTs utilized the GoReact interface to indicate their use of the talk moves (Chapin, O'Connor & Anderson, 2013) and the impact on the discussion. If they did not use a certain talk move, they indicated where they could have used the move and how it would have impacted the session. Finally, they responded to the prompt "Discuss the experience of teaching a number talk. What did you learn about teaching mathematics?"

Each EPST completed this planning, implementation, reflection process for two ICSAs before completing the process with a number talk with elementary students in a 3-5 grade classroom as a part of their parallel practicum experience.

Science Talks. The initial Science Talk assignment described above was redesigned to include ICSA experience. The ICSA experience was added to provide EPSTs with additional rehearsal opportunities to discuss life science topics with avatar students in a simulated environment. EPSTs used the Science Talk plan for implementation within the ICSA before implementing with a peer group.

On an assigned day at the end of each life science disciplinary core idea module, six EPSTs conducted their Science Talk within the ICSA. Each EPST implemented their 10-minute Science Talk with the avatar students and five of their peers. The Science Talk discussions centered around life science disciplinary core ideas such as cell growth, microorganisms found in pond water, life cycles of various organisms, flow of energy within a food chain, impacts on an ecosystem, changes in habitats, genetics, and natural selection.

Data Collection

This study focuses on the first ICSA implementation of both Number and Science Talks. Two types of data were collected for analysis: notes from debriefing session that occur after each talk and personal reflections written by ESPTs about their ICSA experiences.

Debrief Sessions. During each Number and Science talk, instructors and EPSTs took notes for the purpose of providing feedback for the debrief session immediately following the talk. The debriefing session provided immediate feedback which is extremely valuable in development of ambitious teaching practices (Straub, Dieker, Hynes, & Hughes, 2016). The debriefing session notes for mathematics and science were read and coded by both mathematics and science instructors. Common themes are reported below.

Personal Reflections. The complete Number Talk Analysis involves components that deconstruct the mathematics and pedagogy. To account for the mathematics, EPSTs selected two peer strategies and described student thinking, pinpointed mathematical properties underlying the strategy, and created examples and non-examples of effective use of the strategy. To reflect on pedagogy, they responded to the prompt, "How did the use of Talk Moves influence your number talk?" and "Discuss the experience of teaching a number talk. What did you learn about teaching mathematics?" EPSTs used their recorded number talk to assist in this analysis. Twenty personal reflections were analyzed from the Intermediate Mathematics Methods Course.

After the implementation of each Science Talk, EPSTs completed a personal reflection. EPSTs were asked the following questions about their Mursion experience: 1) Did you feel the Mursion experience was helpful? Why or why not? And 2) What changes did you make to your original talk based on your experiences with Mursion and why? EPSTs were able to use a video recording of their Mursion experience for reflection. Twenty personal reflections were analyzed from the Life and Environmental Science Course.

Analysis of Debriefing Sessions of Number Talks and Science Talks

The themes that emerged from the debriefing sessions centered on issues including classroom management, timing of activities and the flow of the talk, content knowledge, and the importance of teacher disposition.

Classroom Management. One of the advantages of using the Mursion lab is to have pre-service teachers practice their classroom management skills in a managed environment (Dieker et al., 2008; Dieker et al., 2014). The ICSA allows instructors to select the level of classroom management between low, medium, and high. The lowest level represents a class of students who are well-behaved and easier to work with and the highest level having students exhibiting negative behaviors that create a more challenging environment for pre-service teachers to learn to manage. For the purpose of this initial assignment, the lowest level of classroom management was selected for both Number and Science Talks since the focus on the lesson was for EPSTs to practice their discourse skills in math and science and not classroom management.

Even though classroom management was not the focus on our assignment, it was discussed as an important theme in our debriefing sessions. The managing of students' behaviors was discussed by a majority of EPSTs as important for learning how to lead discourse. For example, EPSTs were unsure of what to do when the avatar students played on their cell phones or fell asleep during discussions. EPSTs were unsure of how to approach correcting such behaviors while continuing the discussion. Some EPSTs were very nervous, which lead them to concentrate on the talk and not on the behaviors that were occurring. During the debrief sessions, the instructors discussed ways to correct such behaviors in a positive manner to reduce conflict and disruptions.

Timing and Flow of Talk. Another theme discussed during the debrief sessions was the importance of timing and the flow of talk. EPSTs discussed how difficult it was to know how much time questions or activities would take. The issue of managing a classroom activity, especially discourse among students, is a common and complex problem for novice teachers (Weinstein et al., 2004). EPSTs commented that it was beneficial to observe how colleagues dealt with time issues while implementing their own talks.

EPSTs discussed how the flow of the talk was promoted when talk moves were implemented appropriately. For example, when an EPST asked students to elaborate or asked students to restate another students' response, the discussion continued. EPSTs also noticed that the flow of the talk was disrupted when EPSTs responded to students' comments using responses such as, "good answer," "good job," or "do you understand it now?" Although, these responses are commonly used by teachers in regard to student comments. EPSTs observed that when they used these responses, the discussion paused or, in some cases, students stopped talking about the topic because students felt the answer to the question had been expressed, therefore there was no need to continue discussing. Also, EPSTs had difficulties elaborating or providing a variety of examples to students after students' responses. This inability to elaborate on students' responses was noticed by EPSTs. They commented that their limited experiences in discussing the topics, as well as their knowledge of the content, was a barrier in their ability to think of ways to elaborate on students' responses. Teachers' knowledge of content was discussed as vital for allowing the flow of talk to continue uninterrupted.

Knowledge of Content. The knowledge of content was discussed as a key component to prompting discussion. For the number talks, the implicit number properties that were used in solution strategies were explicitly discussed. Also, any issues in the representations of student strategies were also noted. For, example if an EPST wrote 12+12=24+12=36 on the board, the inequality of the number string was discussed to promote accurate representation of the number expression. For the science talks, EPSTs were unsure how to address students' questions posed about particular science concepts when they themselves did not know the answer. As an example, some EPSTs would response to students by saying "I'm not sure if that's right or not" or "It's very confusing," when pressed about topics such as genetics, natural selection, or flow of energy in a food chain. These instances of confusion for EPSTs during their talks were "eye opening" for them regarding the importance of conceptual knowledge.

Teacher Disposition. The last theme discussed in the debriefing sessions was the importance of a teacher's disposition. Several EPSTs were complimented on their "teacher voice" by their peers, which was described as having a voice that students felt comfortable with and, in turn, were more engaged in the discussion. Another positive disposition displayed by EPSTs was described as having confidence in their teaching. EPSTs that had more experiences teaching were extremely more confident in their ability to teach and lead a group of students. EPSTs that lacked experiences in teaching were nervous, scared, and at times had to stop their discussions to gain their composure, determine what to do next, or look to their instructors for a cue. For EPSTs with less experience, they commented on how the ICSA experience allowed them to see different styles of teaching, which they felt was helpful in shaping their own disposition.

Analysis of Personal Reflections

Thirty-eight EPSTs in the mathematics methods course and forty-two EPSTs in the life and environmental science course submitted written personal reflections about their teaching experiences in the ICSA. Reflections were blinded and twenty reflections from both courses, equaling a total of forty, were randomly selected and analyzed.

Reflections were initially analyzed for common themes within the individual courses of math and science. The initial coding of real-life benefits, importance of content knowledge, and appreciation of good questions and questioning skills were identified within the individual courses. The second round of coding consisted of combining the reflections from both courses to clarify the themes as being consistent from both groups of EPSTs.

DISCUSSION OF STUDENT PERSPECTIVES

Math and Science EPSTs discussed the benefits of the ICSA experience in their written personal reflections. They viewed the ICSA experience as helpful in developing their skills as a practicing teacher in math and science. When discussing the beneficial impacts of the ICSA experience, three sub-themes emerged from both the math and science EPSTs reflections. Therefore, we have combined their reflection results in our discussion. The first theme EPSTs discussed as being beneficial was the real-life experience that ICSA offered them as practicing teachers. EPSTs noted that the ICSA experience was more like "real life" teaching versus the teaching experience with a peer group. The real-life experience of ICSA using avatar students lead EPSTs to realize the importance of knowing your content when teaching math and science. EPSTs also recognized that knowledge of content helped with developing better questions to ask students during discussions, as well as understanding the timing of those questions. These three sub-themes are discussed below.

Real-life Experiences. Thirty-six out of forty EPSTs' reflections discussed how the ICSA experience was like being in a "real-life" classroom working with real students. The EPSTs were surprised at how real the ICSA experience was to them as teachers. This is evidenced by one EPST's statement, "I do not think that there is a better way to prepare someone for something like this because of how realistic it actually is" (EPST 5). A majority of EPSTs stated that the experience made them nervous, as shown by another EPST's statement that "I was very nervous going into it, but after my first talk I'm more confident in my ability to lead a number talk in my practicum classroom" (EPST 3). This same sentiment about being nervous and anxious about teaching is often revealed by EPSTs when preparing to go into local elementary schools. The reality of the ICSA experience was characterized through the personalities of the avatar students as discussed by the following EPST:

> "So, I really do feel that Mursion was extremely helpful in demonstrating what types of interactions you can have with students based on their personalities. For example, Jayla was a very outspoken student, which definitely made her answers a little more comical and so if differed from the other students and that really helps you see that each student is very different which in return makes their answers very different from their peers' answers." (EPST 2)

One disadvantage of the ICSA environment mentioned by twenty of the math and science EPSTs involved the inability to use hands-on materials within the simulation. The inability to use materials or manipulatives with the avatar students was one aspect that EPSTs mentioned in their reflections as being difficult when adjusting their plans. "I knew that in Mursion I could not have something like a container of marbles for the avatar students to use to show the amount of energy in a food chain so I just drew the name of the organism on the whiteboard and wrote the amount of energy for each one." The use of hands-on materials are an essential part of effective elementary mathematics and science instruction (Muschla & Muschla-Berry, 2015; NRC, 2008). The use of hands-on instruction can be the focus of instruction for a majority of elementary classrooms while at times eliminating the minds-on part of the instruction. Facilitating the discourse of a lesson is part of the minds-on portion of a lesson. Before, during, and after the hands-on instruction, the discussion of content should be implemented, addressing the investigations made with the materials and manipulatives. For EPSTs, the elimination of the hands-on portion of a lesson and turning the focus of the teaching practice to discourse was seen as difficult.

Knowledge of Content. Across content areas, thirty-four EPSTs shared how their experiences provided an awareness of their weaknesses in content knowledge. The majority of these experiences involved student questions that the EPSTs were not cognizant of how to answer or student solution strategies for which they were not familiar. The experience with student avatars guided them to analyze the content from a child's perspective and anticipate questions from the mind of a child. One ESPT shared, "The students provided answers to my questions that I did not think about as well as when answered by my classmates. It helps us think on our feet and understand how a child might look at this content through their eyes and not just how we see it" (EPST 7). ESPTs' reflections captured how their Mursion experience also motivated them to research and revisit the topics within their talks. One reflection stated, "When I started doing it, I thought I knew more than I actually did. They asked a question and I couldn't answer it. I went back and did some more research on my topic" (EPST 10). Another shared, "For my next talk, I need to…become familiar with all the possible strategies and the proper terms for those strategies that can be used to solve the problem" (ESPT 17). Their desire to know their content is driven by their authentic interactions with students that are possible through the ICSA experience.

Examination of the reflections on the number talks revealed an impact on EPTS' beliefs about the nature of mathematics. For some EPSTs, this was their first time witnessing students solve a multiplication problem other than with the standard algorithm. This is evident in the following response:

> I learned that there are a lot of different ways that students can solve problems and before I really never considered the thought process a student might have. Instead I only think on my own way or the general [standard algorithm] way to solve a problem" (EPST 12).

One goal of the mathematics methods course is to shift beliefs about mathematics; one EPST captured this by saying it is “not just based on knowing equations, but learning about the relationships between numbers and truly understanding it” (EPST 13). Another EPST commented, “I learned that math doesn’t have to be limited to paper worksheets. Math can be discussed, moved around, and manipulated in multiple ways” (EPST 15). The ICSA seems to support this shift by echoing the learned coursework through student interactions.

Questioning. One specific element that was discussed in thirty-one reflections was the impact of questioning on the experience. EPSTs shared that they were now aware that the questions they asked were the force behind how students would share their ideas. One EPST stated, "I learned what kind of questions to ask and WHEN! I never realized how important the timing of your questions is and in what sequence” (EPST 7-capitalization added by participant). Another shared, "I definitely felt that the Mursion experience was helpful...It helped me to understand the importance of asking good questions, without constantly prompting students to say what I would like them to say” (EPST 19). This particular quote exemplifies a shared experience in which EPSTs would ask a string of literal questions instead of allowing students to share their thinking through an open-ended prompt. This is also evident, as one EPST reflected:

> I learned that it is important to step back and allow students the time to explain their strategies. I oftentimes like to jump in and give the answer before students truly get the opportunity to share their thinking and I could see that in this number talk” (EPST 14).

In addition to the impact of questioning, several EPSTs attended to the purposes of certain questions or teacher moves. That is, they wrote about using talk moves for particular reasons and therefore showed a more advanced conceptualization of eliciting student thinking. As one EPST wrote, "In the future, I need to question their strategy to understand where they are coming from...I think one of the most important things I learned about teaching mathematics from this number talk is to question students to assess and advance them” (EPST 14), we can see that she is strategically trying to listen to the students’ strategy for the purposes of understanding their thinking to inform instruction. Another example of this was when EPSTs spoke specifically about wanting students to make connections within the discussion. One EPST commented, “Another thing I learned that I didn’t really think about is how to relate certain problems to their thinking, how to aid connections to their thinking, to others, and to other mathematical problems” (EPST 12). Another EPST shared, "It was nice to see the students come up with their own strategies and then I was able to help other students make connections with the strategies that they didn’t understand right away” (EPST 16). This attention to connections is evidence that within this teaching experience, EPSTs are beginning to grapple with not only how to elicit student thinking, but how to respond in ways that bring student thinking to the forefront of the discussion.

CONCLUSION

Teacher preparation programs across the nation struggle with finding opportunities for EPSTs to engage in ambitious teaching throughout their undergraduate studies. These teaching opportunities traditionally take place in local schools surrounding the university or in peer-to-peer role play experiences. This traditional teaching experience in schools still remains one of best ways for teachers to practice their craft, but at times, it becomes impractical due to school schedules, teachers’ limited time in classrooms for EPSTs to practice teaching, and EPSTs’ schedules with their own classes at the university. This study has shown ICSAs to be a viable alternative for teacher education programs to engage EPSTs in ambitious teaching.

In addition to logistically opening doors for teaching experiences, ICSAs also allow for specific feedback on elements of ambitious teaching that are predesigned within the simulation scenarios. Within the number and science talk scenarios, one of the main focuses was on eliciting and responding to student thinking. In the debriefs, the teacher educators were able to hone into the development of the EPSTs' questioning and how they utilized students' ideas. Current research on rehearsals have involved cycles of peer-to-peer practice and then implementation of the same instructional activity in an elementary classroom (Kazemi et al., 2009). This cycle requires extensive resources that are not available to larger teacher preparation programs. Utilizing simulations is an innovative approach to rehearsals. The immersive nature of the simulation and the structure embedded in the scenarios creates an opportunity for coaching and enactment within one phase. The reflections showed that EPSTs valued the realistic interactions with the avatars and that these interactions illuminated areas for improvement. The debriefings allowed instructors to target key elements of ambitious teaching and connect that feedback with examples from the student avatars.

Another promising impact of ICSAs is the shift in beliefs about mathematics and science that was evident in EPSTs' reflections. As we strive for EPSTs to see mathematics and science as tools for problem solving and experiencing the world around them, we are fighting against ingrained experiences that position these subjects as merely a set of rules or definitions to memorize. After their first experiences with the ICSAs, ESPTs were sharing that they were thinking of math and science in new ways. They were noting the importance of students' prior knowledge and the value of different approaches. These experiences not only seemed to shift their thinking, but also motivated EPSTs to dig deeper and expand their content and pedagogical knowledge. Incorporating ICSAs early in teacher preparation programs may support earlier shifts in beliefs that can further strengthen the development of ambitious teaching.

Lastly, EPSTs were mindful that the ICSAs did not allow for lessons that utilize manipulatives or hands-on learning experiences. While EPSTs need explicit coaching on effective use of manipulatives and hands-on activities, the other themes that emerged from the reflections support attention on other aspects of ambitious teaching before bringing use of manipulatives to the forefront. That is, EPSTs grappled with eliciting students' thinking and how to navigate a semi-structured discussion and therefore it seems they need opportunities to practice this fundamental aspect of instruction. In doing so, it seems that they will be more likely to effectively attend to student thinking when integrating more hands-on experiences and transform instruction to minds-on experiences that do not merely involve doing activities without meaning.

REFERENCES

Alexander, R. (2008). Towards dialogic teaching: Rethinking classroom talk (4th ed.). Cambridge: *Dialogos*.

Allsopp, D.H., DeMarie, D., Alvarez-McHatton, P., & Doone, E. (2006). Bridging the gap between theory and practice: Connecting courses with field experiences. *Teacher Education Quarterly*, 33(1), 19-35.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.

Brownell, M.T., Chard, D., Benedict, A., & Lignugaris/Kraft, B. (2005). Preparing general and special education preservice teachers for Response to Intervention: A practice-based approach. In P.Pullen & M. Kennedy (Eds.), *Handbook of response to intervention and multi-tiered instruction*. New, NY: Routledge.

Candela, A. (2005). Students' participation as co-authoring of science institutional practices. *Cultural and Psychology*, 11(3), 321-337.

Chapin, S. H., O'Connor, C., & Anderson, N. C. (2013). *Classroom discussions in math: A Teacher's Guide for Using Talk Moves to Support the Common Core and More, Grades K-6: A Multimedia Professional Learning Resource*. Sausalito, CA: Math Solutions.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching*, 44(6), 815-843.

Clift, R. T., & Brady, P. (2005). Research on methods courses and field experiences. In M. Cochran-Smith & K. Zeichner (Eds.), *Studying teacher education: The report of the AERA panel on research and teacher education* (pp. 309-324). Mahwah, NJ: Lawrence Erlbaum.

Cornelius, L. L., & Herrenkohl, L. R. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. *Cognition and Instruction*, 22(4), 467-498.

Correnti, R., Stein, M. K., Smith, M. S., Scherrer, J., McKeown, M., Greeno, J., & Ashley, K. Improving Teaching at Scale: Design for the Scientific Measurement and Learning of Discourse Practice. In L.B Resnick, C. Asterham & S. Clark (Eds.), *Socializing Intelligence Through Academic Talk and Dialogue*

Dieker, L. A., Hynes, M., Hughes, C., & Smith, E. (2008). Implications of mixed reality and simulation technologies on special education and teacher preparation. *Focus on Exceptional Children*, 40(6), 1-20.

Dieker, L.A., Rodriquez, J.A., Lignugaris/Kraft, B., Hynes, M.C., & Hughes, C.E. (2014). The potential of simulated environments in teacher education: Current and future possibilities. *Teacher Education and Special Education*, 37, 21-33.

Duit, R., & Treagust, D. (1998). Learning in science: From behaviourism towards social constructivism and beyond. In B.J. Fraser&K.G.Tobin (Eds.), *International Handbook of Science Education* (pp. 3–25). Dordrecht: Kluwer Academic Publishers.

Duschl, R. (2008). Quality argumentation and epistemic criteria. In S. Erduran & M.-P. Jime´nez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp. 159–175). Dordrecht, The Netherlands: Springer.

Elford, M.D. (2013). *Using tele-coaching to increase behavior-specific praise delivered by secondary teachers in an augmented reality learning environment* (Doctoral dissertation). Available from ProQuest. (UMI No. 3559157).

Esmonde, I. (2009). Explanations in Mathematics Classrooms: A Discourse Analysis. *Canadian Journal of Science, Mathematics, and Technology Education*, 9(2), 86-99, doi: 10.1080/14926150902942072

Erodogan, I., & Campbell, T. (2008). Teacher questioning and interaction patterns in classrooms facilitated with differing levels of constructivist teaching practices. *International Journal of Science Education*, 30(14), 1-24.

Ghousseini, H., & Herbst, P. (2016). Pedagogies of practice and opportunities to learn about classroom mathematics discussions. *Journal of Mathematics Teacher Education*, 19(1), 79-103.

Girod, M., & Girod, G. (2008). Simulation and the need for practice in teacher preparation. *Journal of Technology and Teacher Education*, 16, 307-337.

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: theory and practice*, 15(2), 273-289.

Kazemi, E., Franke, M., & Lampert, M. (2009, July). Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction. *In Crossing divides: Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia* (Vol. 1, pp. 12-30). Adelaide, SA: MERGA.

Keeley, P., Eberle, F., & Farrin, L. (2005). Uncovering Student Ideas in Science: 25 formative assessment probes. *National Science Teachers Association Press*. Volume 1.

Kovalainen, M., & Kumpulainen, K. (2005). The discursive practice of participation in an elementary classroom community. *Instructional Science*, 33(3), 213–250.

Lampert, M., Beasley, H., Ghousseini, H., Kazemi, E., & Franke, M. (2010). Using designed instructional activities to enable novices to manage ambitious mathematics teaching. In Instructional explanations in the disciplines (pp. 129-141). Springer, Boston, MA.

Lampert, M., Franke, M. L., Kazemi, E., Ghousseini, H., Turrou, A. C., Beasley, H., & Crowe, K. (2013). Keeping it complex: Using rehearsals to support novice teacher learning of ambitious teaching. *Journal of Teacher Education*, 64(3), 226-243.

Lead States (2013). Next Generation Science Standards: For States, by States. Washington, DC: *The National Academies Press*.

Lehesvuori, S., Viiri, J., & Rasku-Puttonen, H. (2011). Introducing dialogic teaching to science student teachers. *Journal of Science Teacher Education*, 22(8), 705–727.

Lyle, S. (2008). Dialogic teaching: Discussing theoretical contexts and reviewing evidence from classroom practice. *Language and Education*, 23(3), 222–240.

Maheady, L., Smith, C., & Jabot, M. (2014). Field experiences and instructional pedagogies in teacher education: What we know, don't know, and must learn soon. In P. Sindelar, E. D. McRay, M. T. Brownell, & B. Lignugaris/Kraft (Eds.), *Handbook of research on special education teacher preparation* (pp. 161-177). New York, NY: Routledge.

Mercer, N. & Hodgkinson, S. (2008) (eds) *Exploring Talk in School: inspired by the work of Douglas Barnes*. London: Sage

Michaels, S., & O'Connor, C. (2012). Talk Science Primer. *National Science Foundation*. TERC.

Michaels, S., & O'Connor, C. (2015). Conceptualizing talk moves as tools: Professional development approaches for academically productive discussion. *Socializing intelligence through talk and dialogue*, 347-362.

Moje, E., Collazo, T., Carillo, R., & Marx, R. (2001). Maestro what is "quality?" Language, literacy, and discourse in project based science. *Journal of Research in Science Teaching*, 38, 469-498.

Moschkovich, J. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, 4(2–3), 189–212.

Muschla, G. R., & Muschla-Berry, E. (2015). *Teaching the common core math standards with hands-on activities, grades 9-12*. John Wiley & Sons.

National Research Council. (2008). Ready, Set, SCIENCE!: Putting Research to Work in K-8 Science Classrooms. Washington, DC: *The National Academies Press*. https://doi.org/10.17226/11882.

Pretti-Frontczak, K., Brown, T., Senderak, A., & Walsh, J. (2005). A preliminary investigation of the effectiveness of CaseQuests in preparing family-guided and technologically-competent early childhood interventionists. *Journal of Computing in Teacher Education*, 21, 87-93.

Richardson-Bruna, K., Vann, R., & Escudero, M. P. (2007). What's language got to do with it? A case study of academic language instruction in a high school "English Learner Science" class. *Journal of English for Academic Purposes*, 6, 36–54.

Roth, W. M. (2008). The nature of scientific conceptions: A discursive psychological perspective. *Educational Research Review*, 3, 30–50.

Roth, W.M., & Lucas, K.B. (1997). From "truth" to "invented reality": A discourse analysis of high school physics students talk about scientific knowledge. *Journal of Research in Science Teaching*, 34(2), 145-179.

Sandoval, W. A., & Morrison, K. (2003), High school students' ideas about theories and theory change after a biological inquiry unit. *Journal of Research in Science Teaching*, 40, 369-392. doi:10.1002/tea.10081

Scott, P.H., Mortimer, E.F., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education*, 90(4), 605-631.

Sfard, A. (2001) There is more to discourse than meets the ears: Looking at thinking as communicating to learn more about mathematical learning. *Educational Studies in Mathematics*, 46(1-3), 13-57. https://doi.org/10.1023/A:1014097416157

Straub, C., Dieker, L., Hynes, M., & Hughes, C. (2016). *TeachLivE Year 3 Research Report*. Retrieved from http://teachlive.org/wp-content/uploads/2016/09/2016-TeachLivE-Year-3-Technical-Report.pdf

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American Educational Research Journal*, 50(3), 574-615.

Tobin, K. & Tippins, D. (1993). Constructivism as a referent for teaching and learning. In K. Tobin & D. Tippins (Eds.), *The practice of constructivism in science education* (pp. 3–22). Hillsdale, NJ: Erlbaum.

van Eijck, M., & Roth, W. M. (2011). Cultural diversity in science education through novelization: Against the epicization of science and cultural centralization. *Journal of Research in Science Teaching*, 48, 824–847.

Van Zee, E.H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching*, 38(2), 159-190.

Venters, C., McNair, L., & Pareti, M. (2014) *Writing and conceptual knowledge in statics: Does learning approach matter?*

Weinstein, C. S., Tomlinson-Clarke, S., Curran, M. (2004). Toward a conception of culturally responsive classroom management. *Journal of Teacher Education*, 55, 25-38. Doi: 10.1177/0022487103259812

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Understanding Quality Work in Mathematics: Supporting Teachers in Leading Professional Development

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Abstract

Teacher leaders are often responsible for providing professional development to improve teacher effectiveness and student learning. Leading professional development for teachers can be highly effective when the focus is on student learning in on-going and relevant contexts. This article describes a school-based, teacher-led collaborative process conceptualized and facilitated by two teacher leaders using a modified protocol for examining students work in mathematics. The focus of the professional development aligned with a school-wide initiative of increasing the quality of students' mathematical work across a kindergarten through eighth-grade school. This paper shares the structure of the professional development, the nature of the protocol, and how it was implemented followed by a discussion for teacher leaders who are interested in facilitating a similar type of collaborative professional development experience within their own schools. Findings suggest that the use of a well-developed protocol helped focus teachers' attention to specific attributes expected in quality work and served as a reference point for considering how important structures of learning such as whole-class discourse could be evident in individual students' quality work.

Keywords: *Mathematics, Professional Development, Teacher Leaders*

INTRODUCTION

Highly effective schools are in a continual state of improvement and effective leadership is at the heart of this work. Leadership is not about an individual or a team of identified people, but a process. "For the process to be effective, those who direct or facilitate it—the leaders—must act in ways that engender a positive dynamic between them and those with whom they work" (Balka, Hull, & Miles, p. 5). Thus, a teacher leader is an individual who supports, guides, and influences others to accomplish the shared goals. This means a teacher leader can be teachers, coaches, curriculum experts and/or administrators.

Teacher leaders frequently support teachers to meet the goals and complexities of school reform through professional development. However, when these experiences are rooted in teachers' practice and teachers have opportunities to make decisions around their practice and the professional development, the experiences become key moments in their own continual professional growth as well as school-wide advancement in identified initiatives (Desimone, 2009; Wilson & Berne, 1999). As such, teacher leaders play a critical role in facilitating this work without taking over the process. This also means that teacher leaders need to understand the nature of professional development processes and the nuanced aspects that can help guide teachers' efforts in this work. This paper describes how one group of teacher leaders structured a focused, job-embedded, and teacher-led professional development experience centered on the school's goals in mathematics. This work focused on using students' mathematical work as a means of collectively understanding the nature and construct of quality work. This also allowed the teachers to develop more refined understandings of how best to support students across grades in creating quality mathematical work.

REVIEW OF LITERATURE

Professional Development

Much of the current research on professional development indicates that it consists of several key factors that mutually support and build upon each other. Specifically, effective professional development should be on-going, embedded within a classroom context, and be collaborative in nature (e.g. Desimone, 2009; Guskey 2002; Marrongelle, Sztajn, & Smith, 2013). This represents a major shift from the "hit and run" design and delivery of professional development historically offered. Additionally, professional development should be aligned to schools' identified areas of need (Marrongelle, Sztajn, & Smith, 2013). That is, if the teachers do not understand how the intended learning of the professional development fits into their specific context, and if such work is not additionally supported by school or district administration, then change in practice will be less immediate. A connection from the professional development back to teachers' context, and the discussions the teachers have with their colleagues within their school, further ground the importance of the professional development to their practice. This further supports the need for professional development to be inclusive and led by teachers with teacher leaders serving as a facilitator of the process, not the source of knowledge.

Examining Student Work

Professional development should also be focused on student learning (Garet, Porter, Desimone, Birman, & Yoon, 2001; Hiebert, 1999). This means providing opportunities for teachers to closely examine student thinking and understand the nuances and salient aspects within their work and not just the pedagogical techniques to improve student learning. In fact, Hull, Balka, and Harbin-Miles (2011) indicate that attending to student thinking and making it a central point is key to learning mathematics. Attending to student thinking can take many forms and can occur in many contexts, including such things as lesson study-type situations (Lewis, Perry, & Murata, 2006) or engaging the class in whole-class discourse to better understand how students think about the mathematics (Author, 2013). Additional research has shown that collaboratively analyzing student work is another means by which this can occur (Blythe, Allen, & Powell, 2015).

Examining student work can influence professional discussions about teaching and learning. In turn, this can engage teachers in a cycle of experimentation which becomes a starting point for reflection that focuses on student outcomes rather than instructional pedagogy (Kazemi & Franke, 2004). Additionally, the process of examining students' work encourages teachers to approach teaching and learning through an inquiry-based lens and thus helps increase teachers' skill in attending to the words, actions, and ideas of students that are most important in formulating next steps to support mathematical learning. By examining student artifacts in mathematics, teachers are better able to use specific evidence of learning to reflect on their instructional practice (Goldsmith & Seago, 2011) and provide specific feedback to help students routinely create quality work (Hounsell, McCune, Hounsell, & Litjens, 2008).

Using a Mathematical Quality Work Protocol

Various protocols can be used to examine student work (Allen & McDonald, 2003; Blythe, Allen, & Powell, 2015; Easton, 2009; EL Education, 2015) but most protocols are not specific to the teaching and learning of mathematics. For this study, a modified version of the Quality Work Protocol, which, in its original form, is not subject-specific and defined quality work through the lens of complexity, craftsmanship and authenticity (EL Education, 2015), was adapted for mathematics. Specifically, the adapted version retained the categories of complexity, craftsmanship and authenticity, but adapted the attributes specifically for mathematics student work by integrating key aspects of high leverage teaching practices in mathematics (National Council of Teachers of Mathematics, 2014; National Research Council & Mathematics Learning Study Committee, 2001). The actual steps and timing of the original protocol were used and the adaptation became the Mathematics Quality Work Protocol (MQWP), as seen in Appendix A.

Though the school in which this study takes place, called "Academy West," (pseudonym) has used other protocols for analyzing students' quality work, the focus had been on long-term and culminating products created as part of project-based learning and not directly related to mathematics. It became clear to the teacher leaders and the teachers at this school that there was a need to better understand how teachers across grade levels collectively viewed quality mathematical work so they could be more systematic and deliberate in supporting students in creating high-quality mathematical work on a regular basis regardless of grade or mathematical content.

METHODS

The purpose of this study was to better understand how the process of attending to student work in mathematics helped teachers develop a shared understanding of the nature and elements of quality work in mathematics to support one school's initiative centered on helping students continually create quality work. The guiding research question for this qualitative study focused on understanding the extent to which a modified quality work protocol for mathematics helped teachers define quality student work through examining the complexity, craftsmanship, and authenticity of their work. Specifically, the research questions for this qualitative study was "How does a modified quality work protocol help teachers define quality work in mathematics?" This study used a grounded theoretical approach (Corbin & Strauss, 2007) to allow for the development of understandings based on multiple qualitative data sources, including observations, field notes, and artifacts developed from the professional development experiences.

Observations and Fieldnotes

Observations were conducted during the teacher-led professional development experiences using the MQWP. While the researchers attended the professional development experiences, their primary role was to facilitate the experience and only intervene if salient perspectives were not being considered or if agreed-upon norms were being overlooked. The experience was strategically placed during the first half of the school year, after teachers were able to establish routines in the classroom, and had student work to examine. The timing was important to teachers so that they could conduct the protocol early enough in the school year to be able to make any course corrections immediately based on the examination of student work.

Additionally, the researchers wrote descriptive and reflective field notes during and after the professional development experience (Creswell & Poth, 2017). The professional development experience, using the MQWP, lasted two and one-half hours due to the richness of the discussion and the connections being made by the participating teachers. These notes focused on teachers' interpretations and understandings derived during the discussions about the nature and structure of quality student work. These notes also captured data that was otherwise not conveyed in teachers' collaborative written reflections or recorded notes, which were part of the professional development experience.

Implementing the MQWP

Because the protocol required teachers to discuss the quality and nature of student work, which can be influenced by personal experiences with their own students, the teachers agreed upon norms at the beginning of the year in order to engage in as objective of conversations as possible. These norms were displayed prominently during all professional development experiences and were reviewed and discussed before the MQW protocol paying careful attention to the details of what the norms would look like and sound like during their work.

To begin, teachers collected and displayed student work in mathematics; the type of work was not specified and teachers chose daily work samples, multi-day investigations, and long-term projects. Teachers brought three of each piece that, according to their rubrics, met but did not exceed, the content standard(s) being assessed. In the first round of the protocol, teachers utilized the MQWP as they silently examined the student work individually, thinking about and taking notes on the degree to which work samples showed attributes of complexity, craftsmanship, and authenticity along with a justification of their thinking. Teachers then moved into multi-grade level groups to discuss those observed patterns related to each attribute. Then, as a whole group, teachers shared observations and created a list of patterns related to each attribute, noting which attributes were strengths at the school, and which could be a focus for future improvement.

In the second part of the protocol, teachers displayed the rubric, scoring guides, and any specific task descriptions that accompanied the student work. Teachers again examined the work, taking notes on the three aforementioned attributes of quality, this time focusing on the tasks and scoring rubrics associated with the student work and how those supported quality. Teachers first noted patterns individually and then in multi-grade collaborative groups before moving to a whole group discussion. These whole group discussions ultimately focused on how the school could improve the tasks and scoring rubrics to invite higher quality mathematical work from students from the onset of their efforts.

Lastly, the whole group determined possible next steps including the supports needed to continue building a culture of engaging in high quality mathematics throughout the school. After the protocol, pieces of student work (photos and related task descriptions/scoring tools) that represent the status quo at the school were archived, along with a summary of the discussion, to be used as evidence of growth in this area of school improvement.

Participants & Setting: School

Academy West is a K-8 charter school that has been in existence for approximately 15 years with total student enrollment near 350 students who mostly attend multi-age classrooms. The school strives to be a leader in project-based, real-world learning experiences within a collaborative environment. Within the school, teachers and administrators view student achievement as a three-faceted construct. The first focuses on the mastery of skills and knowledge, visible through deeper understanding of each discipline, the ability to apply learning, thinking critically and communicating clearly. The second facet of achievement centers on developing students' character who are effective learners and ethical people that contribute to a better world. Lastly, the third facet concentrates on producing quality work that demonstrates complexity, craftsmanship, and authenticity (EL Education, 2015).

Participants

The participants in this study were a mix of novice and veteran teachers (n=20) with 20 years as the maximum number of years as a teacher. Additionally, two teacher leaders assisted with facilitating this work one of which was the principal and the other was an instructional coach. The 20 teacher participants included two kindergarten teachers, two first grade, and two sixth grade teachers with the other 14 teachers coming from multi-aged classroom. Specifically, three 2nd/3rd grade teachers, three 4th/5th grade teachers, and five middle school (7th/8th grade) teachers in subject specific roles (science, math, social studies, ELA, and Spanish) participated as well as three other part-time specialist teachers (i.e. visual arts, physical education and a part time 4th/5th mathematics teacher).

Of the 20 teacher participants, over half (n=11) had over ten years of teaching with over five of those years at Academy West. Additionally, all teacher participants reported that they choose to teach at Academy West because of the culture of collaboration and inquiry as well as the focus on project-based learning. Most participants also reported that the environment within the school was challenging, yet rewarding, and they were encouraged and expected to engage in professional conversations on a regular basis.

FINDINGS

Defining Quality Work in Mathematics

Overall, teachers indicated that they were mostly satisfied with the attributes of quality as defined and found them useful in promoting dialogue and creating shared meaning as they examined student work in mathematics. One point multiple teachers brought up in conversations centered on how the quality of students thinking was different from the quality of the product students created, or the aesthetics of the work created. While teachers frequently brought up and discussed attributes that would be associated with the quality of student thinking, there were no indicators concerning "beauty" or the visual organization of the work. Other teachers disagreed, stating that indicators in the craftsmanship section were partly about aesthetics. In particular, "well-crafted mathematics is done with care, precision and accuracy" and thus "requires attention to accuracy and detail" which, to them defined "beautiful mathematics."

Other teachers felt that the aesthetics were less important than the evidence of student thinking, as long as the student work was precise and accurate, and thus no other attributes relating to aesthetics were necessary. Teachers agreed that while the visual displays of thinking they saw in the student work could be clearer, more organized, or more aesthetically pleasing to read, the teachers felt they were potentially hindered by previous protocols that examined final long-term products, where "craftsmanship" was defined through the lens of multiple revisions for aesthetics over time. To these teachers, this meant that when the work is daily or of a more short term product (i.e. weekly work), helping students to organize and clarify their work in a visually pleasing manner was not needed in most cases. Essentially, multiple revisions only for the sake of the aesthetic value, that did not further convey meaning or conceptual understanding, were unnecessary.

Another source of dissonance in the use of the attributes was that some teachers attended to both the important teacher responsibilities in the creation of the tasks and assignments (e.g. the application of mathematics to real life contexts rather than "artificial" school experiences) and to other attributes that centered on decisions made by students (e.g. using a variety of representations, strategies and multiple solution methods). As discussion of the purposes of the protocol ensued, teachers realized they needed to develop a "shared vision of quality work" and identify and differentiate between aspects related to quality that are teachers' responsibility as opposed to students'. Identifying that both teachers and students had specific roles that led to the creation of quality student work was considered a major "breakthrough" during the discussions. Teachers came to understand that without assignments and tasks that intentionally encouraged the attributes of quality, then students could not be expected to produce quality work.

Making Students' Thinking Visible Through Discourse

Teachers had previously studied the role of discourse in the mathematics classroom and wondered where, if anywhere, this important and powerful tool lived in the attributes of quality student work. As a result of looking at student work, they came to understand that a byproduct of discourse, in particular the written explanations students provided, could be seen in the student work. While not explicitly discourse, students' writing represents a manifestation of their own internal dialogue, which they nurture and develop as they engage in discursive interactions with their peers. Thus, an aspect of discourse, that was represented in their writing, could be evidence of quality work because they had previously engaged in meaningful opportunities talking about mathematics.

Teachers also referenced the attribute of complexity and craftsmanship by recognizing that "the structure and language of mathematics is present in student writing" and that "students use precise mathematical language, appropriate to their grade, in their explanation and discussion." This led the teachers to understand the link between specific connections made during whole-class discourse and the written expression of ideas from this discourse. Essentially, the language of mathematics, and the complexity of it, "could not appropriately be seen in their explanations if they have not previously engaged in numerous rich discussion with others."

Quality Work Represented in Various Models

In considering complexity, the teachers expected to see a variety of representations of mathematical thinking in the student work. Collectively, the teachers wondered if more complex representations would be more appropriate for certain grade levels. This started a discussion that focused on understanding how the progressions of mathematics, and the models of representation used to show conceptual understanding, might be used to judge the complexity of student thinking at any given grade level. Additionally, teachers wondered if student work was more complex, and thus higher quality, if a variety of representations were present or if a student could clearly articulate why their representation was the best for a particular mathematical context. This shows that teachers were attending to the intended connections students were to make to specific grade-level content standards and then the progression of learning across grade levels.

What do Mathematicians do?

Quality work, as defined in these attributes, also embodies using "real work formats and standards from the professional world, rather than artificial school formats" as found in the attributes related to authenticity. In other words, the work should, at least some of the time, represent the real work of mathematicians. This was a source of confusion for teachers because they did not know what mathematicians really do or what would be an "appropriate product of a mathematician's work?" They seemed to understand that incorporating the habits of mind and interaction evident in the Standards of Mathematical Practice (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010), which they listed as an attribute for authenticity, was part of making the work real for students. However, the teachers ultimately decided that they did not have enough information at the time to fully address this and thus it warranted further study and additional resources to help them answer this question.

DISCUSSION AND IMPLICATIONS

Meaningful opportunities for professional development and time to engage in such experiences are a commodity in short supply. Therefore, leveraging that time in ways that support long-term and school-wide initiatives are critical to the continual growth of the school as well as teachers' classroom practices. In this study, using a quality work protocol focused in mathematics was valuable to help teachers develop a shared understanding of the nature and structure of quality work and had several implications for teacher leaders in designing collaborative work to impact student learning.

First, teachers benefited from structured time to develop a shared understanding of quality work in order to support larger goals of improving pedagogy and student learning. These understandings further supported the overall initiatives within the school and were central to the continued efforts of the teacher leaders within the school. Even though teachers typically spend time looking at student work multiple times a day to provide feedback or design instruction, the use of a structured protocol in a collaborative setting, and time to attend to specific attributes of student work, as in the MQWP, allowed for a different perspective than the everyday solo examination of student work. Creating time for this professional development structure allowed teachers to question potentially ineffective teaching practices, learn new methods, and supported their personal and collective professional growth. Additionally, teachers increased their ability to pay attention to student learning, the attributes of quality work, and to student responses to their tasks and instructional activities, which can improve their instructional decision making process (Little, 2003).

Second, the time spent analyzing this work helped create a strong school-based professional community. For teacher leaders, such experiences are important to changing instructional practice and achieving long-term and school-wide initiatives. Before any conversation about what teachers should be doing, teachers must be considering student thinking which then drives pedagogical practice (Levin, Hammer, Elby, & Coffey, 2013). When teachers' conversations, thinking, and discussions about student learning are at the core of professional development, then teachers are in charge of uncovering and taking on a problem of practice in their own way, coming from their own thinking, not imposed by an external leader. This is important because there is much support for teacher-driven professional development (Bonner, 2006; Garet et al., 2001) where teachers can work together in an environment where they have a common issue to discuss (Zeichner, 2003) and ultimately impacts student motivation, engagement and learning (Colbert, Brown, Choi, & Thomas, 2008). Teachers at Academy West felt empowered to create conditions in their own classroom to improve the quality of student work in mathematics after participating in these experiences in great part because of the leadership at this school. The autonomy and purpose felt by the teachers contributed to the professional community within the school. This kind of professional community sparked interest and engagement to drive the work of teachers and teacher leaders on a daily basis.

For teacher leaders, a teacher-led professional development process such as the one described can positively support school-wide initiatives and goals if proper structures, norms, and tools are in place and available. Using a descriptive protocol was important to the success at Academy West and should be considered by others wishing to focus on similar areas of improvement. What cannot be emphasized enough is that the culture created and nurtured during these professional development experiences were central to the primary intent of the work. Even if the structural elements of effective professional development are in place (Desimone, 2009), a mutually supportive culture is an a priori need.

REFERENCES

Bennett, C. A. (2013). Teachers' perspectives of whole-class discourse: Focusing on effective instruction to improve student learning. *Action in Teacher Education*, 35(5-6), 475-488.

Allen, D., & McDonald, J. (2003). *The Tuning Protocol: A process for reflection on teacher and student work*. Retrieved from: http://essentialschools.org/horace-issues/the-tuning-protocol-a-process-for-reflection-on-teacher-and-student-work/

Balka, D. S., Hull, T. H., & Miles, R. H. (2009). *A guide to mathematics leadership: Sequencing instructional change*. Thousand Oaks, CA: Corwin.

Blythe, T., Allen, D., & Powell, B. S. (2015). Looking together at student work. New York, NY: *Teachers College Press*.

Bonner, P. J. (2006). Transformation of teacher attitude and approach to math instruction through collaborative action research. *Teacher Education Quarterly*, 33(3), 27-44.

Colbert, J. A., Brown, R. S., Choi, S., & Thomas, S. (2008). An investigation of the impacts of teacher-driven professional development on pedagogy and student learning. *Teacher Education Quarterly*, 35(2), 135-154.

Corbin, J., & Strauss, A. (2007). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage publications.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, 38(3), 181–199.

Easton, L. B. (2009). *Protocols for professional learning (The professional learning community series)*. Alexandria, VA: ASCD.

EL Education. (2015). *Quality work protocol facilitation guide*. Unpublished document.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Education Research Journal*, 38(4), 915-945.

Goldsmith, L. T., & Seago, N. (2011). Using classroom artifacts to focus teachers' noticing. In Sherin, M., Jacobs, V., & Phillip, R. (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 169-187). New York, NY: Routledge.

Guskey, T. R. (2002). Does it make a difference? Evaluating professional development. *Educational Leadership*, 59(6), 45-51.

Hiebert, J. (1999). Relationships between research and the NCTM standards. *Journal for Research in Mathematics Education*, 30(1), 3–19.

Hounsell, D., McCune, V., Hounsell, J., & Litjens, J. (2008). The quality of guidance and feedback to students. *Higher Education Research & Development*, 27(1), 55-67.

Hull, T. H., Balka, D. S., & Harbin-Miles, R. (2011). *Visible thinking in the K-8 mathematics classroom*. Thousand Oaks, CA: Corwin and NCTM.

Kazemi, E. & Franke, M.L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, 7(3), 203-235.

Levin, D., Hammer, D., & Elby, A. (2012). Becoming a responsive science teacher: Focusing on student thinking in secondary science. Arlington, VA: *National Science Teachers Association*.

Lewis, C., Perry, R., & Murata, A. (2006). How should research contribute to instructional improvement? The case of lesson study. *Educational Researcher*, 35(3), 3-14.

Little, J. W. (2003). Inside teacher community: Representations of classroom practice. *Teachers College Record*, 105(6), 913-945.

Marrongelle, K., Sztajn, P., & Smith, M. (2013). Scaling up professional development in an era of common state standards. *Journal of Teacher Education*, 64(3), 202-211.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: National Council of Teachers of Mathematics.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*. Washington, D.C.: National Governors Association Center for Best Practices & Council of Chief State School Officers.

National Research Council & Mathematics Learning Study Committee. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academies Press.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of research in education*, 24, 173-209.

Zeichner, K. M. (2003). Teacher research as professional development for P–12 educators in the USA. *Educational Action Research*, 11(2), 301-326.

APPENDIX A

Attributes Quality Work in Mathematics (adapted from EL Education, 2015)

Complexity
● Complex mathematics is rigorous: the structure and language of mathematics is present in student writing and aspects of the shift, rigor (conceptual understanding, procedural skill and fluency, and application) are present. ● Complex mathematics often connects to big concepts and targets the major work of the grade. Or, if the work focuses the supporting work of the grade, it highlights the connection to the major work of the grade. ● Complex mathematics supports application of Standards of Mathematical Practice in learning content. ● Complex mathematics is expressed by using a variety of representations, strategies and often multiple solution methods. ● Complex work may incorporate students' application of higher order math skills through the use of purposeful math tasks and opportunity for math discourse and argument. ● Complex mathematics encourages reasoning and problem solving by posing challenging problems that offer opportunities for productive struggle.
Craftsmanship
● Well-crafted mathematics is done with care, precision, and accuracy. Students use precise mathematical language, appropriate to their grade, in their explanation and discussion. ● Craftsmanship in mathematics requires attention to accuracy, detail, and making use of the structure and language of mathematics. ● Craftsmanship in mathematics requires students to explain and justify work and provides feedback that helps students revise initial work, especially in their explanations and justifications.
Authenticity
● Authentic work demonstrates the original thinking of students rather than simply showing that students can follow directions or fill in the blanks. ● Authentic mathematics often uses real work formats and standards from the professional world, rather than artificial school formats (e.g., students create a report for a local environmental agency rather than a worksheet for the teacher). ● Authentic work often connects academic standards with real-world issues, controversies, and local people and places. ● Authenticity gives purpose to work; the work matters to students and ideally to a larger community as well. When possible, it is created for and shared with an audience beyond the classroom. ● Authentic work demonstrates habits of mathematicians present in the Standards for Mathematical Practice.

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Changes in Teaching Efficacy Beliefs among Elementary Preservice Teachers from a STEM-focused Program: Case Study Analysis

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Abstract

Four case studies of preservice teachers enrolled in a STEM-focused elementary teacher preparation program are used to document changes in mathematics and science teaching efficacy over the course of one academic year. Qualitative analysis revealed that all four case studies experienced changes in their mathematics and science teaching efficacy beliefs over the course of the year. Participants described unique ways of understanding their growth (or lack thereof) in teaching efficacy, the trajectory of teaching efficacy over the course of the year, and the role of teacher training in changing their efficacy beliefs.

Keywords: *efficacy beliefs; preservice teachers; STEM education*

INTRODUCTION

In mathematics and science teaching at the elementary level, research shows that most teachers are not adequately prepared to teach mathematics and science (Sharp et al., 2011) and often, they hold negative views towards teaching mathematics and science (Borko & Whitcomb, 2008). Additionally, elementary teachers do not feel confident about teaching mathematics and science, and in turn, they often exhibit avoidance behaviors by reducing the duration of mathematics and science teaching in favor of other subjects (Lumpe et al., 2000). Understanding the role of efficacy beliefs in teachers' practices, as well as changes in teachers' efficacy, will help teacher education programs determine the types of academic experiences that are necessary to prepare elementary teachers for their careers. This study responds to the need for more research exploring teachers' changes in mathematics and science efficacy, since teacher efficacy is a key predictor of student achievement (Richardson & Liang, 2008).

The aim of this study was to document changes in elementary preservice teachers' mathematics and science efficacy beliefs over one academic year during their professional coursework. We captured participants' reflections on their mathematics and science teaching preparation and their efficacy beliefs through interviews. Contributions from this study can help enhance our understanding about when and how changes in teachers' efficacy occurs during an academic year.

Science Teaching Efficacy Beliefs

Science teaching efficacy beliefs is defined in the literature as teachers' beliefs about their ability to teach science (Bleicher, 2007; Velthuis, Fisser, & Pieters, 2014). The concept of teacher efficacy has two dimensions, namely, the personal science teaching efficacy, which is a teacher's belief in his or her own teaching skills and the ability to deliver effective instruction, and the science teaching outcome expectancy, which is a teacher's belief that effective teaching can impact student learning regardless of external factors such as family background, parental influences, or home environment.

Among the key factors identified in the literature to impact preservice teachers' science teaching efficacy, are mastery learning, vicarious experiences, and verbal persuasion, in addition to science coursework, field experiences, support from peers and school administration, or personal factors (Cantrell, Young, & Moore, 2003; Thomson et al., 2017; Thomson et al., 2019).

Research shows that teacher preparation programs can help improve preservice teachers' science efficacy by providing positive experiences with science learning for preservice teachers, increasing the science content knowledge during teacher preparation programs, and providing opportunities to teach science in elementary classrooms. Science learning experiences are particularly important for improving science teaching self-efficacy if the experiences provide good models for instruction. Teacher preparation programs can provide new, positive science learning experiences for preservice teachers. Science methods courses that include hands-on and constructivist approaches to learning and teaching science have been found to improve efficacy (Bleicher, 2007; Bleicher & Lindgren, 2005; Setlage, 2000). Additionally, increasing teachers' science content knowledge can increase science teaching efficacy (Swackhamer et al., 2009; Velthuis, Fisser, and Pieters (2014), as can increase the time preservice elementary teachers spend teaching science in elementary classrooms (Cantrell et al., 2003).

Mathematics Teaching Efficacy Beliefs

Mathematics teaching efficacy focuses on teachers' feelings of effectiveness in mathematics instruction. The concept of mathematics teaching efficacy consists of two dimensions, namely, the personal mathematics teaching efficacy, which are beliefs about one's own abilities to teach mathematics, and the mathematics teaching outcome expectancy, which are beliefs about one's ability to impact student learning despite students' background experiences (Enochs, Smith, & Huinker, 2000). Key factors identified in the literature to influence preservice teachers' mathematics teaching efficacy, are generally related to mastery learning, vicarious experiences, and verbal persuasion (Charalambous, Philippou, & Kyriakides, 2008; Charalambous & Philippou, 2010). Additionally, other factors, such as the mathematics coursework, field experiences, support from peers and school administration, or personal factors are crucial for developing mathematics teaching efficacy (Thomson et al., 2017).

Research shows that teacher preparation programs can improve preservice teachers' mathematics teaching efficacy, by ensuring positive experiences with mathematics learning, increasing the content knowledge in mathematics during teacher preparation programs, and providing multiple opportunities to teach mathematics in elementary classrooms (e.g., Brown, 2012; Swars et al., 2007). Research found that methods courses within preparation programs had a positive impact on preservice teachers' efficacy and on their attitudes towards teaching mathematics (Brown, 2012; Newton et. al., 2012; Swars, et al., 2007; Utley, Moseley, & Bryant, 2005). Furthermore, Newton et al. (2012) found that preservice teachers with higher content knowledge referred to verbal persuasion (i.e., encouragement, praise) as a common source of efficacy while those with lower content knowledge spoke of vicarious experiences (i.e., learning from others' experiences) as important for their efficacy judgments.

METHODS

Participants

Parker, Morgan, Casey, and Blake (all names are pseudonyms) are the four elementary preservice teachers we selected for documenting changes in efficacy beliefs. The participants were selected from a group of 19 preservice teachers enrolled in a STEM-focused elementary teacher preparation program in the United States. During the freshman and sophomore years, the preservice teachers completed nine courses of STEM content that included one engineering design, three science, and three mathematics courses. During the time of data collection (the junior year), participants completed two full-time semesters of elementary education coursework accompanied with field experiences. The junior-year coursework included: one engineering, two science, and two mathematics methods courses (K-2 and 3-5). Participants completed field-based assignments in their simultaneous K-2 and 3-5 semester-long field experiences. The qualitative data in this study comes from a larger, five-year research project designed to evaluate the outcomes of the elementary teacher preparation program. Participants were very similar in their demographics; all were white females, 19-20 years old, and had very similar grade point averages (GPA). The four preservice teachers' stories were randomly selected from the 19 case studies. The stories presented here, illustrate different pathways that elementary preservice teachers describe related to their science and mathematics teaching efficacy and changes in efficacy beliefs over the course of one academic year.

Data Sources

During the course of an academic year, the study participants were interviewed on seven occasions. Four of these interviews were paired with course required field-based assignments: two video recorded mathematics lessons; one video recorded STEM lesson; and one science inquiry project. The remaining three interviews, at the beginning, middle, and end of the year, were designed to learn more generally about the participants' beliefs, backgrounds, and knowledge. Each interview was approximately one hour and was recorded with participant consent and later transcribed verbatim. Appendix A presents the measures, timeline, and procedures for data collection during the academic year for the case study participants. Interview data related to participants' teaching efficacy were coded and organized in order to examine participants' teaching efficacy beliefs, and reflections on their professional training.

The interview protocols asked a range of questions about participants' coursework, field experiences, reflections on their K-5 lessons taught, and their beliefs about teaching. From each interview, only the qualitative data related to participants' efficacy beliefs was used for analyses in this study. Data coding was performed in several steps using an inductive process. In the initial stage, each of the four researchers from the research project read the transcribed interviews for a particular case study and coded the data. Then, all coders convened to discuss their coding. Next, via comparative procedures, all the coded pieces were organized and merged into larger categories. Results from the data analysis were presented in a descriptive manner, using a sequential approach to capture changes over time in participants' efficacy beliefs, such as initial beliefs, moments of change in beliefs, and reflection on their yearlong efficacy trajectory.

RESULTS

Within each case study, we focus on describing participants' initial efficacy beliefs about mathematics and science teaching, then particular moments in their learning and teaching experiences when they became aware of changes in teaching efficacy, and finally, their trajectory of personal efficacy development over the course of the academic year. We present each case study here along with a summary of the cross-case study analyses (in Appendix B).

Parker: "I am ready to teach math"

Initial efficacy beliefs

Parker expressed interest in becoming an elementary school teacher mostly because of her own fourth grade teacher. She was a wonderful model for Parker, always excited about teaching and this had a strong influence on Parker's desire to instill this excitement in her future students. Parker's initial views on her mathematics teaching abilities were relatively high; during her Introductory Interview and her Math Cognitive Interview #1, she felt very confident about her mathematics teaching abilities due to a strong preparation in mathematics and her personal interests: "I know a lot of people are really nervous about it. I feel like it makes more sense like we were just taught. I feel like this is why you do something and I actually am excited about that, so I think it will be good. I am ready to teach math."

In contrast to her views on mathematics teaching, Parker's initial views about her science teaching abilities were low, due to her weak background in science. During her Introductory Interview and her STEM Cognitive Interview she explained that despite the fact that she had courses in science she feels like she's not mastering the science content well: "I didn't take a weather class or certain classes you didn't like have to take …I am sure I will learn about how to teach like that but like you need to refresh yourself on certain things." Interestingly, she was not aware when she applied to the elementary teacher preparation program that it has a STEM focus, but this lack of awareness did not affect her decision to become an elementary teacher, nor her teaching confidence: "I was not aware that we were like, well we weren't STEM focused whenever I came in, we were math or science strand which I mean doesn't matter to me cause I am a math and science person, more so than a language arts and social studies person. But I didn't like know exactly the requirements coming in."

Moments of changes in efficacy

After her second teaching experience (she had taught two K-5 lessons at this point in time), during her Math Cognitive Interview #2, Parker expressed high mathematics teaching confidence. Further, she demonstrated pedagogical and content knowledge about teaching mathematics by describing in detail her lesson goals, tasks, and how and why she used resources. She also reflected on her own teaching abilities in mathematics:

> Things went pretty okay. I didn't think it was the best thing ever, but I thought it was pretty okay. Towards the end, going over the process of how you would tell a friend how to get the volume, they [students] were all able to give me a step-by-step process of how they would go about that. So, I feel like that was pretty much what the lesson was about, that part was very successful.

While she had high efficacy for mathematics teaching, she was still holding low efficacy beliefs about science teaching expressed in her second science interview (Field Based Science Inquiry Assignment). She recognized that she holds many common misconceptions about science concepts and has a hard time addressing these lacunas to her students. Parker also recognized that teaching a STEM lesson was more challenging than she expected because of the complexity of the topic, combining mathematics, science, and engineering concepts into one lesson and because of her lack of knowledge depth in this area:

> I never actually – we never did engineering type stuff throughout my schooling. Like the first time I ever heard of STEM was actually here; whenever we actually switched over to STEM. So like we never did the

> process where you think something out. You build something. You try to make it better; that was brand new to me. I mean math and stuff like science, everybody pretty much understands those and the technology, maybe we had a couple of classes throughout schooling like about technology but nothing really major.

Reflection on efficacy trajectory

Describing her trajectory of efficacy development over the academic year, Parker emphasized that she believes she made the most growth in mathematics teaching efficacy compared to science teaching efficacy. By the end of the year, she was still holding low science teaching efficacy beliefs. During the End of Year Interview while reflecting on her current level of confidence for teaching mathematics and science, Parker said:

> I feel really confident teaching math. I feel like I have a good understanding of, a better understanding, of how students think and ways to help them to think and how to develop their thinking. So, I feel really confident about how I could go about teaching math in the classroom. Science, I understand, I feel okay about it, but I don't think I truly know how to go about teaching it in the classroom as much as the other, as math I do.

Morgan: "I don't think I know all of it"

Initial efficacy beliefs

During her first interview, Morgan mentioned that she always wanted to be a teacher. She had experience working with young children during summer camps and teaching her younger brother things she learned in school. Before applying to the elementary education program, Morgan was not aware of the STEM focus. However, once she learned about the STEM focus she felt it enhanced the integrity of the program, which influenced her decision to attend this university. Morgan also felt a stronger interest and competence in her ability to teach mathematics compared to science. Morgan described in her Introductory Interview that she had struggled in mathematics when she was in high school but a special teacher helped her with the material and also instilled a love of mathematics. While she did not experience these positive influences in science, "I was never really very confident in my ability to do science," she still liked science, "…even though I had a harder time in those [science] classes it didn't really make me think oh, I hate science."

Morgan described her college coursework in science content areas as disconnected from her learning, and noted that her experiences in large lecture style classes did not interest her and furthered her disconnection. These coursework experiences seem to affect her teaching confidence leaving her not knowing what to expect for her upcoming teaching assignments in K-5 math and science.

Moments of changes in efficacy

After she taught her first science lesson (the STEM Project), during her STEM Cognitive Interview, Morgan said that she felt less comfortable teaching science at this point, compared to where she was in the beginning of the semester. She attributed this to seeing far fewer science lessons compared to math lessons in her field placement classroom. This seems to be detrimental to her views about science teaching: "We've observed a lot of math lessons but…we really have never observed any science lessons up until this point." The minimal amount of elementary science instruction greatly influenced her beliefs about her efficacy in teaching science.

Talking about her mathematics teaching experience Morgan said that she enjoyed teaching mathematics, but she felt anxious every time. During her Math Cognitive Interview #1 she mentioned that her lesson planning and time management needed more attention than she anticipated, "I enjoyed it more than I thought I would. I was really scared at first, well, I went through stages in the few days leading up. I was really nervous and then I was really excited because I know the kids and I know how they would react and stuff but I was also really nervous. It was just the first time I ever taught them all at once and so, but I was really excited after the lesson. I really enjoyed teaching it."

Reflection on efficacy trajectory

In describing her trajectory of personal efficacy development throughout an academic year, Morgan described feeling confident in teaching at the beginning of the year, but that confidence was rattled as she began to recognize the complexity of teaching. She maintained her strong desire to become a teacher. She explained:

> I am more passionate about it now that I know what teachers do, more of what teachers do at least, I don't think I know all of it, and just have more respect in general for teachers. I used to say teaching is so hard, but I had no idea what I was talking about when I said that, so now I feel like I know a lot more but I still want to become a teacher.

At the end of the year, she still described low science teaching efficacy beliefs. In spite of this, as Morgan described in her End of Year Interview, she clearly sees the value in science for elementary students, "It's really important to have science in the curriculum because it's just how everything works, how the world works." She recognized during some of her science teaching experiences that she will have to be a lifelong learner in order to help her students learn science. She acknowledged that teaching science will require her to learn more science content than she thought she needed.

> I guess no matter really what grade I teach, before I start a unit or a lesson I'll have to research it because even with teaching the first graders about Newton's Law of Motion I had to remind myself a lot of things and do a lot of research into that beforehand so I could teach accurately. I feel like I can do it, but I know that like I'll have to look into things beforehand.

After some initial teaching experiences in multiple grades, Morgan's mathematics teaching confidence increased in both lower and upper elementary grades. The actual teaching experiences were important factors for Morgan's efficacy as she learned to attend to student thinking. "I was nervous to teach, since they're so much older than 5 and 6-year-olds and I knew they would have more questions and that scared me a little bit. And then after teaching some more and getting used to them it went up. And then, after my second math lesson, I didn't feel so good about that, so it went down just a little bit, and then it's slowly starting to go back up."

Casey: "I will evoke that confidence"

Initial efficacy beliefs

Casey expressed interest in becoming a teacher since her fourth grade year in elementary school. She feels that she works well with children and takes pride in being recognized for her skills in this area. Casey expressed fond memories of classes during which she had a relationship with the teacher, and she highly valued interaction in her learning experiences. Talking about her efficacy, Casey described a relatively high level of teaching-efficacy in regard to both mathematics and science teaching at the beginning of her professional coursework (junior year). She believed that elementary mathematics and science content is basic and therefore will not be difficult to teach. During her Introductory Interview Casey shared:

> I think everything at elementary school level I'll be able to teach just because it doesn't progress much further. I don't know if it's like this anymore. It didn't progress much further past long division and I, I enjoyed that, that's so much fun.

Moments of changes in efficacy

After her first lesson implementation, Casey continued to express a high level of teaching efficacy for mathematics teaching. In the Math Cognitive Interview #1, Casey stated:

> First grade math isn't difficult for people that are, I guess, that aren't in first grade so I felt confident that I knew what I was saying was right. I know I still have a long time to go before that actually has to be perfect so that's something I know I'm still trying to improve on is making sure the delivery is right.

Casey continued to reference the simplicity of the content as an attribution of her confidence. Her confidence was based on her understanding of the content, but she also acknowledged that she has time to continue to improve her delivery. Casey felt that she learned effective teaching strategies in her methods courses, and she shared, "I'll be able to [teach], as long as I learn the proper approaches here which I know that I will because I already am, then I'll be able to teach, I feel very confident." However, after her second mathematics lesson Casey's mathematics teaching efficacy seemed to decrease, and she put more reliance on the mentor teacher than her own abilities: "I mean, the good thing is I knew that if I didn't do a great job teaching it that their teacher could really go over a lot the next day so that was a comfort to me." When asked how the lesson went Casey pointed out more changes she would have made compared to her first lesson, and she expressed doubts in her instruction.

Casey described confidence in science teaching after her teaching experience. In her Field Based Science Inquiry Interview, Casey mentioned that she feels more confident to teach science because she feels that she has more competence in this area: "I feel like the more competent you feel teaching science the more confident you're gonna be at what you're doing and I think it relates because I think I'm gonna end up leaving school feeling like I can teach it pretty well and I don't think a lot of teachers have that same opportunity."

Reflection on efficacy trajectory

In her description of the efficacy trajectory over one year, Casey seemed to maintain a high level of teaching efficacy for both mathematics and science with some decrease in math teaching efficacy when teaching upper grades mathematics. Casey feels that if she knows the content she is to teach, she will be able to teach it to her students in an effective manner.

At the end of the year, she still feels that she can master mathematics teaching better than science teaching: "I've expanded my knowledge since then [beginning of year], and I've learned more complex math; I think I can help, I'll be able to explain things [in math] because I do know it. But with science, there's some things that I probably won't know." However, she expressed optimism about her ability to learn and she shared that she is aware that she doesn't always have the knowledge, but she knows how to find it: "I have the confidence, I guess, but I don't have the knowledge to back it up all the time, so, and I feel like having that knowledge, that base knowledge is what really helps explain things to the students, so that's definitely something that I know I'm gonna need more of and I know that'll come with time." Furthermore in regards to all teaching, Casey said "I feel like if I go into it confidently I will evoke that confidence and the students will be able to learn." She seems to value content knowledge and self-confidence and acknowledges that experience in the classroom will help her increase in both of these areas.

Blake: "I'm going to try"

Initial efficacy beliefs

Blake described herself as a high achieving student throughout her K-12 schooling, always eager to learn and to share her knowledge with others. This was key in her motivation to become a teacher. Initially, Blake expressed anxiety about teaching mathematics, but felt her early learning experiences in the mathematics methods course were helping her relax. She mentioned that previous mathematics teachers had a great influence on her perception of math abilities, but she feels determined to work hard as a teacher to become better: "I was definitely discounted as like not a math student, and teachers kind of gave up on me; not all teachers, but a lot of my high school mathematics, of course, they just wanted to get me through the class. When I become a teacher, I'm going to try to sit down and work through and figure out why it's not clicking and like how everyone learns in different ways, so like one explanation is not gonna be good for every student in the class."

Blake was not positive about her ability to teach science in the beginning of the semester, during her Introductory Interview. At this point, she did not feel prepared to teach science, and stated that while her science methods course had completed "cool experiments", they had not yet "gotten in depth into how you would teach [science]" because it was still early in the course semester. Importantly, Blake did express a desire to learn to teach high quality science lessons to her students in the future.

Moments of changes in efficacy

Blake's first mathematics teaching experience increased her confidence in teaching, "I think [it] made me feel more comfortable especially for a beginning lesson because I knew they wouldn't be able to ask me a question I wouldn't know." This experience, however, opened her eyes to difficult pedagogical decisions beyond content knowledge that she had not previously considered.

During the Math Cognitive Interview #2, after her second lesson taught, Blake continued to feel confident in her mathematics teaching, but still experienced issues in selecting appropriate strategies and activities for her students. "I didn't realize how much they already knew about volume when I made that lesson plan so I wasn't expecting them to like get everything, but by the end of the class they were really comfortable with word problems and they also knew cubes and the difference between area and volume."

While she was confident in her ability to teach the mathematics lesson she had planned, she was not able to make instructional decisions during the lesson based on her students' prior knowledge and mastery of the content. "Kids who already knew a lot about volume and word problems didn't get as much out of [the lesson] because they didn't have something to challenge them. So, I would've added more challenging aspects to [the lesson] if I were to redo it."

As far as science teaching, Blake's confidence was still low compared to her mathematics teaching. In her Field Based Science Inquiry Interview, after her second science teaching experience, she mentioned that she now feels more comfortable talking about science topics : "I think I became more comfortable with talking about science subjects 'cause science hasn't always been my like best thing and I was kind of scared to teach it, but now I like learning how to do this and like to interview them and figure out what they actually are talking about has given me more of a understanding, like a more comfortable, like how to, how I'm gonna approach science as a teacher, I'm not as intimidated by it."

Reflection on efficacy trajectory

Blake explained that her confidence in teaching had increased while reflecting on her efficacy trajectory over the course of the year. During her initial teaching experiences, Blake was intimidated by the mentor teachers, which was exacerbated by her limited knowledge of content and pedagogy. She stated that, "I became more confident, especially when I can make the connections between our classes [methods courses] and their [mentor teacher] classes."

At the end of her junior year, Blake's math teaching efficacy was still relatively low, which she attributed to her own struggles with math as a student. "It's not that I don't feel confident but I know I need to work on math, like that's something that I'm gonna have to plan extra hard when I start teaching because I was never the best math student." Blake's science teaching efficacy remained low throughout the year. She confessed that she had limited exposure to seeing science taught in the field, which decreased her confidence: "A little bit [observing science lessons]… we'd do a little bit of science at the end [of the day]. It's not as like much science as I've seen in the past classes."

DISCUSSION

Findings from our study document participants' initial efficacy beliefs, changes in their efficacy beliefs in relationship with their gain in pedagogical and domain knowledge, and the final stage of reflection on their efficacy trajectory over the course of a year.

Summary of Key Findings

The study data showed that preservice teachers came into the teacher education program with preconceived notions about their teaching abilities. These initial efficacy beliefs about mathematics and science teaching are grounded in participants' K-12 schooling experiences (i.e., positive or negative mathematics and science experiences), their college coursework, and their personal interests. Research investigating preservice teachers' beliefs has shown that individuals enter teacher education programs with some knowledge of what teaching and learning is, due to their previous schooling experiences (Thomson et al., 2012; Thomson & Palermo, 2014; Saban et al., 2007). Preservice teachers' cognitive schemas about their teaching beliefs have a strong influence on their future teaching activities and classroom decisions (e.g., Cretu, 2017; Löfström & Poom-Valickis, 2013; Thomson & McIntyre, 2013). All four case study participants made references during their interviews to the fact that their K-12 schooling experiences in mathematics and science classrooms influenced to some degree their present mathematics and science teaching efficacy, and their views about instruction. The lack of experience with elementary science influenced the preservice teachers' expectations regarding their abilities to teach science. They had limited models of effective science teaching, which impacted their efficacy for teaching science (Bong & Skaalvik, 2003; Thomson et al., 2017). In addition, preservice teachers who personally struggled in learning mathematics or science when they were students were influenced by their negative memories of learning science and mathematics (Thomson et al., 2017).

Findings from our study show that the preservice teachers' initial impressions of teaching mathematics and science changed throughout the academic year and their efficacy trajectories were influenced by learning about pedagogical strategies in mathematics and science that did not necessarily align with their K-5 schooling experiences. While preservice teachers negotiated the teaching strategies learned in methods courses with their memories (or lack of) of elementary mathematics and science instruction, they found benefit in helping young children learn mathematics and science. The preservice teachers' experiences working in schools combined with their methods courses helped them to begin to see their potential as teachers of STEM (Bandura, 1977; Bong & Skaalvik, 2003).

Also, study results showed that all participants experienced changes in their efficacy throughout the academic year. These changes occurred typically after a profound learning activity, especially after their teaching experiences. Changes happened when the participants were confronted with novel, challenging, and oftentimes, unexpected tasks. Examples from interviews referred to participants' inability to adapt their teaching based on student feedback during the lesson or the science content for upper grades seemed unexpectedly complex for planning a lesson.

The way each participant described their efficacy trajectory reflected distinctive, personal changes that are a reflection of their personal interests, opportunities to teach, the quality of their field experiences and their expertise in the content. In the current study, each individual expressed unique views about their professional teacher preparation and described different trajectories of their efficacy during the year with different time points in efficacy changes. Most of them entered their professional studies with naïve, perhaps simplistic visions of teaching. However, through lessons learned in methods coursework and field experiences with mentor teachers and elementary students, these views and thus the preservice teachers' feelings of efficacy began to shift. These shifts in thinking often aligned with growth in content knowledge or increased field classroom exposure. All four participants talked about the importance of getting strong academic experiences and solid pedagogical preparation to be able to support students' in-depth understandings of concepts.

International studies show that elementary teachers are required to adopt STEM reform initiatives and prepare their students for the state standardized tests, but most of them feel weak in their STEM preparation and under confident (Hill, Rowan, & Ball, 2005; Sharp et al., 2011). Sharp and colleagues (2011), in a study of elementary teachers from the UK, showed that most teachers feel unprepared, or have weak content STEM preparation which impeded their daily instructional choices and affected negatively the quality of their teaching.

Limitations

This study took place in the context of a STEM-focused teacher preparation program that is rather selective; that is, most of the preservice teachers enrolled in the program have experienced success in school (but not necessarily in math and science). Therefore, it is important that future research examines the same phenomenon in other contexts and settings.

Implications

There are several implications of this work for teacher preparation programs. First, teacher preparation programs need to structure and tailor activities in mathematics and science that help preservice teachers align their beliefs about how science and mathematics is taught with research-based practices that support quality instruction and reform initiatives (Charalambous & Philippou, 2010; Velthuis et al., 2014).

Second, since past experiences in mathematics and science learning impact preservice teachers' confidence in teaching these subjects, it seems collaboration between faculty in education and faculty in mathematics and the sciences may be helpful in changing learning experiences for preservice teachers. While these courses are intended to focus on deepening an understanding of the content, they also should demonstrate pedagogical strategies that are inquiry-focused or standards-based.

Third, teacher preparation programs should give attention to the field experiences that are offered in conjunction with the methods coursework. As found among our participants, the field experience is an important activity for impacting preservice teachers' confidence to teach. Therefore, alignment between methods coursework and field experiences in terms of the advocated practices should be considered. Additionally, ensuring that preservice teachers have opportunities to observe science teaching seems important in impacting efficacy to teach science, in particular.

REFERENCES

Bandura, A. (1993). Perceived self-efficacy in cognitive development functioning. *Educational Psychologist*, 28(2), 117-148

Bleicher, R. E. (2007). Nurturing confidence in preservice elementary science teachers. *Journal of Science Teacher Education*, 18, 841-860.

Bleicher, R. E. & Lindgren, J. (2005). Success in science learning and preservice teaching self-efficacy. *Journal of Science Teacher Education*, 16, 205-225.

Bong, M. & Skaalvik, E.M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, 15(1), 1-40.

Borko, H., & Whitcomb, J.A. (2008). Teachers, teaching, and teacher education: Comments on the National Mathematics Advisory Panel's report. *Educational Researcher*, 37, 565-572.

Brown, A. B. (2012). Non-traditional preservice teachers and their mathematics efficacy beliefs. *School Science and Mathematics*, 112(3), 191-198.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching efficacy of preservice elementary teachers. *Journal of Science Teacher Education*, 14(3), 177-192.

Charalambous, C.Y. & Philippou, G.N. (2010). Teachers' concerns and efficacy beliefs about implementing a mathematics curriculum reform: integrating two lines of inquiry. *Educational Studies in Mathematics*, 75(1),1-21.

Charalambous, C.Y., Philippou,G.N., & Kyriakides, L. (2008). Tracing the development of preservice teachers' efficacy beliefs in teaching mathematics during fieldwork. *Educational Studies in Mathematics*, 67 (2), 125-142.

Cretu, D. (2017). Hopes and fears of teacher candidates concerning the teaching profession. *MATEC Web of Conferences*, 121, 1-8. DOI: 10.1051/matecconf/201712112002

Enochs, L. G., Smith, P. L., & Huinker, D. (2000). Establishing factorial validity of the mathematics teaching efficacy beliefs instrument. *School Science and Mathematics*, 100(4), 194–202.

Hill, H., Rowan, B. & Ball, D. B. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. American *Educational Research Journal*, 42(2), 371-406.

Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, 37 (3), 275-292.

Löfström, E., & Poom-Valickis, K. (2013). Beliefs about teaching: Persistent or malleable? A longitudinal study of prospective student teachers' beliefs. *Teaching and Teacher Education*, 35, 104–113.

Newton,K.J., Leonard,J., Evans, B.R., & Eastburn, J.A. (2012). Preservice elementary teachers' mathematics content knowledge and teacher efficacy. *School Science and Mathematics*,112 (5), 289–299.

Richardson, G. M., & Liang, L.L. (2008). The use of inquiry in the development of preservice teacher efficacy in mathematics and science. *Journal of Elementary Science Education*, 20 (1), 1-16.

Saban, A., Kocbeker, N. B., & Saban, A. (2007). Prospective teachers' conceptions of teaching and learning revealed through metaphor analysis. *Learning and Instruction*, 17, 123–139.

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: theory, research, and applications*. Upper Saddle River, NJ: Pearson.

Setlage, J. (2000). Understanding the learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Teacher Education*, 84(1), 43-50.

Sharp, J. G., Hopkin, R., & Lewthwaite, B. (2011). Teacher perceptions of science in the National Curriculum. *International Journal of Science Education*, 33(17), 2407-2436.

Swackhamer, L. E., Koellner, K., Basile, C., & Kimbrough, D. (2009). Increasing the self-efficacy of inservice teachers through content knowledge. *Teacher Education Quarterly*, 36(2), 63-78.

Swars, S., Hart, L. C., Smith, S. Z., Smith, M., & Tolar, T. (2007). A longitudinal study of elementary pre-service teachers' mathematics beliefs and content knowledge. *School Science and Mathematics*, 107, 325-335.

Thomson, M. M., Turner, J.E., & Nietfeld, J. (2012). A typological approach to investigate motivation for teaching and beliefs about teaching of preservice teacher candidates. *Teaching and Teacher Education*, 28, 324-335.

Thomson, M. M., & McIntyre, E. (2013). Teachers' professional goals: An examination of different teachers' typologies with respect to motivations and beliefs about teaching. *Teacher Development*, 17(4),409-430.

Thomson, M.M. & Palermo, C. (2014). Preservice teachers' understanding of their professional goal: Case studies from three different typologies. *Teaching and Teacher Education*,44, 56–68.

Thomson, M.M., DiFrancesca, D., Carrier, S., & Lee, C. (2017). Teaching efficacy: Exploring relationships between mathematics and science self-efficacy beliefs, PCK and domain knowledge among preservice teachers from the United States. *Teacher Development*, 21 (1), 1-20.

Thomson, M.M., Huggins, E. & Williams, W. (2019). Developmental science efficacy trajectories of novice teachers from a STEM-focused program: A longitudinal mixed-methods investigation. *Teaching and Teacher Education*, 77, 253-265.

Utley, J., Moseley, C., & Bryant, R. (2005). Relationship between science and mathematics teaching efficacy of preservice elementary teachers. *School Science and Mathematics*, 105 (2), 82-87.

Velthuis, C., Fisser, P., & Pieters, J. (2014). Teacher training and preservice primary teachers' self-efficacy for science teaching. *Journal of Science Teacher Education*, 25, 445-464.

Appendix A

Measures, Timeline and Procedures for Data Collection

A. Fall Semester

1. Introductory Interview was conducted in the early Fall semester at the very beginning of the junior year, capturing initial views on teacher preparation, efficacy beliefs and planned instruction.

2. Math Cognitive Interview #1 was conducted mid Fall semester after participants' first mathematics lesson; captured participants' reflections on their mathematics teaching.

3. STEM Cognitive Interview conducted mid Fall semester after participants' first STEM lesson (STEM Project) was taught to elementary students; captured participants' reflections on science teaching.

A. Spring Semester

4. Math Cognitive Interview #2 was conducted mid Spring semester after participants' second mathematics lesson was taught to analyze the lesson and their mathematics teaching.

5. Field Based Science Inquiry Assignment Interview conducted mid Spring semester after participants' science lesson (Field Based Science Inquiry Assignment) was taught to analyze the course of the lesson and their science teaching.

6. Getting to Know You Interview was conducted at the end of Spring semester to learn more about participants' background.

7. End of Year Interview was conducted at the very end of the junior year, end Spring semester capturing views on teacher preparation, efficacy beliefs, and changes in their thinking during the year.

Appendix B
Summary of Cross-Case Study Analysis

	Descriptions of initial efficacy beliefs before mathematics and science teaching	Descriptions of particular moments capturing changes in efficacy beliefs	Descriptions of their trajectory of efficacy beliefs development over the year
Parker	High efficacy for mathematics teaching ("I am ready to teach math"); but not very confident about science teaching ("you need to refresh yourself on certain things.")	Moderate mathematics efficacy beliefs after her first math lesson ("It wasn't that bad"), and slightly higher confidence about science teaching("lesson went pretty well, better than math") Increased mathematics efficacy after second teaching ("I thought it was fine. I was okay with it."), and moderate science efficacy, but intimidated by students' learning and responses to her teaching ("maybe that can be a little bit intimidating.")	Feels high math efficacy over the course of the year; starts with very low science efficacy but slight increase by the end of the year ("And then, I feel confident about science but then sometimes I feel unconfident …like with English and math we actually have taught, but with science we really haven't so I'm not as confident in that as the other two."
Morgan	High efficacy in math teaching with less comfort in science instruction. Science courses in high school and college not as engaging as math. She described one high school science course, "So, mostly it was just very notes intensive and I was just memorizing things. " She related a lot of her feelings of efficacy to her teachers. "I was never really very confident in my ability to do science and in high school my teachers helped me with math and so I felt really confident about that."	Morgan felt confident to teach the lesson because of her math content knowledge. She felt satisfaction to witness student success. "I enjoyed it more than I thought I would. I was really scared at first...It was just the first time I ever taught them all at once and so but I was really excited after the lesson." The teaching experience improved her teaching science views "I was just nervous about science just because I was never that interested in science but now I think it's one of my favorite subjects to teach."	Confidence started out high but upon realization that teaching is much more complex than expected, her confidence declined. After the teaching experiences her confidence is "starting to come back." In the coming year she looks forward to learning more about how to be a good teacher "I really want to learn is just what it's like to be in a classroom for a whole year or almost a whole year."
Casey	High efficacy for her ability and teaching reading and literacy "And so, I've, it's always been my favorite, reading and literacy has been my focus, that's what I'm most excited to teach and I think it showed in my grades this semester." High efficacy for teaching mathematics and science based on belief that the content is at a basic level in elementary school. "I think everything at elementary school level I'll be able to teach just because it doesn't progress much further, I mean, when I was	High efficacy for mathematics teaching after her first lesson, but low efficacy for teaching mathematics due to specific issues she noticed when reviewing her lesson. Reliance on mentor teacher to reteach the content. "I mean, the good thing is I knew that if I didn't do a great job teaching it that their teacher could really go over a lot the next day but so that was a comfort to me but also like it's the first lesson, you want to make sure they get it because it rests on you."	Starts with high science teaching efficacy on same bases that it is on a basic level. Continues to express high efficacy for teaching science with her focus on making learning fun and activity-based. Feels that her confidence will continue to increase as she teaches the same content multiple times. "I feel like the more competent you feel teaching science the more confident you're gonna be at what you're doing and I think it relates because I think I'm gonna end up leaving school feeling like I can teach it pretty well and I don't think

	in elementary school. I don't know if it's like this anymore. It didn't progress much further past long division and I, I enjoyed that, that's so much fun."		a lot of teachers have that same opportunity"
Blake	Initial beliefs revealed anxiety about teaching mathematics, but felt her early learning experiences in the math methods course were helping her relax: "I think [it] made me feel more comfortable especially for a beginning lesson cause I knew they wouldn't be able to ask me a question I wouldn't know." Also, lacked confidence about science teaching in the beginning and understood science teaching as engaging.	Mathematics efficacy increased after second lesson taught, and due to increased exposure to mathematics content and pedagogical knowledge. However, Blake's science teaching efficacy remained low throughout the year. She had limited experience teaching science, which decreased her confidence.	Blake's math teaching efficacy was initially low, increased slightly after her first teaching lesson, but generally remained low during the year, which she attributed to her own struggles with math as a student. Her science teaching efficacy was constantly perceived as lower due to her limited experience teaching science during the year.

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Teacher Leadership in Special Education: Exploring Skills, Roles, and Perceptions

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Abstract

Special Education teachers frequently assume formal or informal leadership roles and responsibilities across disciplines (Council for Exceptional Children, 2015a, 2015b). However, despite the increasing attention paid to teacher leadership on an international scale (Wenner & Campbell, 2016), little research exists on the experiences and needs of teacher leaders within the diverse field of Special Education. In this descriptive phenomenological study, we addressed the following questions: 1) What does teacher leadership within the landscape of Special Education look like? 2) How does this work relate to the roles and dispositions laid out in both the Teacher Leader Model Standards (2011) and the Council for Exceptional Children's Special Education Specialist Preparation Standards (2015a, 2015b)? We found that Special Education teacher leaders primarily demonstrate leadership via support, specifically through the skills of advocacy, facilitating, innovating, and 'administrating'.

Keywords: *special education, teacher leadership, professional development, teacher education, qualitative methods*

INTRODUCTION

Special Education teachers frequently take on formal and informal teacher leadership roles at their schools (Council for Exceptional Children, 2015a, 2015b). Indeed, it could be argued that all Special Education teachers serve as teacher leaders simply given the scope of their collaborative responsibilities across disciplines and grade levels (Billingsley, 2007; Council for Exceptional Children, 2015a, 2015b; Klingner & Vaughn, 2002; York-Barr, Sommerness, Duke, & Ghere, 2005). Despite the de facto role of experienced Special Education teachers as teacher leaders, however, there is little research specifically on teacher leadership within Special Education. Existing studies include York-Barr et al.'s (2005) exploration of the roles and responsibilities of inclusive Special Education teachers; Billingsley's (2007) case study of a Special Education teacher who took on leadership roles at her school site and within her district; and Vernon-Dotson's (2008) study on teacher collaboration to promote inclusion in General Education classrooms.

In this descriptive study, we drew primarily upon Billingsley's (2007) findings to examine 17 additional cases of teacher leaders in Special Education. We were interested in exploring what teacher leadership looks like within the interdisciplinary landscape of Special Education, and how this relates to the roles and responsibilities laid out in the Teacher Leader Model Standards (2011)[1] and the Council for Exceptional Children's Special Education Specialist Advanced Preparation Standards (2015a). Our goal was to contribute to a better understanding of the variety of

[1] Since initiating our study in 2010, a revised document entitled "The Teacher Leadership Competencies" has been collaboratively published by the National Education Association, the National Board for Professional Teaching Standards, and the Center for Teaching Quality (2018), designed to replace the Teacher Leader Model Standards. However, since our study was crafted with the original Teacher Leadership Model Standards in mind – as presented to our participants – we have maintained the original wording. We should note that Special Education remains conspicuously absent from the newly published Teacher Leadership Competencies, thus substantiating the relevancy of our concerns as outlined in this paper.

leadership roles and responsibilities Special Education teacher leaders (or SETLs) currently take on, thus allowing SETLs working within and across diverse disciplines to receive appropriate support and guidance from administrators, teacher-educators, and professional development providers – all with the ultimate outcome of benefiting students with diverse learning needs.

LITERATURE REVIEW

Teacher leadership has been defined in numerous ways (NEA, NBTS, & CTQ, 2018; Wenner & Campbell, 2016; York-Barr & Duke, 2004), with most researchers echoing Katzenmeyer and Moller's (2009) description of a teacher leader as "one who leads both in and beyond the classroom, identifies with and contributes towards a community of teacher learners and leaders, and influences others toward improved educational practice" (pp. 164-165). The roles taken on by teacher leaders can be either formal or informal, paid or unpaid, full-time or part-time (Katzenmeyer & Moller, 2009; Margolis & Huggins, 2012; Sun, Frank, Penuel & Kim, 2013). While more research is needed directly linking teacher leadership to improved student outcomes, numerous benefits to teachers and schools have been noted (Wenner & Campbell, 2016).

Missing from current literature on teacher leadership, with just a few exceptions, is an explicit discussion of how teacher leadership plays out within the field of Special Education. In her case study of a single Special Education teacher taking on leadership roles, Billingsley (2007) noted that most discussions about leadership within Special Education center around roles for administrators, without taking into account the variety of leadership responsibilities assumed by Special Education teachers themselves. She posed numerous questions for future research, including one which served as a direct impetus for our own study: How do Special Education teacher leaders perceive their roles?

York-Barr et al. (2005) explored the roles and responsibilities required of Special Education teachers supporting students with low incidence disabilities in inclusive educational settings, and their findings unexpectedly yielded results related to teacher leadership. They posited that "the work of special educators in inclusive education settings is appropriately viewed as teacher leadership" (p. 193), and more specifically, they found that "embedded in the work of the special educators were leadership functions required to create and sustain the momentum for inclusivity which is not a dominant cultural norm" (p. 205). Among the ideas noted by York-Barr et al. as "areas for learning and development" for teacher leaders within Special Education were "directing the work of paraprofessionals and working within a variety of curricular frameworks" (p. 212). These suggestions emerged in our own findings, as we discuss below. Finally, in a multiple case study project, Vernon-Dotson (2008) documented the impact of three school-based teacher leadership teams focused on improving inclusive opportunities for students with mild to moderate disabilities. Vernon-Dotson found that levels of inclusion increased, though the quality of inclusion remained poorly defined.

The Council for Exceptional Children's (2015) Special Education Specialist Advanced Preparation Standards outline seven core areas of skills Special Education teachers are expected to meet as they achieve increased competency in their craft. While these standards do not specifically mention teacher leadership, many of them relate to the Teacher Leader Model Standards (2011). See Table 1 below for a side-by-side comparison of both sets of standards.

Table 1

Teacher Leader Model Standards and Special Education Specialist Advanced Preparation Standards

Teacher Leader Model Standards (2011)	**Special Education Specialist Advanced Preparation Standards (2015)**
Domain I: Fostering a Collaborative Culture to Support Educator Development and Student Learning Domain II: Accessing and Using Research to Improve Practice and Student Learning Domain III: Promoting Professional Learning for Continuous Improvement Domain IV: Facilitating Improvements in Instruction and Student Learning Domain V: Promoting the Use of Assessments and Data for School and District Improvement Domain VI: Improving Outreach and Collaboration with Families and Community Domain VII: Advocating for Student Learning and the Profession	1. Assessment 2. Curricular Content Knowledge 3. Program, Services, and Outcomes 4. Research and Inquiry 5. Leadership and Policy 6. Professional and Ethical Practice 7. Collaboration

As we conducted a deeper analysis of these two documents, we found an overlap between teacher leadership expectations – either explicit or implicit – in both General and Special Education, across disciplines. However, the unique work taken on by Special Education teachers adds an extra dimension to the discussion, one that merits the direct attention we give it here.

RESEARCH DESIGN AND METHODS

We designed our project as a phenomenological study to explore “the common meaning for several individuals" – in this case, Special Education teacher leaders – “of their lived experiences of a concept or phenomenon” (Creswell, 2013, p. 76). Our aim was to develop “a composite description of the essence of the experience… for all of the individuals” (p. 76), with a culminating emphasis on the “what” and “how” of this experience.

When developing our guiding research questions for this study, we began by determining three keys areas of inquiry, then added more specific sub-questions to focus our research. The resulting questions – a mix of descriptive and interpretive questions (Maxwell, 1996) – are as follows, with broader questions followed by related sub-questions:

1) How do Special Education teachers define and perceive teacher leadership within their field? What characteristics, skills, or roles do Special Education teachers believe are relevant to teacher leadership more broadly within Special Education, and specifically in their current positions?

2) What leadership roles and responsibilities do Special Education Teacher leaders (SETLs) take on? How does this vary within different grade spans, school settings (private versus public), and job descriptions/titles?

3) How do SETLs believe they can become more effective as teacher leaders? What teacher leadership skills do SETLs feel they are strong or not so strong in? What form(s) of training and support from administrators would SETLs most like to receive in terms of continuing their professional development as teacher leaders?

In this paper, we report on findings from research questions one and two; findings from question three are discussed in a separate paper.

Participants

Participants in a phenomenological study are strategically selected so that they have all experienced the phenomenon in question – in this case, teacher leadership within Special Education. To that end, we employed a purposeful sampling approach to identify potential Special Education teacher leaders (SETLs) who might serve as key informants for our study (Fraenkel & Wallen, 2009). Given that no operationalized definition exists of a "teacher leader", we relied on a combination of administrative referral and self-identification of individuals to select participants. A sample of 17 potential SETLs in Southern California were sent an email inviting them to consider participation in the study if they felt they met the criteria (answering yes to the question, "Would you define yourself as a teacher leader?"), and were informed about the goals and methods of the study, as well as their rights as participants. All agreed to participate.

In order to achieve maximum variation within our sample (Maxwell, 1996), we solicited participation from Special Education teachers working in a variety of settings, capacities, and disciplines. Our 17 participants (2 men, 15 women) taught in classes ranging from pre-school to elementary to high school, across a span of disciplines, in a variety of school settings. They represented a range of ethnicities (three Latino, two Asian-American, two African-American and ten White), ages (from 25 to 62), and years of experience (from newer teachers with just 5-6 years of teaching experience, to veteran teachers with more than two decades of teaching and other leadership duties). All participants were assigned pseudonyms. Table 2 below provides an overview of participating teacher leaders' stated ethnicities, genders, ages, school settings, and years of teaching experience.

Table 2

Participants' Ethnicity, Age, Gender, School Setting, and Years of Experience

PARTICIPANT (pseudonym)	**STATED ETHNICITY**	**STATED AGE**	**STATED GENDER**	**TYPE OF SCHOOL**	**TOTAL YEARS TEACHING**
Allie	White	25	Female	Catholic	4
Daniel	Latino	32	Male	Public	5
Cynthia	White	43	Female	Non-Private School	5
Kimberly	White	29	Female	Catholic	6
Erica	Latina	34	Female	Public	6
Marie	White	56	Female	Public	6
Olivia	Latina	45	Female	Public	7
Louisa	White	32	Female	Non-Private School	8
Jon	Asian-American	32	Male	Public Charter	8
Julianne	White	43	Female	Public Charter	11
Gloria	White	62	Female	Public	14
Karen	White	45	Female	Public	17
Tameka	African-American	42	Female	Public	20
Sharon	Asian-American	54	Female	Public	21
Susan	White	44	Female	Public	22
Benita	African-American	53	Female	Public	22
Linda	White	59	Female	Public	38

Instruments

We conducted semi-structured interviews (20-45 minutes long) with each participant in order to better understand their specific experiences as Special Education teacher leaders (Seidman, 1991). Participants were asked a series of open-ended questions designed to elicit their thoughts and opinions on teacher leadership within Special Education (Lawy, 2003) (see Appendix A).

Data Analysis

Interview data were analyzed using an inductive, constant comparative approach, which allowed us to refine our interview questions and begin to make sense of our findings early in the process (Charmaz, 2006; Glaser & Strauss, 1967). In our first coding cycle, we employed several integrated coding methods. First we utilized line-by-line Initial Coding to break our data into discrete units, examining them and comparing them for similarities and differences (Saldana, 2009). During this process, we also employed In Vivo codes by highlighting quotes from the participants that seemed especially powerful or salient as "symbolic markers of participants' speech and meanings" (Charmaz, 2006, p. 55). Next, we utilized Structural Coding to label and index responses to our key questions (Saldana, 2009). We coded all responses to the question, "What leadership roles do you currently take on as an educational specialist at your school?" as CURRENT TL ROLES. We employed a third initial coding process – Process

Codes – to capture key activities engaged in by each of the participants, using gerunds to preserve "the fluidity of [participants'] experience" (Charmaz, 2006, p. 49).

For instance, the following Process Codes emerged in our analysis of Kimberly's transcript: advocating for students, communicating with parents, educating colleagues, facilitating collaboration, handling discomfort, modeling lifelong learning, pioneering special education initiatives, seeing the bigger picture and shifting school culture. Process codes were then compared across transcripts.

We conducted a second cycle of coding to further refine our initial codes and determine salient categories and themes (Saldana, 2009). During this cycle, we "developed a sense of thematic…organization from [our] array of First Cycle Codes" (p. 149). Our final Theoretical Code – serving as an "umbrella that covers and accounts for all other codes and categories" (Saldana, 2009, p. 163) – was Supporting, with the following sub-categories further shaping our collective findings: Advocating, Facilitating, "Administrating", and Innovating.

FINDINGS: DEFINITIONS, ROLES, AND SKILLS OF SPECIAL EDUCATION TEACHER LEADERS

In this section, we discuss participants' responses to the following interview questions:

1) How do you define teacher leadership?
2) Do you believe there is a role for teacher leadership in the world of Special Education? Why or why not?
3) What leadership roles do you currently take on as an Educational Specialist at your school?
4) In your opinion, what characteristics or skills do Educational Specialists need to possess in order to be effective leaders?

We use the abbreviation "SETLs" as short-hand for the specific participants in our study, while acknowledging that their responses can't necessarily be generalized to all Special Education teacher leaders.

Defining Teacher Leadership

Although our study focused specifically on teacher leadership within Special Education, we began by asking participants to define the term "teacher leadership" more broadly; responses were varied and complex. In her lengthy definition of teacher leadership, for instance, Julianne noted responsibilities ranging from "being a strong force in the classroom [to] creating an enriching environment conducive to learning which fosters student strengths and allows these students to progress academically", to serving as "a positive mentor to colleagues", to being someone who "works collaboratively with all stakeholders to better instruction for students" (Interview, February 23, 2011).

Linda pointed out that teacher leaders will invariably manifest their leadership in different ways, depending on their comfort level and personality:

> Teacher leadership, I think, comes in different ways – it can be at the classroom level, as a mentor, as a colleague, that helps to lead others… There's the leader who wants to stay in their own classroom and lead that way and there's the leader who wants to jump out and find other places to lead as well. (Interview, June 13, 2011)

Indeed, SETLs (like teacher leaders across all settings) take on a variety of roles and responsibilities depending on their unique situations, strengths, interests, and capacities. One common theme across participant responses was the belief that a teacher leader is someone who does more than "just" teach – that is, he or she is “willing to take on more than just the daily requirements of teaching” (Marie, Interview, February 15, 2011) and is available to serve in other capacities. As Sharon described it: “I [see] teacher leadership as being lead teacher, or being like a central person your principal and co-teachers can come to to get information or to get help, or to be a mentor” (Interview, February 15, 2011).

According to our participants, teacher leadership encompasses a broader commitment to improving one’s school (Levenson, 2014). Karen, a recent teacher-of-the-year at her school site and in her district, noted that teacher leadership involves “doing a lot of research in new ideas, bringing new ideas to the table, constantly trying to come up with new things that you can do for your department or for the school in general” (Interview, June 17, 2011) – thus keeping the school’s broader vision and well-being in mind. Daniel similarly noted that a teacher leader is one who “really looks at the school as a whole, and really takes into consideration the strengths and needs of other people in their department… [to] work together to close the achievement gap with their kids” (Interview, June 13, 2011).

Being a voice of the school and an advocate for students was also seen by our participants as a critical element of teacher leadership, particularly within the sphere of Special Education. Kimberly, the only Special Education teacher at her small private school, described a teacher leader as “a teacher who takes charge and has the students’ best interests at heart and is willing to stand up and, you know, do whatever he or she needs to do to make sure the needs of the students are met” (Interview, January 19, 2011).

Situating Teacher leadership within Special Education

While our first question encouraged participants simply to define teacher leadership, our follow-up question provided an opportunity for them to think more specifically about teacher leadership in the context of Special Education. In response to the question, “Is there a role for teacher leadership in the world of Special Education?”, every participant responded “yes” without hesitation. Eight began their response with “definitely”, six with “absolutely”, and one with “of course”.

Without prompting, all participants elaborated on why they feel the way they do about this issue. One common theme was the need for SETLs to move out of the “silos” in which Special Education teachers often find themselves (Hunt, Powell, Little & Mike, 2013). As Louisa stated:

> I think it’s necessary; otherwise you’re out on an island by yourself. If you’re not collaborating and taking the initiative to take ideas to the next level, then I just think you can only function at half capacity. You can’t really do everything that needs to be done, or better the program that you’re in, or better your knowledge. (Interview, March 7, 2011)

Similarly, Gloria mentioned the need to be proactive with General Education teachers:

> It used to be that when a teacher went into their classroom and closed the door, they were an island unto themselves, [which is not] the way it is these days. We have to be open and collaborative with anybody, no matter what part of the education field. (Interview, February 15, 2011)

Thus, the SETLs in our study view teacher leadership as a way to encourage and support more collaboration between General Education and Special Education teachers.

Marie’s response focused on mentoring as a salient facet of teacher leadership, noting that “a lot of people who come into Special Education don’t have a clue what they are getting into” and that sharing her expertise with new teachers is where she has “found that [her] role in leadership has been really valuable” (Interview, February 15,

2011) (c.f. Duffy & Forgan, 2004; Mastropieri, 2001; Shillingstad, McGlamery, Davis & Gilles, 2015). Susan similarly noted:

> I've worked with district interns… and it's interesting to hear them week to week describe scenarios where they are supported in their first year, and scenarios where individuals are not supported… There's a big difference in how those individuals take classes, how they interact socially. So yes, they need a mentor, they need a leader to support them. (Interview, February 3, 2011)

SETLs' Current Leadership Roles and Responsibilities

Special Education teachers take on a variety of different leadership roles by the very nature and description of their multi-faceted and interdisciplinary jobs (Conderman & Katsiyannis, 2002; Council for Exceptional Children, 2015a, 2015b). When asking our SETL participants to tell us some of the specific leadership roles they have inhabited, we anticipated hearing a variety of responses – however, certain commonalities emerged, which we discuss below.

Collaboration with colleagues was a key responsibility named by most participants. Erica, who is currently working in a district office and was reflecting back on her days as a teacher leader at her school, noted that "partnering with all of my General Education friends was a big piece of that leadership work, and I think I saw the most ripple effects when I partnered not just with my Special Education colleagues; we found ways to bring all those folks together, instead of working in isolation" (Interview, June 13, 2011).

For Daniel (also currently working in a district office), collaborating with and befriending his General Education colleagues when he was a teacher served the larger goal of helping to effectively mainstream his special needs students into General Education classrooms. He noted: "I really tried to kind of connect on a personal level, and once I had that connection – I had to do what I had to do, I kind of threw a curve ball in there and got my kids in the door" (Interview, June 13, 2011). Daniel's statement ties into the notion of advocacy for students with special needs – a critical role of SETLs that we return to later in this article.

Another common responsibility reflected in participants' responses was modeling best teaching practices. Julianne noted: "I am responsible for promoting good teaching practices that allow students access to grade level curriculum" (Interview, February 23, 2011). This role may involve explicit mentoring or coaching; as Jon pointed out, "I've also… mentored other teachers, new teachers coming in to Special Education as well as General Education – just giving them tips and strategies, just being a support network for them as well" (Interview, February 22, 2011). Working to improve best practices may also involve the formation of professional learning communities (Vernon-Dotson, 2008), such as the "IEP [Individualized Education Plan] clinic" mentioned by Susan, in which she and her colleagues look at "what problems are we having with IEPs and the process, or, looking at grade-level standards, looking at strategies, looking at a lesson, how can we improve" (Interview, February 3, 2011).

Other SETLs in our study mentioned the leadership role of being the "go to" person or "point person" at their school site. Susan told us that in her second year as a Special Education teacher, she began "managing the IEP schedule for the school, making sure the communication between related service providers, administration, parents… was coordinated" (Interview, February 3, 2011). Marie similarly noted:

> I'm part of the professional learning community [at my school], which means I'm considered a teacher leader by my peers. I'm the person they come to if they have a question about behavior, about Special Education, or the classroom, about how a student qualified for Special Education. And on occasion if they

are having challenges with some of my [Special Education teaching] peers, other teachers will seek me out and we'll discuss ways to solve that problem in a way that's positive. (Interview, February 15, 2011)

Thus, according to Marie's experiences, SETLs not only serve as essential "gatekeepers" for Special Education at their schools, but also function in a mediating capacity as needed, when interpersonal problems arise between colleagues (Vernon-Dotson, 2008).

Sharon, who co-teaches Pre-K half-day classes, mentioned that her primary role as a teacher leader is serving as the lead teacher for the "morning team" at her school; however, she noted that her other duties include working with the principal and the lead speech team on curriculum development; helping with interviewing new staff and faculty; disseminating information to all teachers; and being available to help with administrative duties when her principal is away from the site once a week (Interview, February 21, 2011). Thus, for Sharon, being a teacher leader occasionally shifts into administrative duties as needed. Jon also officially splits his time between classroom teaching (as a Resource Teacher) and administrative responsibilities as a vice principal at his public charter school (Interview, February 22, 2011).

Other roles and responsibilities mentioned were coordinating the software used to help generate IEPs; serving as testing coordinator; participating on various other committees and teams; and working closely with and training paraprofessionals.

Characteristics and Skills of Special Education Teacher leaders

When our participants were asked to describe what characteristics and skills they felt should be possessed by SETLs, the most dominant response was "people skills" – specifically, an ability to communicate well, collaborate effectively with others and see situations from others' perspectives (von Frank, 2013). Erica's immediate response to this question was that "those social emotional skills, I think, are very important – that emotional intelligence to collaborate with other people" (Interview, June 13, 2011). Sharon similarly stated right away, "I guess the first [trait I would list] would be 'approachable'" (Interview, February 21, 2011). Louisa specifically noted that it is important for SETLs to be able to communicate "in a way that's constructive and doesn't alienate anybody" (Interview, March 7, 2011) These responses all point towards our participants' belief in the importance of SETLs being able to communicate effectively with their colleagues and others they work with, and to come across as an approachable colleague who is available and willing to help.

Indeed, the ability to successfully interact and communicate information without alienating one's colleagues was mentioned by several participants as especially important for SETLs. Kimberly, for instance, noted, "I think you need to be able to… sound professional, but not be intimidating, be able to talk on a parent's level, a student's level, talk to a teacher so you don't come across like you know everything and what they're doing is completely wrong" (Interview, January 19, 2011) Karen similarly pointed out that "you have to be able to communicate very well with [colleagues], and be a team player, yet at the same time guide them in certain areas, so that it's a team decision, and not just top down" (Interview, June 17, 2011).

Other interpersonal skills and characteristics were also named in participants' responses to this question. Jon stated the value of both "patience" and "compassion" (Interview, February 22, 2011), while Susan pointed out the "win-win" nature of effective collaboration as a teacher leader, noting:

> I will always see [an issue] through my lens, and a very busy lens, and so I need to collaborate with the General Ed teacher, or my colleague, or the person that's on the yard watching the child at lunch or such,

because if you only, for example, write an IEP through your eyes, it's very limited. (Interview, February 3, 2011)

The ability to view a situation through others' perspectives points to the broader need for SETLs to exhibit flexibility – not just when working with colleagues, but in one's classroom as well. As Jon stated, "You'll have a few students sent to you with behavior problems, and that will shift your whole day. Being able to take that, be flexible with it, but still maintain your course of action [is critical]" (Interview, February 22, 2011).

Flexibility is just one among many skills the SETLs in our study say they have demonstrated when serving as a professional role model to colleagues. Jon noted that SETLs must continuously be:

> … demonstrating some skills or experiences that you have in helping others to be able to support students in Special Education or General Education, because my belief is that good teaching is good teaching, so the strategies that we're learning in Special Education apply for gifted kids as well as those who may have autism or [are] lower functioning [in a General Education setting]. (Interview, February 22, 2011).

Given how many roles a SETL plays on a daily basis, and the numerous critical details involved in Special Education documentation, organization on both a micro and macro level was another important skill mentioned by our participants. Gloria noted:

> You have to be able to coordinate your primary job and all the other little things that you do" (Interview, February 15, 2011), while Jon pointed out that, "You have to be able to cross your Ts and dot your I's – I guess that goes back to details. You have to be very detail oriented" (Interview, February 22, 2011).

Expertise with curriculum and standards across a range of grade levels and disciplines was also an important concern for the SETLs in our study (Council for Exceptional Children, 2015a, 2015b). Sharon mentioned the need to be knowledgeable "about… how to modify lesson planning, and how to even assess a child's level and adapt" (Interview, February 21, 2011), while Erica noted that SETLs "have to have a deep understanding of their pedagogy", to "really… understand why you're doing what you're doing" (Interview, June 13, 2011). Several participants pointed out the importance of being familiar with academic standards across disciplines and at all grade levels, to "be supportive of all students and teachers" (Gloria, Interview, February 15, 2011).

A final SETL trait which appeared repeatedly as a broader theme throughout all interview responses was that of being proactive. As Jon put it, if you are a SETL you must be "proactive in your planning and anticipating problems that may occur, or even anticipating how you want to take a class as far as content, or as far as instruction or even behavior management or behavior plans" (Interview, February 22, 2011). Being proactive implies not simply sitting back and being told what to do; as Gloria noted, "You… have to be a person who is outgoing, somebody who's willing to take on responsibilities. You have to be motivated" (Interview, February 15, 2011).

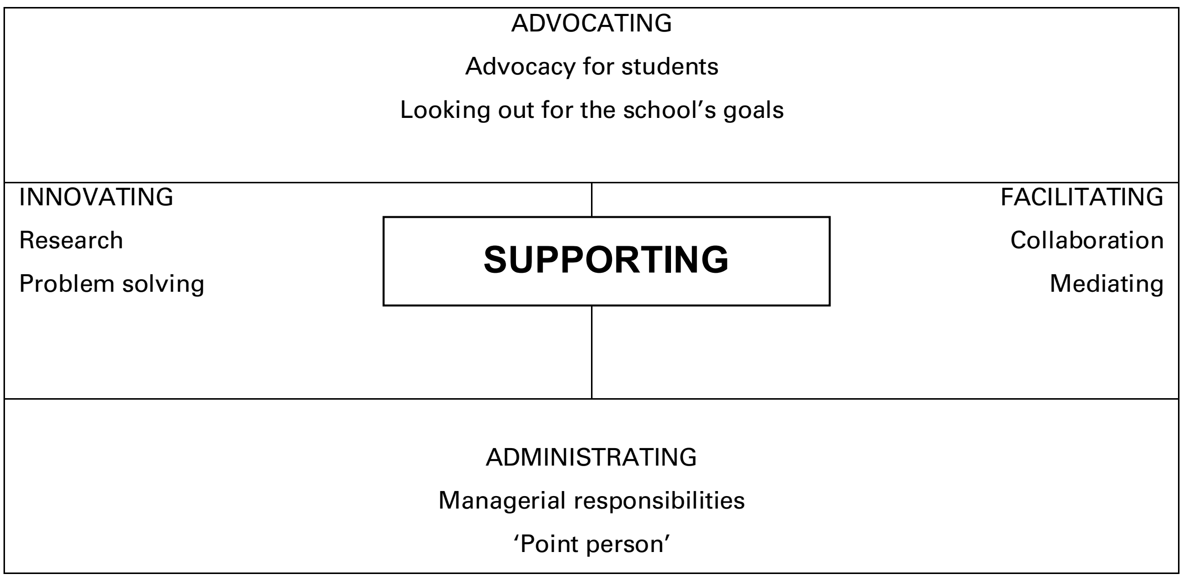
This particular characteristic ties in to the broader theme of advocacy (discussed in more detail below). Benita, for instance, specifically noted that a SETL must "be a fighter – so that's the first thing; you have to always be looking out for the needs of others" (Interview, November 30, 2010). Indeed, most of the participants we interviewed mentioned instances in which they have had to take initiative at their schools in order to make positive changes on behalf of students (Jacobs, Beck, & Crowell, 2014). Daniel's previously cited story about establishing connections with his General Education peers in order to effectively mainstream his students is one example of this (Interview, June 13, 2011). Kimberly shared an anecdote in which her principal wanted her to "take more [of a] back seat" and let teachers come to her rather than going to them, but she said she "[has] a problem with that", given that "the students are then the ones that are going to suffer" (Interview, January 19, 2011). Indeed, Kimberly's definition of a Special Education teacher leader as someone "who takes charge and has the student's best interests at heart and is willing to stand up and, you know, do whatever he or she needs to do to make sure the needs of the students are met" reflects this sense of commitment to serving as an advocate for students' needs.

DISCUSSION: SETLS SUPPORTING STUDENT SUCCESS

Much of what we learned from our participants' interview responses corresponds to similar findings from previous studies with General Education teacher leaders (York-Barr & Duke, 2004); however, there are a number of distinctions as well. As we engaged in second cycle coding of our initial findings, we looked for dominant themes related to the phenomenological "essence" of teacher leadership specifically within Special Education (Creswell, 2013). Our final Theoretical Code – serving as an "umbrella that covers and accounts for all other codes and categories" (Saldana, 2009, p. 163) – was Supporting, with the following sub-themes further shaping our collective findings: Advocating, Facilitating, "Administrating", and Innovating. In Figure 1 below, Supporting is positioned as the core of teacher leadership in Special Education, with the four sub-themes surrounding it in no particular order or orientation:

Figure 1

How do SETLs lead through support?



While data supporting these sub-themes inevitably overlap, for the sake of clarity each is discussed individually below. Each section begins with an interview quote which provides a snapshot of how SETLs impact students and schools. Throughout our discussion, we make connections to both the Teacher Leader Model Standards (2011) and the Council for Exceptional Children's Special Education Specialist Advanced Preparation Standards (2015a).

Advocating

"I kind of threw a curve ball in there and got my kids in the door." – Daniel (Interview, June 13, 2011)

SETLs in our study made it clear that they are first and foremost advocates for their students. Interview responses indicated that SETLs work in a variety of ways to proactively ensure that all students' needs are being met. This includes meaningful collaboration with General Education teachers (also discussed in the next theme of Facilitating);

staying up-to-date on effective strategies and laws related to serving students with special needs; and serving as the "gatekeeper" for mandated plans (such as IEPs) at their school site.

Erica noted the importance of ensuring that students with special needs are integrated into a broader school community that is welcoming for all:

> Our students are part of a school community – and so, recognizing that I could just work with kids with disabilities, but the reality is our students are part of a school community, and how do we create an environment where all students are welcome? (Interview, June 13, 2011)

The skill of advocacy is highlighted in Domain 7 of the Teacher Leader Model Standards (Advocating for Student Learning and the Profession) and in Standard 5 (Leadership and Policy) of the Special Education Specialist Advanced Professional Standards (2015a):

> 5.4 Special education specialists advocate for policies and practices that improve programs, services, and outcomes for individuals with exceptionalities.
>
> 5.5 Special education specialists advocate for the allocation of appropriate resources for the preparation and professional development of all personnel who serve individuals with exceptionalities. (p. 5)

While being proactive is implied in York-Barr and Duke's (2004) statement that teacher leaders are "creative innovative seekers of challenge and growth" (p. 268), advocacy per se is noticeably missing from the studies included in their widely cited meta-review. In recent years, however, advocacy on behalf of students, teachers, parents, the school, and the broader community has emerged as an increasingly important facet of teacher leadership (Lukacs & Galluzzo, 2014; NEA et al., 2018). Jacobs et al. (2014), for instance, explore teacher leaders as "equity-driven change agents" who work to address the "inequities that continue to be present for students of color, for English-language learners, for students from low-income households, for LGBTQ students and for students with disabilities" (p. 576). Yet teacher leadership within Special Education – such as meeting the specific needs of students with disabilities – is noted only in the abstract of Jacobs et al.'s article, indicating a need for further exploration and study within this area.

Facilitating

"Otherwise, you're out on an island by yourself." – Louisa (Interview, March 7, 2011)

Louisa's statement above (referenced earlier in our article) was an elaboration on her "yes" response to the question, "Do you believe that there is a role for teacher leadership in the world of Special Education?" She asserted, "If you're not collaborating and taking the initiative to take ideas to the next level, then I just think you can only function at half capacity." The sub-theme of Facilitating encompasses a broad set of interpersonal skills needed to successfully collaborate with colleagues across disciplines and grade spans, including but not limited to modeling best teaching practices, proactively training paraprofessionals, and mediating conflicts or misunderstandings. These skills emerged time and again throughout all the interviews we conducted, and resonate with findings in other studies that "the success of teacher leadership depends largely on the cooperation and interaction between teacher leaders and their colleagues" (Yarger & Lee, 1994, p. 229).

The skill of facilitating is highlighted in Domain 4 of the Teacher Leader Model Standards (Facilitating Improvements in Instruction and Student Learning) and in Standard 3 (Program, Services, and Outcomes) of the Special Education Specialist Advanced Professional Standards (2015a): "Special education specialists facilitate the continuous improvement of general and special education programs, supports, and services at the classroom, school, and system levels for individuals with exceptionalities" (p. 3). As indicated by several of our participants – and supported by recent research on co-teaching and mentoring (Brown, Howerter & Morgan, 2013; Hunt, Powell, Little & Mike, 2013) – Special Education teachers cannot exist in a "silo" by themselves. They must exhibit strong interpersonal and facilitation skills in order to proactively navigate between various stakeholders – parents, teachers, administrators, and paraprofessionals – to ensure each child's success in school (McInerney, Zumeta, Gandhi, & Gersten, 2014).

SETLs not only need up-to-date knowledge on laws and research pertaining to Special Education, but they must be able to pass this information on to their colleagues in a way that does not sound intimidating or demanding. As Erica noted:

> Those teacher leaders on school campuses are those people who just know how to connect with other people on the campus, at all levels. Being able to partner with them, to bring them along, to meet that vision – and participate in the work, because we all know there's plenty of work to be done. (Interview, June 13, 2011)

Jon spoke specifically about the importance of facilitating interactions with parents, noting, "You're talking with parents, you're giving them feedback, you're updating them about students' academic progress, their challenged academic progress, what may be hindering them" (Interview, February 22, 2011).

Administrating

"I'm the person they come to." – Marie (Interview, February 15, 2011)

SETLs' work as supportive teacher leaders can also be viewed through the lens of administrating, a gerund we've chosen deliberately here to avoid more hierarchical and evaluative terms such as managing, directing, or supervising. For Sharon (a pre-K teacher), administrating means taking direct leadership of her school when the director is gone: "If anything comes up that needs an administrator, we're responsible for handling it." Sharon added that taking on a role as Lead Teacher with occasional administrative responsibilities has allowed her to take a "systems perspective" and understand "there are a lot of other things [besides teaching] that are needed to make the program or school run. What better way to do than to be actively involved in it?" She stated this helps her to see the "bigger picture" of facilitating success for students.

SETLs are often viewed as the "point person" teachers, administrators, and parents can go to at a school. As Marie put it:

> I'm the person [my peers] come to if they have a question about behavior, about Special Education, or the classroom, about how a student qualified for special education. And on occasion if they are having challenges with some of my [Special Education teaching] peers, other teachers will seek me out and we'll discuss ways to solve that problem in a way that's positive.

The skill of "administrating" is not overtly stated in either the Teacher Leader Model Standards (2011) or the Special Education Specialist Advanced Professional Standards (2015a), leading us to believe it may be less of an intentional goal for teacher leaders and more of a pragmatic function and outcome of the work.

Innovating

"Make sure the needs of the students are met." – Kimberly.

Kimberly's quote above speaks to the fourth sub-theme to emerge from our findings: SETLs are continuously Innovating to ensure that students' needs are met. This includes conducting research, attending conferences, bringing new information back to colleagues, and problem solving. Erica noted that Special Education teacher leaders need to be part of new initiatives and policy implementation at a school site from an early stage:

> There's a lot going on from the General Education world, and Special Education just gets pulled in at the end, to give it the final stamp of approval, and that's a little late! By then, everyone's already established it – so it's really about getting in at the beginning, establishing the vision, being there when they establish that, being part of the work of developing the tools or the policies that they're trying to establish.

In addition to being a critical part of initial policy implementation, SETLs can play a crucial role in ensuring continuity of services for exceptional children in the face of principal turnover and other systemic challenges (Strickland-Cohen, McIntosh, & Horner, 2014).

The teacher leadership skill of Innovating through facilitation of their own and colleagues' learning is highlighted in several domains of the Teacher Leader Model Standards – most notably Domain 2 (Accessing and Using Research to Improve Practice and Student Learning), Domain 3 (Promoting Professional Learning for Continuous Improvement), and Domain 4 (Facilitating Improvements in Instruction and Student Learning). Similarly, it is explicit in many of the Special Education Specialist Advanced Professional Standards (2015a), such as the following, to name just a few:

> 2.2: Special educators continuously broaden and deepen professional knowledge, and expand expertise with instructional technologies, curriculum standards, effective teaching strategies, and assistive technologies to support access to and learning of challenging content. (p. 2)
>
> 3.0: Special education specialists facilitate the continuous improvement of general and special education programs, supports, and s ervices at the classroom, school, and system levels for individuals with exceptionalities. (p. 3)
>
> 4.0: Special education specialists conduct, evaluate, and use inquiry to guide professional practice. (p. 4)

Clearly, SETLs – like General Education teacher leaders – are innovators whose work can potentially have a profound impact on student outcomes, across disciplines.

CONCLUSION

Limitations

A limitation to our study was the fact that our sample was small and primarily self-selected. Without clear criteria for who should be considered a Special Education teacher leader – a definition that does not yet exist – we were unable to identify potential participants other than through self-selection, which we then corroborated through administrative recommendations and our personal knowledge of participants' leadership skills and responsibilities. While we attempted to interview as diverse a set of participants as possible (see Table 2), we are aware that their responses cannot necessarily be generalized more broadly.

Another limitation was that our participants did not possess a comprehensive sense of the various leadership duties and responsibilities taken on by SETLs, or what types of duties would be considered relevant under this heading. Future research is clearly needed – ideally with an observational component included – in order to more accurately identify the breadth and depth of responsibilities taken on by SETLs. This is especially important given York-Barr and Duke (2004)'s suggestion (citing a study by Smylie & Denny, 1990) to use caution when asking teacher leaders to describe what types of leadership roles they take on, given that the reality of what they state they do may differ from what they intend or actually are able to do.

Implications and Next Steps

As noted previously, many skills and dispositions possessed by SETLs map directly onto teacher leadership within General Education. We do not intend to perpetuate a division between General Education and Special Education teacher leaders, given that all are working together towards the common goal of student success across all disciplines; with that said, we believe it is important to specifically highlight and discuss teacher leadership within Special Education in order to ensure that SETLs receive targeted support and are able to capitalize on their unique strengths and positions. While our discussion here focused on Special Education teacher leaders promoting student success, teacher leadership research has largely found positive effects on teacher leaders themselves. For instance, providing teacher leadership responsibilities can potentially prevent teacher burnout, which is an especially pressing problem within Special Education (Brunsting & Sreckovic, 2013); this connection merits further exploration.

A broader question to be explored in the future is whether all Special Education teachers might be considered teacher leaders, simply by the nature of their diverse job descriptions. In the CEC's Initial Preparation Standards (2015b) – which outline expectations for novice Special Education teachers – Standards 6.5 and 6.6 within the domain of Professional Learning and Ethical Practice include language directly related to teacher leadership, such as advocacy, mentoring, and providing guidance to other adults. For instance, Standard 6.5 indicates that "Beginning special education professionals advance the profession by engaging in activities such as advocacy and mentoring", while Standard 6.6 states that "Beginning special education professionals provide guidance and direction to paraeducators, tutors, and volunteers" (p. 7).

Collaboration is also an essential expectation for novice Special Education teachers. Standard 7 (Collaboration) states:

> Beginning special education professionals collaborate with families, other educators, related service providers, individuals with exceptionalities, and personnel from community agencies in culturally responsive ways to address the needs of individuals with exceptionalities across a range of learning experiences. (p. 7)

We believe the CEC initial preparation standards clearly encompass elements of teacher leadership, as substantiated by our findings. To that end, while we were intentional in our solicitation of experienced teachers who self-described as SETLs (and thus clearly viewed themselves as leaders), a future study should solicit responses from a more representative sample of Special Education teachers, including novice teachers, to see how many of the traits we uncovered are inherent in the role itself.

As we noted in our introduction, we believe a more specific definition of a SETL – as distinct from a General Education teacher leader – is necessary, especially given that such a distinction has not traditionally been called out in the literature. While many of the characteristics and skills possessed by General Education teacher leaders certainly apply to SETLs, there are unique qualities and roles that should be highlighted. Elaborating upon

Katzenmeyer and Moller's (2009) definition of a teacher leader as "one who leads both in and beyond the classroom, identifies with and contributes towards a community of teacher learners and leaders, and influences others toward improved educational practice" (pp. 164-165), we propose the following preliminary definition of a SETL:

> A Special Education Teacher Leader (SETL) is one who leads both in and beyond the classroom, proactively influencing colleagues towards improved educational practice for diverse learners across disciplines. A SETL continuously advocates on behalf of students with special needs; serves as a gatekeeper for important legal and ethical information regarding Special Education (and effectively communicates this with all stakeholders); trains paraprofessionals and other colleagues to work effectively with students with special needs; and maintains an active familiarity with a range of grade level standards and effective pedagogical tools.

This definition is lengthy, but begins to more accurately reflect the true breadth of critical roles and responsibilities played by SETLs.

In addition to this preliminary definition, we propose that the existing Teacher Leader Standards (2011) and the newly published Teacher Leadership Competencies (NEA et al., 2018) (see Footnote 1) be amended to account for unique leadership responsibilities taken on by Special Education teacher leaders. Possible examples include:

- Assists colleagues in representing and advocating for the rights and needs of students with special needs.
- Promotes a positive schoolwide attitude towards inclusion.
- Ensures that paraprofessionals are engaged in relevant and appropriate activities, and adequately trained to provide effective assistance for students with special needs in diverse disciplines.
- Shares information with colleagues regarding how trends and policies related to Special Education can impact classroom practices and expectations for student learning.

Finally, we recommend explicitly highlighting teacher leadership within the Special Education Specialist Advanced Preparation Standards, to call out this facet of expected expertise within the field.

Our findings in this initial study are just the beginning of what we hope will be an ongoing exploration of the complex landscape of teacher leadership within Special Education. Although our study is descriptive rather than explanatory, we believe our findings represent a necessary first step in the direction of understanding how teacher leadership plays out specifically within Special Education. Once we possess a rich description of how SETLs carry out their work and what leadership skills they feel are critical to their success, educators and administrators can build on this understanding to offer new and seasoned Special Education teachers the opportunities to improve and enhance their leadership – ultimately benefiting all students with diverse needs.

Appendix A: Interview Questions

1. What is your name? Age?
2. What school do you currently teach at?
3. What type of school is it? Public or private?
4. What grade level(s) do you currently teach?
5. What is/are your official title(s)?
6. How many years have you been teaching (in General or Special Education)?
7. How do you define teacher leadership?
8. Do you believe there is a role for teacher leadership in the world of Special Education? Why or why not?
9. What leadership roles do you currently take on as an Educational Specialist at your school?
    a. When and why did you first start taking on these roles?
10. Would you like to be able to take on additional leadership roles? If not, why? If so, which ones, and why?
11. In your opinion, what characteristics or skills do Educational Specialists need to possess in order to be effective leaders? Do you possess these qualities yourself?
12. What qualities do you feel you still need to develop in yourself in order to be an effective teacher leader?
13. Is your administrator supportive of Special Education on campus, in general? Why or why not? Please give specific examples.
14. Do you feel your administrator is supportive of you taking on leadership roles? If not, why? If so, in what ways?
15. Do you feel that others on your campus (i.e., your colleagues, your administrators, paraprofessionals, parents) perceive you as a leader? Why or why not?
16. Do you work with paraprofessionals? If so, how many and in what capacity?
17. Did you work as a teacher's assistant before becoming a teacher? If so, for how long, and in what capacity? Please tell me a little bit about this experience.
    a. Were you encouraged (and/or given the opportunity) to take on more of an active role in the classroom?
    b. Were you encouraged (and/or given the opportunity) to increase your leadership skills?
18. Why did you decide to become an Educational Specialist? Did you know from the start that this was the direction you wanted to take within the teaching field?
19. Finally, in an ideal world, what type of training and/or support would you like to have in order to become more effective as a teacher leader on your campus?

REFERENCES

Billingsley, B.S. (2007). Recognizing and supporting the critical roles of teachers in Special Education leadership. *Exceptionality*, 15(3), 163-176.

Brown, N.B., Howerter, C.S., & Morgan, J. (2013). Tools and strategies for making co-teaching work. Intervention in *School and Clinic*, 49(2), 84-91.

Brunsting, N.C., & Sreckovic, M. (2013). Special education teacher burnout: A synthesis of research from 1979 to 2013. *Education and Treatment of Children*, 37(4), 681-712.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Los Angeles: SAGE.

Conderman, G. J., & Katsiyannis, A. (2002). Instructional issues and practices in secondary Special Education. *Teacher Education and Special Education*, 23(1), 167-179.

Council for Exceptional Children (CEC). (2015a). *Advanced preparation standards. What Every Special Educator Must Know: Professional Ethics and Standards*. Arlington, VA: CEC. Retrieved from: https://www.cec.sped.org/~/media/Files/Standards/Professional%20Preparation%20Standards/Advanced%20Preparation%20Standards%20with%20Explanation.pdf

Council for Exceptional Children (CEC). (2015b). *Initial preparation standards. What Every Special Educator Must Know: Professional Ethics and Standards*. Arlington, VA: CEC. Retrieved from: https://www.cec.sped.org/~/media/Files/Standards/Professional%20Preparation%20Standards/Initial%20Preparation%20Standards%20with%20Explanation.pdf

Duffy, M.L., & Forgan, J.W. (2004). *Mentoring new special education teachers: A guide for mentors and program developers*. Thousand Oaks: Corwin Press.

Fraenkel, J.R., & Wallen, N.E. (2009). *How to design and evaluate research in education* (7th edition). New York: McGraw Hill.

Glaser, B.G., & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York: Aldine de Gruyter.

Hunt, J., Powell, S., Little, M.E., & Mike, A. (2013). The effects of e-mentoring on beginning teacher competencies. *Teacher Education and Special Education: The Journal of the Teacher Education Council for Exceptional Children*, 36(4), 286-297.

Jacobs, J., Gordon, S.P., & Solis, R. (2016). Critical issues in teacher leadership: A national look at teachers' perception. *Journal of School Leadership*, 26, 374-406.

Jacobs, J., Beck, B., & Crowell, L. (2014). Teacher leaders as equity-centered change agents: Exploring the conditions that influence navigating change to promote educational equity. *Professional Development in Education*, 40(4), 576-596.

Katzenmeyer, M.H. & Moller, G.V. (2009). *Awakening the sleeping giant: Helping teachers develop as leaders*. Thousand Oaks: Corwin Press.

Klingner, J.K., & Vaughn, S. (2002). The changing roles and responsibilities of an LD specialist. *Learning Disability Quarterly*, 25(1), 19-31.

Lampert, L. (2011). What does leadership capacity really mean? In E.B. Hilty (Ed.), *Teacher leadership: The new foundations of education* (pp. 34-36). New York: Peter Lang.

Lawy, R. (2003). Transformation of person, identity, and understanding: A case study. *British Journal of Sociology of Education*, 24(3), 331-345.

Levenson, M. (2014). *Pathways to teacher leadership: Emerging models, changing roles*. Cambridge: Harvard Education Press.

Lieberman, A., & Friedrich, L. D. (2010). (Eds.). *How teachers become leaders*. New York: Teachers College Press.

Lukacs, K.S., & Galluzzo, G.R. (2014). Beyond empty vessels and bridges: Toward defining teachers as the agents of school change. *Teacher Development*, 18(1), 100-106.

Margolis, J., & Doring, A. (2013). What do today's teachers want (and not want) from teacher leaders? *The New Educator*, 9(3), 192-209.

Margolis, J., & Huggins, K.S. (2012). Distributed but undefined: New teacher roles to change schools. *Journal of School Leadership*, 22, 953-981.

Mastropieri, M. A. (2001). Introduction to the special issue: Is the glass half full or half empty? Challenges encountered by first year Special Education teachers. *The Journal of Special Education*, 35, 66-74.

Maxwell, J. A. (1996). *Qualitative research design: An interactive approach*. Thousand Oaks: SAGE Publications.

McInerney, M., Zumeta, R., Gandhi, A., & Gersten, R. (2014). Building and sustaining complex systems: Addressing common challenges to implementing intensive intervention. *Teaching Exceptional Children*, 46(4), 54-63.

National Education Association (NEA), National Board for Professional Teaching Standards (NBPTS), and the Center for Teaching Quality (CTQ). (2018). *The Teacher Leadership Competencies*. Retrieved from: http://www.nea.org/assets/docs/NEA_TLCF_20180824.pdf

Saldaña, J. (2009). *The coding manual for qualitative researchers*. Los Angeles: Sage Publications.

Seidman, I.E. (1991). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. New York: Teachers College Press.

Shillingstad, S.L., McGlamery, S., Davis, B. & Gilles, C. (2015). Navigating the roles of leadership: Mentors' perspectives on teacher leadership. *Delta Kappa Gamma Bulletin*, Winter 2015, 12-20.

Strickland-Cohen, M.K., McIntosh, K., & Horner, R. (2014). Effective practices in the face of principal turnover. *Teaching Exceptional Children*, 46(3), 19-25.

Sun, M., Frank, K., Penuel, W., & Kim, C.M. (2013). How external institutions penetrate schools through formal and informal leaders. *Educational Administration Quarterly*, 49(4), 610-644.

Teacher Leadership Competencies, The. (2016). Available at https://www.nea.org/assets/docs/AZK1408_TLC_FINAL.pdf

Teacher Leadership Exploratory Consortium. (2010). Model Teacher Leader Standards Developed by the Teacher Leadership Exploratory Consortium: February 17, 2010 Draft. Retrieved from http://tlstandards.pbworks.com/f/13852_TeacherLeaderStnds_HR.pdf

Thompson, S., Lazarus, S., & Thurlow, M.L. (2003). *Preparing educators to teach students with disabilities in an era of standards-based reform and accountability*. College Park, MD: Institute for the Study of Exceptional Children and Youth.

Vernon-Dotson, L.J. (2008). Promoting inclusive education through teacher leadership teams: A school reform initiative. *Journal of School Leadership*, 18(3), 344-373.

von Frank, V. (2013). Finding your voice in facilitating productive conversations. *The Leading Teacher*, 8(4), 3-5.

Waitoller, F.R., & Artiles, A. (2013). A decade of professional development research for inclusive education: A critical review and notes for a research program. *Review of Educational Research*, 83(3), 319–356.

Walther-Thomas, C., Korinek, L., McLaughlin, V. L., & Williams, B. T. (2000). *Collaboration for inclusive education: Developing successful programs*. Needham Heights, MA: Allyn & Bacon.

Wenner, J.A., & Campbell, T. (2016). The theoretical and empirical basis of teacher leadership: A review of the literature. *Review of Educational Research*. DOI: 10.3102/0034654316653478

Yarger, S.J., & Lee, O. (1994). The development and sustenance of instructional leadership. In D.R. Walling (Ed.), *Teachers as leaders: Perspectives on the professional development of teachers* (223-237). Bloomington, IN: Phi Delta Kappa Educational Foundation.

York-Barr, J., & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research*, 74(3), 255-316.

York-Barr, J., Sommerness, J., Duke, K., & Ghere, G. (2005). Special educators in inclusive education programmes: Reframing their work as teacher leadership. *International Journal of Inclusive Education*, 9(2), 193-215.

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Attaining the Elusive: Efficacy, Math Education and Black and Latino Students

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Abstract

Low enrollment of Latino, African American, Native American, and Southeast Asian American students in science, technology, engineering, and math (STEM) classes, via advanced placement (AP) courses, remains a problem for high schools, and education leaders across the United States. More than just examining the factors behind this enrollment issue, we wanted to understand the focal factors underpinning success in AP courses of those few who do enroll. For that purpose, we grounded this case study on social cognitive theory's central variable of self-efficacy. We found that teacher facilitated experience plays a pivotal function in students' success in STEM education, more specifically, AP math.

Keywords: mathematics, efficacy, diversity

INTRODUCTION

Low enrollment of Latino, African American, Native American, and Southeast Asian American students in science, technology, engineering, and Math (STEM) advanced placement (AP) classes, remains a challenge for high schools across the United States (Brown & Campbell, 2008; Klopfenstein, 2004; Lichten, 2007; Ndura, Robinson, 2003; Trounson & Colvin, 2002). The impact of this issue can more immediately be felt on the day-to-day experience of youth in schools. In the long term, we fear this issue could have far reaching effects that impact economic security and, perhaps, the nature of the country's democratic system.

More than the factors behind the school system's enrollment failure, we wanted to understand the focal factors underpinning success in AP math courses of those few who do enroll. For that purpose, we grounded this study on social cognitive theory's central variable of self-efficacy. We followed Bandura's (1991) four factors defining self-efficacy: (a) Experience, (b) Modeling, (c) Social Persuasion, and (d) Physiological Factors. We explored these factors as sources of self-efficacy in terms of exposure to, or the lack of, the following six categories: early childhood education, family and community differences, expectations, exposure to advanced placement courses, stereotype threat, and socioeconomic status.

Thus, the research question was this: which of the four factors of self-efficacy (a) Experience, (b) Modeling, (c) Social Persuasion, and (d) Physiology - has the greatest impact on Latino and African American students enrollment in AP math courses? This paper first discusses the focal issue; second, it reviews the available literature; third, it defines the methodology guiding the study, fourth, the article shows the key findings, and then it closes with a set of conclusions.

THE FOCAL ISSUE

High schools with high concentrations of Latinos and African Americans massively fail to offer advanced placement (AP) courses (Zarate & Pachon, 2006). When these high schools do offer advanced placement courses, very few students score proficient or better in the AP exams (Brownell, Furry, & Beasley, 1999; Whiting & Ford, 2009). When youth attend schools in which Black and Latino make up the numerical majority, they tend to be under-enrolled in said courses (Handwerk, 2008; Solorzano & Ornelas, 2004). Yet, one of the main drivers of STEM education is the perceived lack of sufficient scientists and engineers entering the country's workforce which in turn, as Salzman & Lowell (2007) have argued, threatens the United States' economic health and relevant position in global innovation. This workforce shortage appears worse among Black, Latino, Native American, and South-East Asian populations.

Whiting and Ford (2009), among others, have suggested a link between this under representation and a low offering of AP courses in schools, particularly serving low-income families, where these populations form the majority. Moreover, as Arellano & Padilla (1996), and Gándara (2006) have shown, the lack of familiarity with crucial information - such as the prerequisites of AP courses, when to take SAT exams, how to apply for financial aid - plays a key role in explaining the low numbers of Blacks and Latinos in the AP track. Environments such as the ones so far described, may only engender a perpetual cycle of low tracking in math and science. But the fact that in these same environments students from these two communities still enroll and some even succeed, confirmed to us the need to look closely at self-efficacy, as a counter subjective force.

Although ample research (e.g. Pajares & Kranzler, 1996; Pajares, 1995; Usher & Pajares, 2006, 2008; Usher, 2009; Zeldin, Britner & Pajares, 2008; Zimmerman, Badura & Martinez Pons, 1992; Zimmerman, 2000) attests to the predictive power of self-efficacy - i.e. the sense of accomplishment and self-control - fewer studies have associated self-efficacy of underrepresented students to AP math and science courses. Some research has suggested that self-efficacy influences interests, goals, performance, and persistence (Eccles, 1994; Lent, Brown, & Hackett, 1994). Additionally, building efficacy has directly been connected to self-regulation. As defined by Zimmerman (2002b) self-regulation denotes "the self-directive process by which learners transform their mental abilities into academic skills" (p. 65). Self-regulation, in other words, implies a metacognitive process that requires students to explore their own thought processes so as to evaluate the results of their actions, and plan alternative pathways to success.

REVIEW OF THE LITERATURE

Studies conducted by Murphy and Sullivan (1997) showed that in the mid-80s Latinos, African Americans, and Native Americans represented 20% of the total population of the United States but they embodied less than 7% of the employees in the fields of STEM related careers. These statistics have not significantly changed over time. Kendricks and Arment (2011) found that freshman STEM majors (social sciences excluded) made up 21.5% of all college freshmen in 2006. Of this group, about one of every five were African Americans. However, documenting the 2007 graduation statistics. Kendricks & Arment (2011) showed that African Americans attained 7% to 8% of STEM bachelor's degrees compared to 64% of the Caucasian cohort. Efforts to uncover the potential governing factors of this issue have produced numerous studies, some of which we review below.

Researchers such as Green, Walker, Hoover-Dempsey, & Sandler (2007), and Pomerantz, Grolnick, & Price (2005) argue that a critical factor at play in low STEM fields representation of Latino and Black, possibly originates from low parent involvement in the early stages of the education processes of these populations. Klopfenstein (2004), Martínez Alemán (2006), and Whiting & Ford, (2009) looked at the impact of family income on this issue. Klopfenstein (2004): indeed discovered that students in high-poverty and rural schools continue to have limited access to or be underrepresented in AP courses.

According to national academic performance data (National Center of Education Statistics, 2007), Latino children were less likely than other economically poor children to take part in early childhood development programs (e.g. Head Start). Martinez Alemán (2006), following national statistics, suggested that in the United States fewer than half (45.3%) of Latino four-year-olds were enrolled in pre–primary education, as compared with almost sixty percent of White four-year-olds. Latino children, according to these national figures, were more likely to repeat grades than Whites. Although Latino nine-to-eleven-year-olds were as likely to be retained in grades as Whites, among older children (12-to-14-year-olds) 35.5% Latinos were not promoted in grade. By the time Latino children were 15-to-17-years-old, forty percent risked being held back. Crucially, 6.4% of all Latino children nation-wide participated in advanced or "gifted" programs. Whites - who constituted 17% of the entire K–12 population in the country- accounted for eighty percent of the enrollment in these programs (Alemán, 2006).

Moreover, Solorzano & Ornelas (2002, 2004) argue that race-based unequal access to both general education and to AP courses leaves Latino and Black students out of high track course-work. The authors detailed the lack of educational parity through cases where Latino students attended schools with high AP enrollment, but were generally not equitably represented, which amounted to what they labeled "schools within schools" (p. 15). In other words, the school as a whole, and the insidious presence of a segregated one within, existed. Similarly, Zarate & Pachon, (2006) pointed out that economically depressed school districts typically offered far fewer AP courses, where only a handful of students scored proficient or better in AP exams. But low Latino and Black involvement in STEM fields may also originate in the school's treatment of these populations. Archbald, Glutting, & Xiaoyu (2009), Flowers (2008), Rosenbaum, Miller, & Krei, (1996) have explained that teachers and counselors convey expectations that deter African American and Latino students from placement in college preparatory or honors level courses. These expectations typically include non academic characteristics such as ethnicity, socioeconomic status, and even personality traits.

Furthermore, a lack of early education opportunities may also promote low student enrollment in advanced science and math courses in middle and high school (Dejarnette, 2012). The importance of early exposure to engineering courses at pre-K levels (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Gándara, 2010), as well as the use of assessment to improve science education in preschool (Brenneman, 2011) holds great promise in redressing Black and Latino students' lack of AP involvement. Some researchers suggest that early education impacts social and academic performance over time (e.g. McWayne, Cheung, Wright & Hahs-Vaughn, 2012; Pungello et al., 2010; Ramey et al., 2000); Brown & Campbell (2008); Klopfenstein (2004); Lichten (2007); Ndura, Robinson, & Ochs (2003b); and Trounson & Colvin (2002) have shown that AP enrollment of Latino, Black, Native American, and Southeast Asian students remains largely below these groups' relative numbers. Not only do high schools with high concentrations of Latino and Black students continue to lag in their AP course offerings (Zarate & Pachon, 2006), but also - as Brownell, Furry, & Beasley (1999), and Whiting & Ford (2009) uncovered - these schools show even fewer students scoring proficient or better in AP exams. In other words, underrepresented students attending schools in which they are in the majority, tend to still be underrepresented in AP courses.

Lastly, research exploring the relationship between self-efficacy and performance in math and science courses offers some clues to explaining what is not working and potential avenues to solve the issue. Studies conducted by Judge, Jackson, Shaw, Scott, & Rich, (2007), Rittmayer & Beier, (2008); H. Wang & Pape, 2004; X. Wang, (2012) suggest that high school math achievement, exposure to math and science courses, and math self-efficacy beliefs, significantly affect students' intent to major in STEM fields, which in turn influences entrance into STEM majors. Given the knowledge thus far reviewed, and the focus of our research interest, we decided to follow social cognitive theory (SCT). More specifically we honed in on self-efficacy, a central tenet of SCT, as the key construct of our theoretical framework.

According to Bandura (1991) self-efficacy contains four factors (a) experience, (b) modeling, (c) social persuasion, and (d) physiological factors. Bandura (1982) has shown that experiencing mastery is the most important factor positively affecting a person's self-efficacy, whereas failure lowers it. Students, the author shows, who perform well on math tests and earn high grades in math classes seem likely to develop a strong sense of confidence in their capabilities on this subject. Pajares (2002) uncovered that a sense of efficacy helps ensure that students enroll in subsequent math-related classes, approach math tasks with serenity, and increase their efforts when a difficulty arises. Starting with modeling we briefly examine each of the four factors. Modeling is experienced when one observes mastery in others and, consequently one's self-efficacy tends to increase, but when one sees failure occurring, one's self-efficacy tends to decrease (Bandura, 1982). The modeling process, the author notes, seems most effective when individuals see themselves as similar to the model they observe – teachers in our study's case. Although not as influential as direct experience, Pajares (2002) writes, when a highly regarded teacher models excellence in an academic endeavor or activity, students will more likely develop the belief that "I can do that".

Offering mentorship opportunities to students - such as internships, independent studies, enrichment programs, and dual-enrollment - and creating mentoring programs tailored to inform educators and practitioners about mentoring programs based on the needs of specific student populations, appear to hold strong potential benefits (Nora & Crisp, 2012). Some results suggest, for instance, that visiting a counselor for college entrance information had a positive and significant influence on students' likelihood of postsecondary enrollment, and counseling-related effects were greatest for students from low socioeconomic status (Belasco, 2013). According to Bandura (1991) social persuasion generally manifests as direct encouragement or discouragement from another person. Discouragement may generally be more effective at decreasing a person's self-efficacy than encouragement might be at increasing it. Most adults can recall something that was said to them - or done to, or carried out for them during their childhood - that had a profound effect on their confidence throughout the rest of their lives (Pajares, 2002).

SCT allows for interventions to be designed in the classroom to improve student's learning (Rice, Lopez, Richardson, & Stinson, 2013). Some studies suggest that one way to increase scores on standardized math tests is to increase students' math self-efficacy. Teachers can positively influence math self-efficacy (Judge et al., 2007) by creating a caring, challenging, and mastery-oriented environment in math and reading in elementary schools (Pianta, Belsky, Vandergrift, Houts, & Morrison, 2008). Similarly, students who perceived their classroom environments as more caring, challenging, and mastery-oriented, had significantly higher levels of math self-efficacy than those in less caring, non-challenging, and non-mastery-oriented classrooms (Fast, Lewis, Bryant, Bocian, Cardullo, Rettig & Hammond 2010).

METHODOLOGY

Framework Design

This study used a sequential mixed method to develop a rich description of four factors of self-efficacy - (a) Experience, (b) Modeling, (c) Social Persuasion, and (d) Physiological Factors - and their associated impact on Latino and African American entrance into AP math courses. Following Bandura (1986), these four factors involve the reciprocal interplay between cognitive, behavioral, and environmental forces. The sequential design sought to elaborate or expand on the findings of one method with another method (Creswell, 2009). Beginning with a survey method of 35 twelfth graders enrolled in AP calculus, the study followed with a detailed interview series of twelve, twelfth graders, enrolled in AP calculus. This was a convenience sample based on parental response to our request.

Interview data were transcribed, coded, and analyzed according to the guidelines set forth by Hibbs (2012), and Usher (2009) and using the Hyper-RESEARCH program. A total of (N) 35 twelfth graders enrolled across three AP calculus courses and in two different high schools were first surveyed. From this convenience sample we selected twelve for a series of interviews; they were organized in five small focus groups with the intent to cross-reference and triangulate the results of the survey. The survey questions for this study employed the intermediate degrees of assurance. The study also applied the Statistical Package for the Social Sciences (SPSS) to conduct a frequency analysis for each of the survey questions. In order to understand which variable contributed the most to the Latino and African American students' entry into AP calculus, we conducted a frequency analysis of each response by ethnicity.

Setting

This sequential mixed methods study took place in Urban Unified School District (UUSD), a large, comprehensive school district in northern California. It enrolled 37,040 students in the 2013-2014 school year. Of the seven high schools, two were selected for the study based on two criteria. The first one being the general geographical distinction: one school is set in "the hills", which serves a neighborhood that tends to be more affluent than the rest of the city, and the other located in "the flatlands", a generally economically depressed neighborhood. The second criteria was that the overall enrollment had to reflect the ethnic diversity of the school district's population.

Participants

All members of the final group of twelve participants were enrolled in AP calculus in twelfth grade: nine Latinos and three African American, across the two high schools. They were self-selected from the original thirty-five, according to who returned the consent forms approved by themselves and by their parents. Through these interviews we wanted to elaborate and expand on the survey results from the 35 students in phase one. The twelve participants represented more than three quarters of the total Black and Latino AP enrollment across the two high schools as well as the total of four AP calculus courses offered.

Instruments

We explored the following question: Which of the four factors of self-efficacy - (a) Experience, (b) Modeling, (c) Social Persuasion, and (d) Physiological Factors - has the greatest impact on Latino and African American entry into AP math courses? These factors – redefined as variables – were operationalized considering gender and ethnicity throughout the survey, and interview questionnaire.

Following Bandura's (2006) notion that no all-purpose measure of perceived self-efficacy exists, we used the standard methodology for measuring self-efficacy; we listed items portraying different levels of task demands and asked participants to rate the strength of their belief in their ability to execute said items. We measured strength of efficacy beliefs on a 100-point scale, ranging in 10-unit intervals from 0 ("Cannot do") through intermediate degrees of assurance, 50 ("Moderately certain can do") to complete assurance, 100 ("Highly certain can do"). The semi-structured interview protocol was adapted specifically for the Latino and African American participants. Similar protocol has been used by Zeldin and Pajares (2000), and Usher (2009). These protocols were designed to engage the participants in comprehensive discussion about the factors they considered important in order to further analyze similarities and differences of the survey results. These interviews were conducted with a total of four questions which set parameters, while still allowing for flexibility in terms of follow-up question. For example: "In the survey you rated your math ability on a scale of 1 to 10. How would you rate your confidence in math?"

FINDINGS

The salient role of experience — as a factor forging efficacy — throughout the study's data, lead us to report here the study results for this variable and its different components. We decided that the other three variables - modeling, social persuasion, and physiological factors - needed separate attention. These emerged as insignificant forces shaping students' determination to enroll in AP course work. Indeed, about four (45%) out of nine of Latino and 2 (100%) out of 2 of Black participating students attributed their enrollment in math programs, starting in kindergarten, as the most positive influential variable for their entry in calculus courses in high school. This finding suggests that the math experiences in early childhood education most definitely aided these participants' self-efficacy. See figure 1 below.

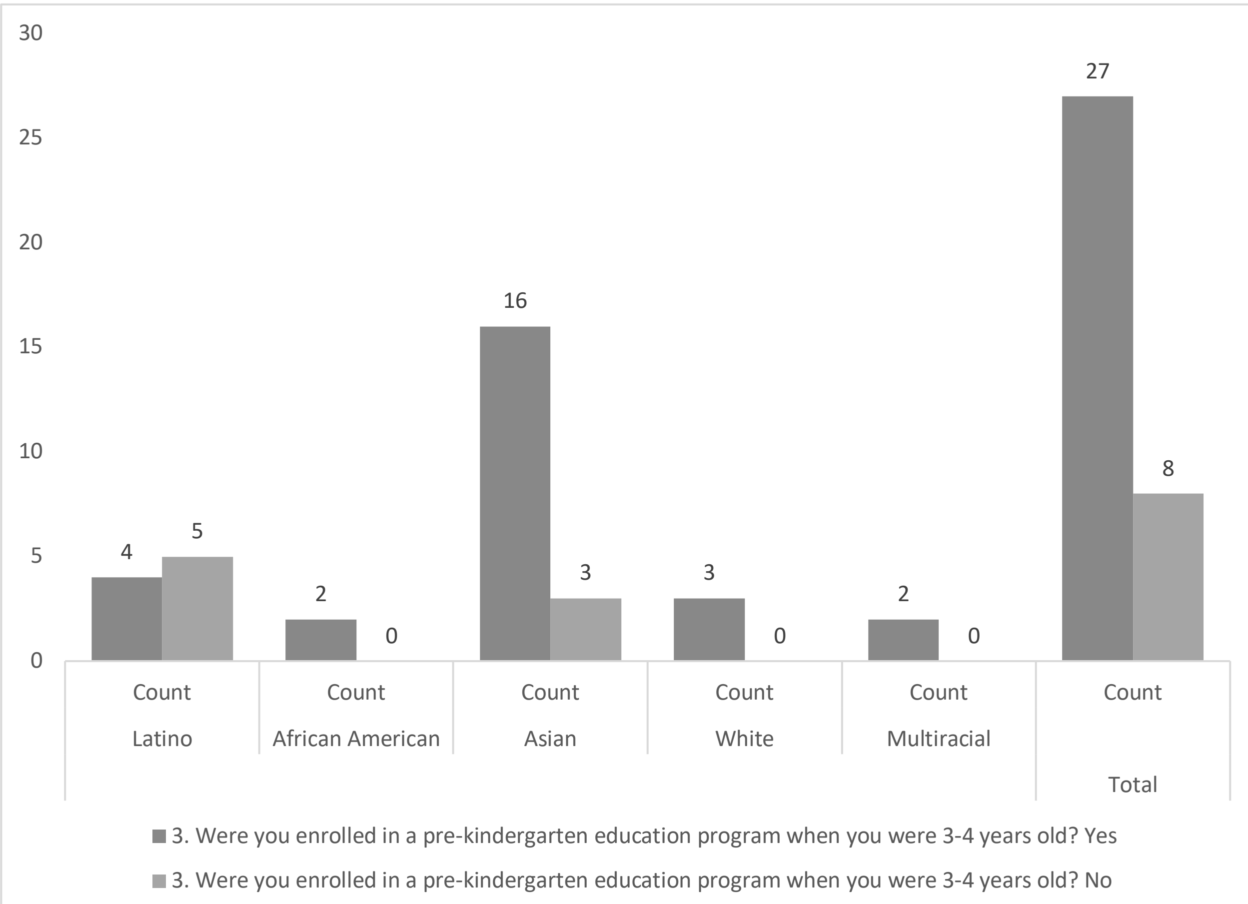

Figure 1. Survey results pre-kindergarten education program.

A significant majority (eight out of nine) of Latino participants (80%) ranked their math ability as moderate (scale 5-7), while all (100 %) African American participants rated it as high (scale 8-10). See figure 2 below.

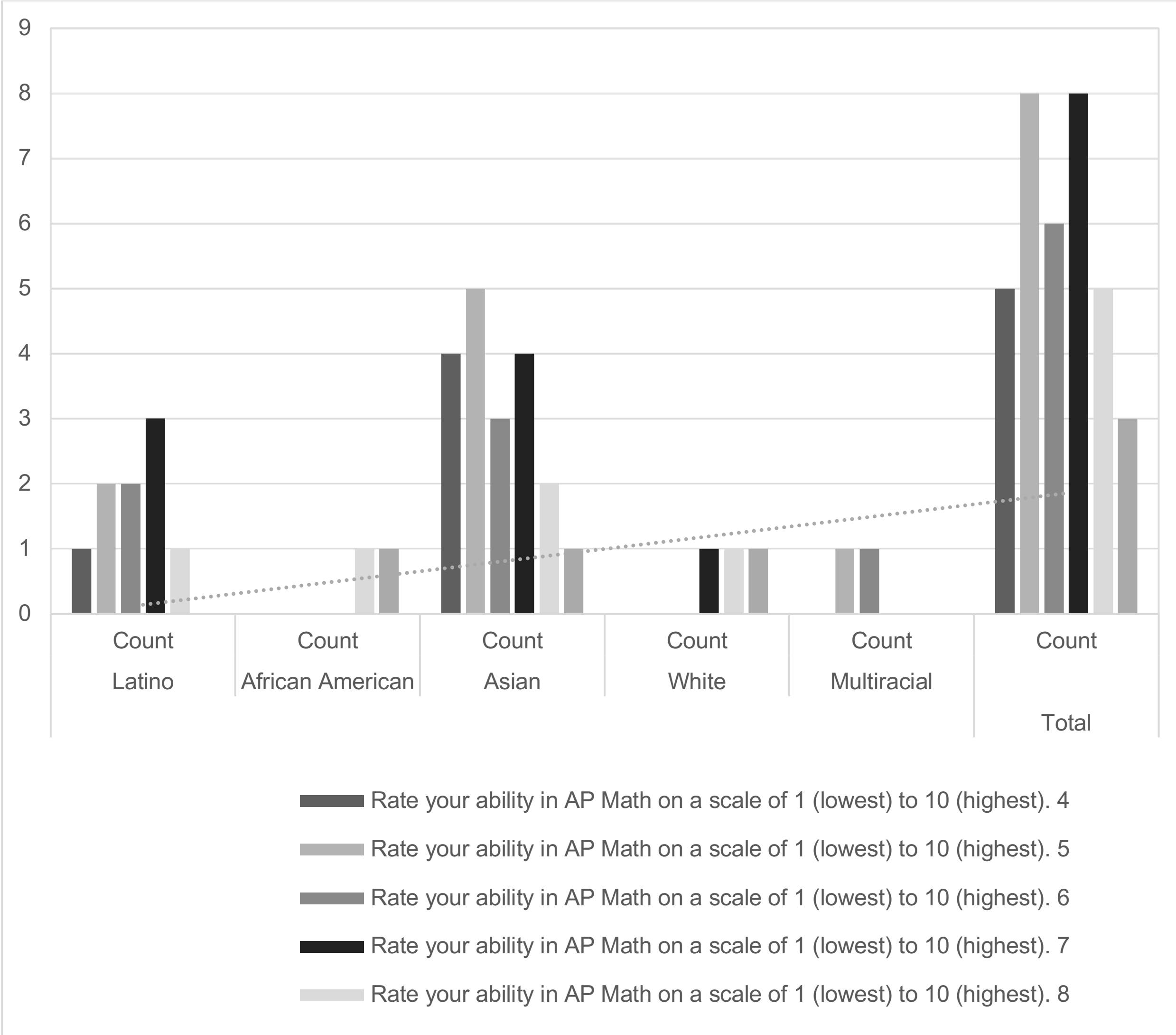

Figure 2. Survey results perceived ability in AP math courses.

As for the importance of math preparation in the middle grades, ratings were higher for both groups. More than half (56%) of Latino participants considered it moderate and one third high (33%), but all (100%) African Americans rated it high (two out of two). Furthermore, taking pre-calculus courses in high school as a facilitating experience to later enroll in calculus, revealed a similar trend to the middle grades experience. One third (33%) of moderate, and the other half as high. Latino participants considered it moderate, and almost half (44%) high; half (50%) of all African Americans rated it as moderate, and the other half as high. See figure 3 below.

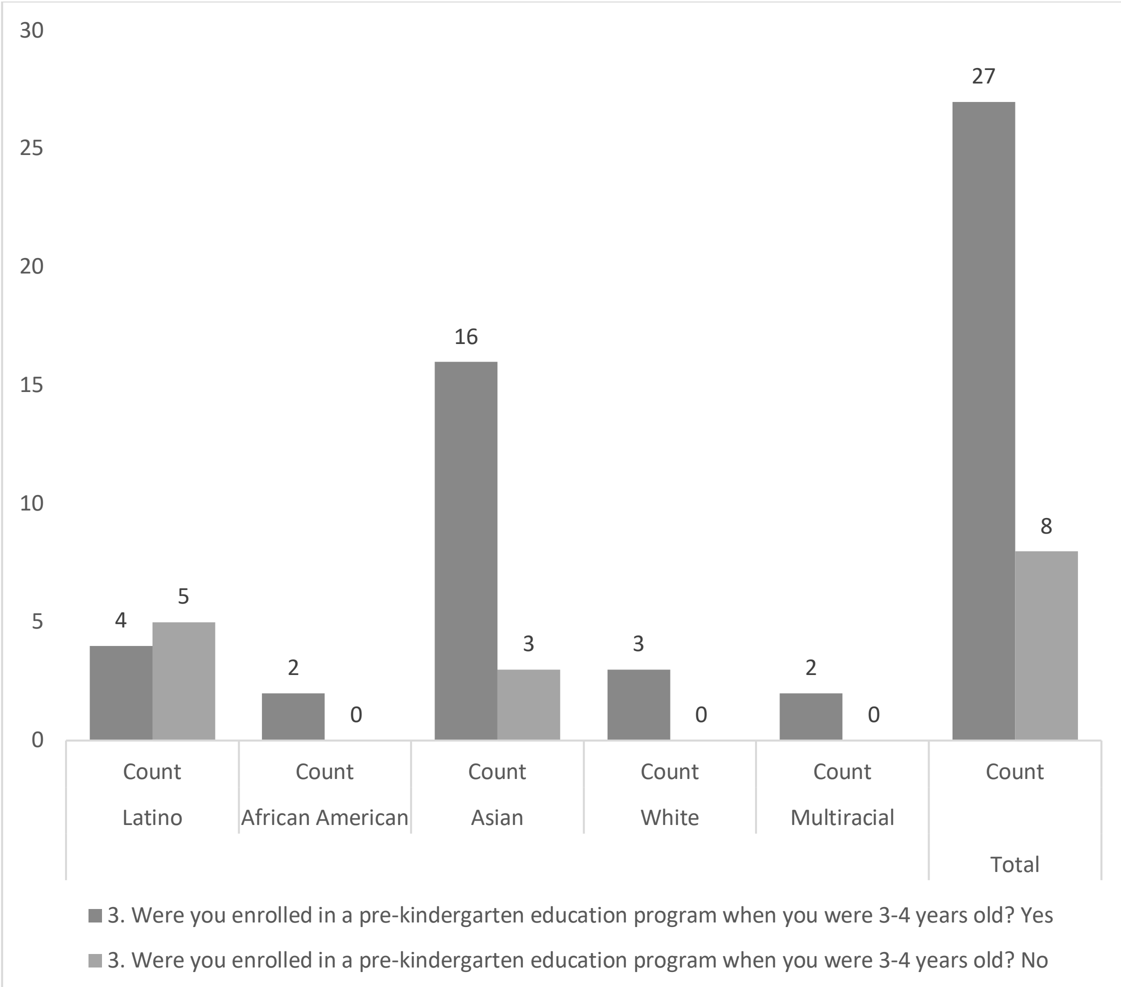

Figure 3. Survey results based on middle school preparation.

Our frequency analysis revealed perceived confidence as the greatest reoccurring factor for both participating groups. This fact stresses the significance of experience given its tight relation to perceived confidence. Data also revealed the relevant role of teachers' agency: confidence pivots on clear explanation of coursework; high expectations, and celebration of success.

We confirmed this pattern throughout our qualitative data. Recalling her middle grades experience, Rosalba captured the important influential role of her math teacher:

> I think the best teacher I've had in math, there was my 7th grade teacher, his
> name is Mr. W., I would struggle and struggle when I realized what I had
> to do is to take it step by step to do the work. I actually got my first "A"
> because he helped me. (Interview series, March, 2015).

As Rosalba tells here, the teacher's persistence in her learning the computation process, imprinted an experience that helped build confidence (she earned her first A) and stayed for a long time as a searing cognitive moment. When we interviewed Rosalba, she was in the high track of mathematics in high school.

Mario's experience resonates with that of Rosalba's. Without naming a specific teacher, he sums up his general positive experience from his early schooling this way:

> I went to elementary school in an urban school, which was not the highest quality, but I was considered a good student, a smart student. (Interview series, March, 2015)

Mario speaks of the surrounding environment. He knew that adults had framed his participation as good, and personally, as someone intelligent. In such a context Mario seemed to be cognizant that his only option consisted of one thing: high academic performance as a way to meet teachers' expectations.

Benard, an African American youngster, explains teacher's agency in similar terms to the other participants. He says:

> My best teacher was in 7th grade, his name was Mr. P. The way he would teach was calm and he wouldn't teach directly out of the book, he had his own techniques. The students in that class would actually understand more than just reading of the paper and trying to figure out. (Interview series, February, 2015).

Sheena, also African American, refers to the role played by the adults. She extends the positive, gentle cajoling of a teacher to include that of a tutor:

> One is Ms. M. and another is a tutor that teaches at Urban Technical High School, his name is Mr. H. They pushed me. I started going there at the beginning of the year. They pushed [me] to do beyond what I thought I could. It takes a lot of information, a lot of knowledge. They are so good, I don't think I would be able to do or know what I know now without those two teachers. (Interview series, February, 2015).

Data also showed that, while peripheral to teachers, parents exerted a persuasive influence in the early grades, and friends in the later ones. This finding confirms Pajares' (2002) study, who found that as students moved through elementary, middle and high school and performed well in math tests and classes, they were likely to develop a strong sense of confidence in their math capabilities, which seemed to only increase from grade level to grade level.

Again, Mario confirmed this fact. Besides naming the positive environment, he stated that his "parents, they always put expectations on me. I wouldn't necessarily say high but they always expected me to do well." (Interview series March 6, 2015).

CONCLUSION

We found that experience is the most prominent force influencing African American and Latino students to enroll in AP courses in high school. Of all agents present in their academic experience it is teachers first, and parents secondly, the ones who tend to exert the greatest influence on the decision to take math and science courses. While such influence varies from grade level to grade level, the teachers' central role stayed constant.

Findings revealed that perceived confidence was the greatest reoccurring factor for participants, and that again teachers played a central role in facilitating it. Experience that contributes to the development of confidence is what students in general must be exposed to. In the case of African American and Latino students, this assertion not only becomes magnified but also urgent. To increase the quality and numbers of these two population's entrances into the high track of math and science, and the engineering professions in college, educators ought to pay closer attention and be willing to disrupt these students low-tracking experiences early on.

As with Pajares' (2002) research, our study found that students who perform well on math tests and earn high grades in math classes are likely to develop a strong sense of confidence in their math capabilities. We discovered that confidence seemed to increase as the participants moved from elementary to high school. In other words, positive experience beginning in early childhood education appears to serve as precondition for building self-efficacy in later grades.

Our study is limited in scope — small number of participants — and it is also short in terms of time. Thus, its conclusions may only apply to the schools and the student population directly involved. However, the study points out a possible direction for future research and scholarship in the area of self-efficacy. We posit that the study of modeling and the forging of early constructive experiences may lead to the discovery of pedagogies that will serve all children and youth, but especially Latino and African American children of low socio-economic background. Moreover, the study of the strategic value of modeling as a factor in building self-efficacy, may offer a potential area of professional growth to education leaders in general, and teachers in particular.

REFERENCES

Archbald, D., Glutting, J., & Qian, X. (2009). Getting into honors or not: An analysis of the relative influence of grades, test scores, and race on track placement in a comprehensive high school. *American Secondary Education*, 65-81.

Arellano, A. R., & Padilla, A. M. (1996). Academic invulnerability among a select group of Latino university students. *Hispanic Journal of Behavioral Sciences*, 18(4), 485-507.

Bagiati, A., Yoon, S. Y., Evangelou, D., & Ngambeki, I. (2010). Engineering Curricula in Early Education: Describing the Landscape of Open Resources. *Early Childhood Research & Practice*, 12(2), n2.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American psychologist*, 37(2), 122.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational behavior and human decision processes*, 50(2), 248-287.

Bandura, A. (1994). *Self-efficacy*: Wiley Online Library.

Bandura, A. (2006). Guide for constructing self-efficacy scales. *Self-efficacy beliefs of adolescents*, 5(307-337).

Belasco, A. S. (2013). Creating college opportunity: School counselors and their influence on postsecondary enrollment. *Research in Higher Education*, 54(7), 781-804.

Brenneman, K. (2011). Assessment for Preschool Science Learning and Learning Environments. *Early Childhood Research & Practice*, 13(1), n1.

Brown, R., & Campbell, D. M. (2008). Recent trends in preparing ethnic minorities for careers in mathematics and science. *Journal of Hispanic Higher Education*.

Brownell, N., Furry, W., & Beasley, J. (1999). The advanced placement program California's 1997-1998 experience. *Institute for Education Reform*: Sacramento.

DeJarnette, N. (2012). America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education*, 133(1), 77-84.

Fast, L. A., Lewis, J. L., Bryant, M. J., Bocian, K. A., Cardullo, R. A., Rettig, M., & Hammond, K. A. (2010). Does math self-efficacy mediate the effect of the perceived classroom environment on standardized math test performance? *Journal of educational psychology*, 102(3), 729.

Flowers, T. A., & Flowers, L. A. (2008). Factors affecting urban African American high school students' achievement in reading. *Urban Education*, 43(2), 154-171.

Gándara, P. (2006). Strengthening the academic pipeline leading to careers in math, science, and technology for Latino students. *Journal of Hispanic Higher Education*, 5(3), 222-237.

Gándara, P. (2010). The Latino Education Crisis. Educational Leadership, 67(5), 24-30.

Green, C. L., Walker, J. M., Hoover-Dempsey, K. V., & Sandler, H. M. (2007). Parents' motivations for involvement in children's education: An empirical test of a theoretical model of parental involvement. *Journal of educational psychology*, 99(3), 532.

Handwerk, P., Tognatta, N., Coley, R. J., & Gitomer, D. H. (2008). Access to Success: Patterns of Advanced Placement Participation in US High Schools. Policy Information Report. *Educational Testing Service*.

Hibbs, D. F. (2012). An investigation of the self-efficacy beliefs of Black and Hispanic students that have experienced success or failure in mathematics.

Judge, T. A., Jackson, C. L., Shaw, J. C., Scott, B. A., & Rich, B. L. (2007). Self-efficacy and work-related performance: the integral role of individual differences. *Journal of applied psychology*, 92(1), 107.

Kendricks, K. D., & Arment, A. R. (2011). Adopting A K-12 Family Model With Undergraduate Research To Enhance STEM. *Educational Review*, 62, 26-44.

Klopfenstein, K. (2004). The advanced placement expansion of the 1990s: How did traditionally underserved students fare? *education policy analysis archives*, 12, 68.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of vocational behavior*, 45(1), 79-122.

Lichten, W. (2007). Equity and excellence in the College Board Advanced Placement program. *Teachers College Record*, 6(07).

Martínez Alemán, A. M. (2006). Latino demographics, democratic individuality, and educational accountability: A pragmatist's view. *Educational Researcher*, 35(7), 25-31. doi: 10.3102/0013189x035007025

McWayne, C. M., Hahs-Vaughn, D. L., Cheung, K., & Wright, L. E. G. (2012). National profiles of school readiness skills for Head Start children: An investigation of stability and change. *Early Childhood Research Quarterly*, 27(4), 668-683.

Murphy, D. S., & Sullivan, K. (1997). Connecting Adolescent Girls of Color and Math/Science Interventions.

National Center of Education Statistics (2007). The condition of education, 2007. Institute of Education Science. US Department of Education, Washington, DC.

Ndura, E., Robinson, M., & Ochs, G. (2003). Minority students in high school advanced placement courses: Opportunity and equity denied. *American Secondary Education*, 21-38.

Nora, A., & Crisp, G. (2012). Hispanic Student Participation and Success in Developmental Education. White Paper Prepared for the Hispanic Association of Colleges and Universities. *Hispanic Association of Colleges and Universities*.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of educational research*, 66(4), 543-578.

Pajares, F. (2002). Gender and perceived self-efficacy in self-regulated learning. *Theory into practice*, 41(2), 116-125.

Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving. *Contemporary educational psychology*, 20(4), 426-443.

Pape, S. J., & Wang, C. (2003). Middle school children's strategic behavior: Classification and relation to academic achievement and mathematical problem solving. *Instructional Science*, 31(6), 419-449.

Pianta, R. C., Belsky, J., Vandergrift, N., Houts, R., & Morrison, F. J. (2008). Classroom effects on children's achievement trajectories in elementary school. *American Educational Research Journal*, 45(2), 365-397.

Pomerantz, E. M., Grolnick, W. S., & Price, C. E. (2005). The role of parents in how children approach achievement. *Handbook of competence and motivation*, 259-278.

Pungello, E. P., Kainz, K., Burchinal, M., Wasik, B. H., Sparling, J. J., Ramey, C. T., & Campbell, F. A. (2010). Early Educational Intervention, Early Cumulative Risk, and the Early Home Environment as Predictors of Young Adult Outcomes Within a High-Risk Sample. *Child development*, 81(1), 410-426.

Ramey, C. T., Campbell, F. A., Burchinal, M., Skinner, M. L., Gardner, D. M., & Ramey, S. L. (2000). Persistent effects of early childhood education on high-risk children and their mothers. *Applied developmental science*, 4(1), 2-14.

Rice, K. G., Lopez, F. G., Richardson, C. M., & Stinson, J. M. (2013). Perfectionism moderates stereotype threat effects on STEM majors' academic performance. *Journal of counseling psychology*, 60(2), 287.

Rittmayer, A. D., & Beier, M. E. (2008). Overview: Self-efficacy in STEM. *SWE-AWE CASEE Overviews*.

Robinson, M. (2003). Student enrollment in high school AP sciences and calculus: How does it correlate with STEM careers? *Bulletin of Science, Technology & Society*, 23(4), 265-273.

Rosenbaum, J. E., Miller, S. R., & Krei, M. S. (1996). Gatekeeping in an era of more open gates: High school counselors' views of their influence on students' college plans. *American Journal of Education*, 257-279.

Salzman, H., & Lowell, B. L. (2007). Into the eye of the storm: Assessing the evidence on science and engineering education, quality, and workforce demand. *Quality, and Workforce Demand* (October 29, 2007).

Solorzano, D. G., & Ornelas, A. (2004). A critical race analysis of Latina/o and African American advanced placement enrollment in public high schools. *The High School Journal*, 87(3), 15-26.

Solorzano, D., & Ornelas, A. (2002). A critical race analysis of advanced placement classes: A case of educational inequality. *Journal of Latinos and Education*, 1(4), 215-229.

Trounson, R., & Colvin, R. (2002). The Nation: Rapid growth of Advanced Placement classes raises concerns. *Los Angeles Times*.

Usher, E. L. (2009). Sources of middle school students' self-efficacy in mathematics: A qualitative investigation. *American Educational Research Journal*, 46(1), 275-314.

Usher, E. L., & Pajares, F. (2006). Sources of academic and self-regulatory efficacy beliefs of entering middle school students. *Contemporary educational psychology*, 31(2), 125-141.

Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of educational research*, 78(4), 751-796.

Wang, X. (2013). Why students choose STEM majors motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, 0002831213488622.

Whiting, G. W., & Ford, D. Y. (2009). Multicultural Issues: Black Students and Advanced Placement Classes: Summary, Concerns, and Recommendations. *Gifted Child Today*, 32(1), 23-26.

Wigfield, A., & Eccles, J. S. (1994). Children's competence beliefs, achievement values, and general self-esteem change across elementary and middle school. *The Journal of Early Adolescence*, 14(2), 107-138.

Zarate, M. E., & Pachon, H. P. (2006). Perceptions of College Financial Aid among California Latino Youth. Policy Brief. *Tomas Rivera Policy Institute*.

Zeldin, A. L., Britner, S. L., & Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers. *Journal of Research in Science Teaching*, 45(9), 1036-1058.

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary educational psychology*, 25(1), 82-91.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, 41(2), 64-70.

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal*, 29(3), 663-676.

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Professional Development that Changes Teaching and Improves Learning

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EvalWorks

Each year school districts invest financial resources in professional development for their educators. Beyond the cost, educators spend countless hours in workshops, training, webinars, and other learning environments intended to enhance and deepen their knowledge and skills to increase student success. Too often the return on this investment is minimal in learning transfer for educators or measurable academic gains for students and maximum in participant dissatisfaction. Substantial research in effective professional development models exists. When applied to professional development, measurable change in the learning process occurs.

In 2015 WakeEd Partnership and Wake County Public School System (WCPSS), North Carolina's largest school system, applied that research to the design of an engaging, results-oriented professional development opportunity for elementary and secondary educators - SummerSTEM. WakeEd Partnership is an education non-profit (501c3) that exists to inform, mobilize and engage the business community in support of strong public schools in Wake County. During its 35-year history WakeEd has differentiated itself as an organization dedicated to supporting educators through professional development and resources. SummerSTEM is a hands-on professional development experience that addresses the needs of educators - adult learners - and brings real-world lessons to the classroom. As part of SummerSTEM, teachers receive seven days of professional development (five in the summer and two in the fall) in project-based learning following the Buck Institute for Education Gold Standard model. Additionally, they are immersed in STEM businesses and industries to experience work processes and workforce development needs. Teachers, who participate as teams of two, remain focused on integrating the components of PBL with lessons learned from their immersion, as they create Project-Based Learning (PBL) units and transform their classroom culture. Throughout the experience they are coached by current WCPSS teachers. SummerSTEM culminates in STEMposium, a public event in which teachers and their students share their PBL outcomes.

Effective Professional Development

Effective teaching, defined as "instruction that enables a wide range of students to learn" (Darling-Hammond, 2012), is the strongest school-level determinant of student achievement (Hanushek, 2011; Leithwood et al., 2004; Nye, Konstantopoulos, & Hedges, 2004; Rivkin, Hanushek, & Kain, 2005). Teacher professional development that supports effective teaching practices is therefore critically important for improving student learning. Despite this, most professional development programs experienced by teachers involve traditional workshops (Darling-Hammond et al., 2009), which rarely change teachers' practice and have no positive effect on student achievement (Yoon et al., 2007; Bush, 1984).

Research on teacher professional development reveals that while teachers may learn new practices, they rarely apply them to their work. This is often due to lack of support during the implementation stage, including lack of encouragement and guidance when implementing new approaches in the classroom. Thus, professional development must be structured in such a manner that it inspires teachers to change their practice. Research into effective professional development, defined as professional development that changes teachers' practice, reveals the following:

Teachers desire professional development that supports their autonomy, mastery, and purpose. For professional development to be effective, it must be based on research findings about theories of motivation and learning. In his seminal book Drive (2009) Daniel Pink identified the three main drivers that cause persons to strive to do their best work: autonomy (the desire to direct one's own life), mastery (the urge to continually improve at something that matters), and purpose (the desire to do what we do in the service of something larger than ourselves).

Ongoing, embedded professional development is needed to ensure learning transfer to practice. Research has shown that only ten percent of teachers can transfer a new skill to actual practice when no additional support is provided. In comparison, embedded support for implementation can result in over 90% of teachers transferring the skills they developed to their practice (Bush, 1984; Truesdale, 2003). Additional research reveals that coaching is one way to successfully change teacher practice (Showers, 1984; Slinger, 2004; Knight 2007; Batt, 2009; Stephens et al., 2007; Knight and Cornett, 2009), including modeling by coaches before teachers attempt implementation (Roy, 2005; Goldberg, 2002; Rice, 2001; Black, 1998; Licklider, 1997).

It takes time for teachers to become comfortable enough with new skills to use them with their students. Studies show that effective professional development programs require anywhere from 30 to 80 hours of instruction, practice, and coaching before teachers master new skills (French, 1997; Banilower, 2002; Joyce & Showers, 2002; Yoon et al., 2007). One-shot or fragmented workshops lasting 14 hours or less show no statistically significant effect on student learning (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009).

Developing content knowledge is particularly important in STEM professional development. Particularly for math and science professional development programs, research indicates that to improve student learning most teachers need to acquire math and science content knowledge as well as pedagogical techniques specific to the STEM content area. (Blank, de las Alas, & Smith, 2008; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012).

Effective professional learning communities support teacher collaboration and changes practice. Structured and focused professional learning communities that support teacher collaboration and risk-taking change teacher practice and increase student achievement (Dunne et al., 2000; Rosenholtz, 1989; Louis & Marks, 1998; Little, 1982). Student success has also been shown to be higher in schools with strong professional communities where collective responsibility, collaboration, and collegiality among teachers are fostered (Little, 1982; Newmann & Wehlage, 1995; Louis et al., 1996; Vescio et al., 2008). Research on teacher collaboration has shown that teachers who collaborate with colleagues are more effective, have higher student achievement (Kraft & Papay, 2014), and are more willing to adopt new practices (Granovetter & Soong, 1983). In addition, teachers improve at greater rates when they work in schools where collaboration is the norm (Ronfeldt et al., 2015).

Administrator support is key to teachers' willingness to change their practices. School administrators are second only to teachers in their effect on student achievement (Leithwood et al., 2004). Their influence can come in the form of instructional leadership, expectations of codes of conduct and climate, and support (verbal, written, financial) for change. Teachers whose administrators support their efforts apply new skills and strategies more frequently than teachers whose administrators do not provide such support. (Showers & Joyce, 1996).

Additionally, many of these tenets are included in Learning Forward's Standards for Professional Learning:

- Learning Communities: Professional learning that increases educator effectiveness and results for all students occurs within learning communities committed to continuous improvement, collective responsibility, and goal alignment.

- Leadership: Professional learning that increases educator effectiveness and results for all students requires skillful leaders who develop capacity, advocate, and create support systems for professional learning.
- Implementation: Professional learning that increases educator effectiveness and results for all students applies research on change and sustains implementation of professional learning for long-term change.

SummerSTEM: By Design

In a survey of SummerSTEM participants (66 out of 193 for a 33% response rate) from the past two years, 98% reported that they would recommend SummerSTEM to their colleagues. This endorsement is because SummerSTEM represents professional development that is designed with the teacher -- the adult learner -- in mind. Participants come to SummerSTEM in teams of two, representing various disciplines and roles within the school. They must have the foundational skills necessary for effective collaboration. The application process sets the tone for the program's rigor and expectations. The participants must not only receive their principal's endorsement, but must also sign an agreement that outlines the program's requirements: a) attend each of the seven days of the program, b) develop a Project-Based Learning unit, c) present the unit and its impact at the year-end culminating event (STEMposium), and d) share the SummerSTEM and PBL experience with colleagues in at least two formats. Educators are compensated for their time and their work, including stipends for participating in the summer workshop and payment for curriculum development.

SummerSTEM balances structure with learner autonomy throughout the program. Once accepted into the program, teams rank the career clusters they wish to explore. Learner choice is embedded and evident from the start. Career clusters reflect the STEM industries of the host organizations.

SummerSTEM's unique design is apparent from the first day. Participants come to the workshop as teams that have been endorsed by their principals. Their SummerSTEM coaches, who have contacted them prior to the first day, meet with them to create a kind of "advisory group" that will be their anchor placement throughout the eight days of the program. This coach, a master teacher from WCPSS, has successfully implemented PBL and coached others to do the same. The coaches guide participants throughout the program; since they are colleagues and teacher leaders, they cultivate authenticity and credibility with the teachers.

On Day 1 of SummerSTEM, teachers self-identify their level of PBL design skill: novice, proficient, or advanced. This creates opportunities for all learners to develop mastery in new areas. Teachers do not have to participate in this portion of the program with their teammate. SummerSTEM coaches facilitate leveled PBL workshops throughout the week when participants are not immersed in a STEM industry experience, a total of 2.5 days of professional development.

In the novice session, the coach's approach combines inquiry with didactic instruction to teach the essential project design elements of the Buck Institute Gold-Standard PBL process: Challenging Problem or Question; Sustained Inquiry; Authenticity; Student Voice and Choice; Reflection; Critique and Revision; and Public Product. The goal is for novices to understand the PBL components at a knowledge level. They will apply this knowledge as they continue their work with their teammate during the school year. The proficient workshop builds on the PBL framework, with focus on specific challenge areas, like classroom culture, the "messy middle," developing collaborative teams, project and process management, and other topics that are sourced from the participants' level of understanding and experience with PBL. The goal is for participants to improve areas of their practice that have challenged them in prior PBL experiences. The coach provides didactic instruction and one-to-one support based on areas of need. Finally, the advanced session functions as a seminar, with participants sharing problems of practice in their work with PBL that the "community of learners" who are present explore with them. At this level, the coach functions as a facilitator for the group. Throughout the week, participants may alter their perceived skill level with PBL and move between the differentiated groups.

Professional learning, pedagogy, child development, classroom culture, are the standard areas for educator professional development. SummerSTEM's industry immersion experience brings the unexpected to the program. Each team participates in 2.5 days of STEM immersion. Host business/organization sites structure their immersion with the PBL cycle in mind. They integrate information about their core business, workforce development, and talent pipeline needs with hands-on engagement, thus providing teachers with experience in problem simulation and professional processes essential to the site's daily operations. Teachers engage with diverse employees, who are subject matter experts, from across the business, gaining insight into the knowledge, skills, attitudes, and aptitudes students need.

In addition to the industry immersion experience, educators spend a half-day in a community college class that aligns with the career cluster. This experience serves many purposes, including broadening educators' understanding of the value and resources of technical post-secondary programs. Educators benefit from exploring the certificate, diploma, and degree programs of high-need career areas. The immersion also provides teachers with an opportunity to do the work that is required in these applied STEM fields. This demonstrates to teachers the need for all students to understand math and science and to develop the essential skills of collaboration, critical thinking, communication, and creativity.

Embedded in the two and half days of professional development participants are provided blocks of time to work with their school teams to process and synthesize their pedagogical growth as well as the "nuggets" gained from their immersion experience. Their coaches, who have participated with them in the industry immersion, support their leap from immersion to PBL unit development. The coach's goal for each team is the successful design and implementation of a PBL unit that may be submitted to the school district's curriculum warehouse for use by all WCPSS educators.

The SummerSTEM five-day experience serves as a launch for teachers' development of a PBL unit. During the academic year, the coach supports their efforts. Essential to teachers' success is the addition of two professional development days, spaced one month apart, during the first semester of the school year. These days re-ignite educators' passion for PBL, provide additional learning opportunities, and, most importantly, include dedicated time for them to continue developing their PBL unit. Educators can experiment with their PBL unit while receiving coaching; they are encouraged to review and revise their work to best support student proficiency and learning transfer, key components for impactful professional development.

SummerSTEM culminates in STEMposium, a public display of the impact of the immersion experience and the integration of teachers' PBL units with their classes. Educator and student representatives meet with colleagues and community leaders and provide them testimony about the program's effectiveness. Students are the real evidence of SummerSTEM's impact and, most frequently, it is the students who act as spokespersons for SummerSTEM's success.

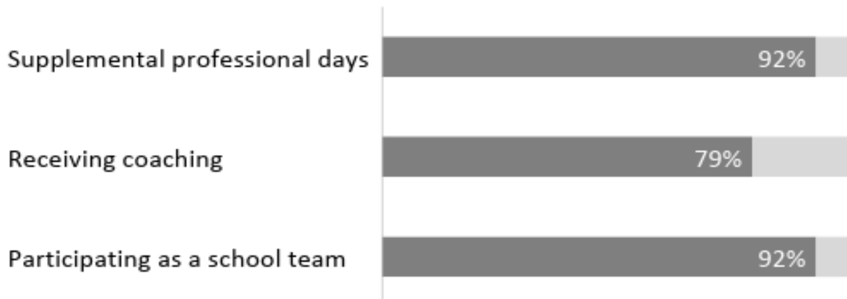
Teachers devote 65–75 hours to the SummerSTEM learning process. The combination of differentiated instruction, coaching, and engaging experiences along with the requirements of presenting a high-impact unit lead to the sustained interest, engagement, and enthusiasm necessary for successful professional development. Thus, actual learning transfer occurs.

SummerSTEM and Best Practices in Professional Development

The table below outlines best practices in teacher professional development as identified through research and explains where SummerSTEM reflects these best practices.

Best Practices	SummerSTEM
Supports teachers' autonomy, mastery, and purpose	● Provides teachers with the opportunity to develop PBLs on a topic of interest to them and with the support of a STEM host.
Incorporates active learning	● Teachers immerse in STEM businesses and community college simulations as they work in pairs to develop materials, videos, etc. related to their PBL.
Uses models of effective practice	● PBL is a dynamic student-centered instructional approach whereby students gain deeper knowledge through exploring real-world problems.
Provides coaching and expert support	● Select colleagues who have graduated from SummerSTEM lead the professional development and provide ongoing support as coaches.
Offers feedback and reflection	● Teachers are provided time to reflect on how to improve their PBL to ensure greater student learning. Coaches offer guidance throughout the process.
Is ongoing and embedded	● Teachers spend five days in the summer and two days in the fall working with coaches on their PBLs.
Provides time for teachers to develop new skills	● Across the seven months/ 56+ hours of formal support, teachers learn how to develop and implement effective PBLs.
Develops teachers' content knowledge	● Teachers' immersions with STEM organizations support new learning and skill development.
Supports learning communities / teacher collaboration	● Teachers work in pairs as part of a larger learning community.
Is supported by administrators	● As part of the application to Summer STEM, administrators submit a Principal's Endorsement, in which they commit to providing time for teacher collaboration and coverage for professional development. In addition, administrators create opportunities for teachers to share their SummerSTEM experience and PBL with faculty through Professional Learning Teams (PLTs) and teacher-led professional development.

Participants reported that SummerSTEM's design positively contributed to their overall experience. Over 90% of participants reported that supplemental professional days and participating as a school team positively affected their experience and 79% indicated that receiving coaching positively affected their experience. As one teacher reported, "Time is always a limited resource in the world of teaching. Having that time set aside for us to devote to our PBL units was awesome. Also, being able to come together with the other SummerSTEM members was helpful because we were able to share our ideas and utilize each other." Another explained, "I think that one of the issues with PD for teachers is that there is never any built-in time to reflect, ask questions, get feedback, or start implementing what you learned. SummerSTEM was amazing because it included time to work on your unit, time with coaches to ask questions or get clarification, and time to talk with other teachers/groups to get feedback and other opinions. I think the extra days were a part of making this so successful!" Summarily, teachers know their content and they "make the leap" from their SummerSTEM experience to their classroom, their colleagues, and their schools.



A review of SummerSTEM's design further reveals that it supports a variety of essential teaching standards linked to Standard IV of North Carolina's Teacher Evaluation Rubric (a copy of which is included in the Appendix). Standard IV: Teachers Facilitate Learning for Their Students includes the following subcomponents:

- Teachers know the ways in which learning takes place, and they know the appropriate levels of intellectual, physical, social, and emotional development of their students.
- Teachers plan instruction appropriate for their students.
- Teachers use a variety of instructional methods.
- Teachers integrate and utilize technology in their instruction.
- Teachers help students develop critical thinking and problem-solving skills.
- Teachers help students work in teams and develop leadership qualities.
- Teachers communicate effectively.
- Teachers use a variety of methods to assess student learning.

SummerSTEM supports appropriate instructional planning using a variety of methods and incorporating technology under the framework of Project-Based Learning. Students' critical thinking, problem-solving skill, and leadership skills are developed through Project-Based Learning as they collaborate to answer the overarching question. As part of SummerSTEM, teachers develop plans for formative and summative assessments of students' understanding and learning and use these data to review and improve their PBL lessons.

Evaluation of SummerSTEM

To evaluate SummerSTEM, EvalWorks, a local firm with experience evaluating national/federal, state, and local STEM initiatives conducted surveys, focus groups, and teacher and student interviews to understand impacts.

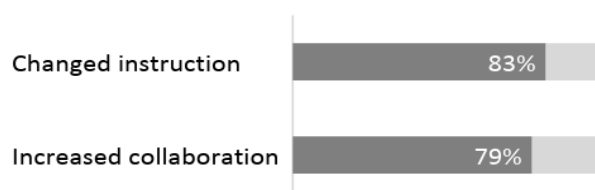
Evaluation questions were designed to determine teacher development in the four levels of professional impact identified by Kirkpatrick (1994): Reaction (how participants perceive the professional development), Learning (the extent to which professional development has improved knowledge and/or skills), Behavior (the extent to which those who received the professional development have changed their behavior because of what they learned in the professional development), and Results (the impact of participants' behavioral changes due to the professional development). Using this model as a framework, the evaluation of SummerSTEM sought to understand the degree to which participants believed that the professional development was relevant, meaningful, useful, and worthwhile; the degree to which participants learned how to develop and implement PBL units (or improve their development and implementation of PBL units); the degree to which participants developed and implemented PBL units or other activities/methods they learned related to PBLs in the interim; and the impact of implementation of PBL units on students' engagement, understanding, and achievement.

The evaluation utilized a mixed-methods concurrent design, giving equal priority to both quantitative and qualitative methods (Creswell, Plano Clark, Gutmann, & Hanson, 2003). A mixed-methods approach to conducting evaluation is different from using multiple methods or a combination of methods in that data from one type of method (quantitative or qualitative) is merged, connected, or embedded with data from the other type of method (Creswell & Clark, 2006). The study's quantitative and qualitative methods occur simultaneously and are assigned equal weighting in the interpretation of findings.

SummerSTEM: Teacher Impacts

At the conclusion of SummerSTEM, participants are asked to indicate the degree of impact their SummerSTEM experience had on such areas as instruction, collaboration with colleagues, views about themselves as teachers and teacher leaders, and the degree to which they have assumed new responsibilities. They also rate the changes they have seen among their students. Ratings are on a 5-point scale as follows: Very Small, Small, Moderate, Large, and Very Large. Two years of data have been collected thus far.

The percentage of SummerSTEM participants that reported that SummerSTEM had changed their instruction and increased their collaboration to a large or very large degree was 83% and 79%, respectively.



Participants also reported that their business immersion experience and the program's coaching helped them identify new ways to strengthen their role as facilitator, thus engaging more students and supporting them to take responsibility for their own learning. As one teacher shared, "This PBL unit opened a door for our 3rd graders and one was offered a scholarship to attend a summer camp at the Arboretum. This student comes from a low-income family and would not have been able to attend without this program. PBL and SummerSTEM has taught teachers to network and take advantage of what the community has to offer. This experience may change this child's whole future for the better. "

Comments by educators on SummerSTEM's impact include the following:

> "The information presented at SummerSTEM empowered me with processes, procedures, and protocol to effectively lead my students and team through PBL creation and implementation."

> "SummerSTEM has motivated me to empower a global approach and leadership skills with my students. It has also inspired me as an educator to motivate others in my profession!"

> "I cannot stress enough how this experience was truly amazing and cannot wait until next year to see what my students come up with. My students owned this experience and as their teacher I was humbled by their actions. Please continue projects like this because it makes the content relevant and the students are actively engaged."

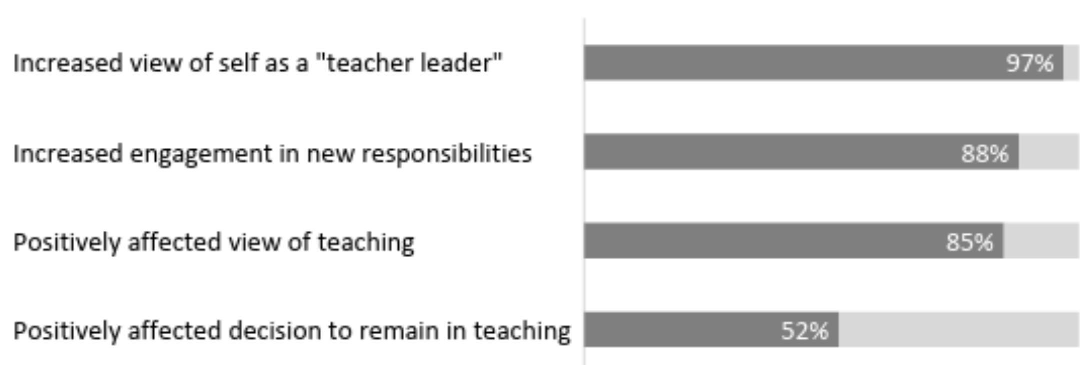
> "I have written a grant to help with other PBL opportunities within the school. I have also worked to get other teachers in our school to try PBL or participate in more PBL professional development."

> "SummerSTEM empowered me to be a teacher that is willing to take risks for her students. Giving students creative freedom and choice in a project, instead of the traditional teacher-leads-everything, allowed them to grow in a way I didn't realize was possible."

> "I now have knowledge of the types of jobs available to my students and the skills needed to perform them. I make links to my kids ALL the time now. Even though they are elementary students, I try to plant the seed for possible jobs for the future based on their talents and interests."

> "Many other teachers in our school have inquired about PBL experiences. Several have asked to attend next year's SummerSTEM training."

97% of teachers indicated that participation in SummerSTEM largely or very largely increased their view of themselves as a teacher leader, 88% indicated that they had taken on new responsibilities, and 85% indicated that SummerSTEM had positively affected their view of teaching to a large or very large degree. For over half of participants, SummerSTEM had a large or very large positive effect on their decision to remain in teaching.



Following are several exemplary comments:

> "I really enjoyed the process of it all. With the students, teachers, community and specialists and anyone else that was involved. It just shows that this profession is ever changing and ever growing

which just makes me want to stick around to see what will happen next!"

"Sometimes as the years go by, you wonder if you really make a difference in our students' lives. This experience validates why we do what we do. I know I make a difference as a teacher and hope to continue to inspire on a daily basis."

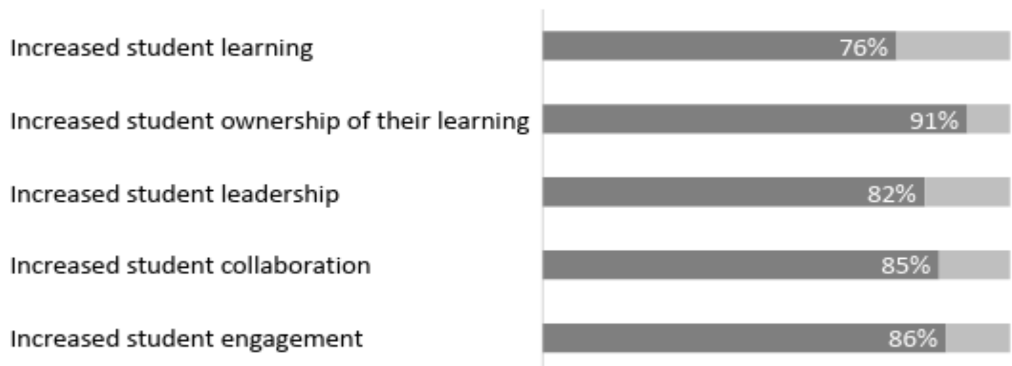
"Knowing that companies are willing to volunteer time and resources to my classroom helps me believe that what I'm doing is important."

"SummerSTEM helped me to see the "bigger picture" that lies before our students in terms of their future. I now better understand that I need to plan and facilitate tasks that allow students to build soft skills to use in their future professional lives."

"I have enjoyed the freedom of choice my students have to explore the world around them. They feel more confident about their learning and I feel like more like a facilitator and less like the only decision maker in the classroom."

SummerSTEM: Student Impacts

Over three-quarters of SummerSTEM participants reported that SummerSTEM had a large or very large impact on students' learning, engagement, collaboration, and leadership, with over 90% indicating that it had a large or very large impact on the degree to which their students took ownership of their learning.



Participants cited the following as evidence for their agreement to the above statements:

- Student projects /products resulting from PBL (91%)
- Student oral presentations demonstrating deeper understanding of core objectives and content (67%)
- Student or class completion of assignments (65%)
- Student performance on teacher-made assessments, including formative and summative assessments (58%)
- Student performance on standardized assessments (20%)

SummerSTEM: A Model for Effective Teacher Professional Development

"I thoroughly enjoyed my SummerSTEM experience. The coaches who helped were extremely supportive. The program was SUPER organized and well thought out. I enjoyed the support of the community / business and being able to experience a day in the life of a scientist, etc.--a field trip for teachers! Mostly, I appreciate that I was able to apply what I had learned to my teaching!"

The structure of SummerSTEM (differentiated professional development, team collaboration time, use of PBL coaches) is critical to its success. The time for collaboration and reflection, especially the professional development days during the school year, was highly valued. SummerSTEM participants used the business immersion as a catalyst for developing appropriate and effective PBL units, and for understanding the knowledge, skills, and behaviors employers are seeking in potential employees.

> "SummerSTEM was a fantastic experience. Networking with the professionals at the various businesses and learning about the Scrum project management style has broadened my knowledge about current real-life opportunities. It has transformed the way that I introduce, implement, and manage student projects. It was also refreshing and rejuvenating for me personally, which translates to putting more excitement and energy into my craft."

As a result of developing their PBL units, teachers increased their collaboration with others and changed their classroom practices. Many participants indicated that they saw themselves increasingly as teacher leaders, which led them to take on new responsibilities and roles, and positively affected not only their view of teaching, but also, for over half of the participants, their decision to remain teaching. The PBL units benefitted students by increasing their opportunities to collaborate and lead, and, as a result, encouraging them to assume greater ownership of their learning. Taken together, findings are that SummerSTEM is a model for effective teacher professional development that positively impacts students by changing teachers' practices and mindsets.

> "Thank you for this career changing experience. I have completely revived my instructional methods and have a renewed passion for a job that I already loved."

REFERENCES

Banilower, E. (2002). *Results of the 2001-2002 study of the impact of the local systemic change initiative on student achievement in science*. Arlington, VA: National Science Foundation.

Batt, E. G. (2010). Cognitive coaching: A critical phase in professional development to implement sheltered instruction. *Teaching and Teacher Education*, 26 (2010), 997-1005.

Black, S. (1998). Money and the art of staff development. *Journal of Staff Development*, 19 (2), 14-17.

Bush, R.N. (1984). Effective staff development in making schools more effective. *Proceedings of three state conferences*. San Francisco, CA: Far West Laboratory.

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. In A. Tashakkori & C. Teddlie (Eds), *Handbook on mixed methods in the behavioral and social sciences* (pp. 209-240). Thousand Oaks, CA: Sage Publications.

Creswell, J. W., & Plano Clark, V. L. (2006). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage Publications.

Darling-Hammond, L., Chung Wei, R., Andree, A., & Richardson, N. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Oxford, OH: National Staff Development Council.

Darling-Hammond, L. (2012). *Creating a comprehensive system for evaluating and supporting effective teaching*. Stanford, CA: Stanford Center for Opportunity Policy in Education.

Darling-Hammond, L., Wei, R.C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Stanford, CA: National Staff Development Council and the School Redesign Network at Stanford University.

Dunne, F., Nave, B., & Lewis, A. (2000). Critical friends: Teachers helping to improve student learning. *Phi Delta Kappa International Research Bulletin* (CEDR) (28), 9-12.

French, V.W. (1997). Teachers must be learners, too: Professional development and national teaching standards. *NASSP Bulletin*, 81 (585), 38-44.

Garet, M.S., Porter, A., Desimone, L., Birman, B., & Yoon, K.S. (2001, Winter). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38(4), 915-945.

Goldberg, M.F. (2002). *15 school questions and discussion: From class size, standards, and school safety to leadership and more*. Blue Ridge Summit, PA: Scarecrow Education.

Granovetter, M. & Soong, R. (1983). Threshold models of diffusion and collective behavior. *Journal of Mathematical Sociology* 9 (3), 165-179.

Guskey, T. R., & Yoon, K. S. (2009). What works in professional development? *Phi Delta Kappan*, 90(7), 495-500.

Hanushek, E.A. (2011). The economic value of higher teacher quality (PDF). *Economics of Education Review*, 30, 466-479.

Joyce, B. & Showers, B. (1982). The coaching of teaching. *Educational Leadership*, 40 (1), 4-10.

Kirkpatrick, D. (1994). *Evaluating training programs*. San Francisco: Berrett-Koehler Publishers, Inc.

Knight, J. (2007). *Instructional coaching: A partnership approach to improving instruction*. Thousand Oaks, CA: Corwin Press.

Knight, J. & Cornett, J. (2009). *Studying the impact of instructional coaching*. Lawrence, KS: Kansas Coaching Project for the Center on Research on Learning.

Kraft, M.A. & Papay, J.P. (2004). Can professional environments in schools promote teacher development? Explaining heterogeneity in returns to teaching experience. *Educational Effectiveness and Policy Analysis* 36 (4), 476-500.

Learning Forward. (2011). *Standards for professional learning*. Learning Forward.

Leithwood, K., Seashore Louis, K., Anderson, S.E., and Wahlstrom, K. L. (2004). *Review of research: How leadership influences student learning*. University of Minnesota and University of Toronto.

Licklider, B.L. (1997). Breaking ranks: Changing the in-service institution. *NASSP Bulletin*, 81 (585), 9- 22.

Little, J. (1982). Norms of collegiality and experimentation: Workplace conditions of school success. *American Educational Research Journal*, 19(3), 325-340.

Louis, K. S., Kruse, S. D., & Associates. (1995). *Professionalism and community: Perspectives in reforming urban schools*. Thousand Oaks, CA: Corwin Press Inc.

Louis, K. S., & Marks, H. (1998). Does professional community affect the classroom? Teachers' work and student experience in restructured schools. *American Journal of Education*, 106 (4), 532-575.

Newman, F. & Wehlage, G. (1997). *Successful school restructuring: A report to the public and educators by the Center on Organization and Restructuring of Schools*. Madison, WI: Document Service, Wisconsin Center for Educational Research.

Nye, B., Konstantopoulos, S., and Hedges, L.V. (2004). How large are teacher effects? (PDF). *Educational Evaluation and Policy Analysis*, 26(3), 237-257.

Pink, Daniel H. (2009) *Drive: The surprising truth about what motivates us*. Riverhead Books, New York, New York.

Rice, J.K. (2001). Fiscal implications of new directions in teacher professional development. *School Business Affairs*, 67 (4), 19-24.

Ronfeldt, M., Farmer, S. O., McQueen, K., & Grissom, J. A. (2015). Teacher collaboration in instructional teams and student achievement. *American Educational Research Journal*, 52(3), 475-514.

Rosenholtz, S. J. (1989). *Teachers' workplace: The social organization of schools*. New York: Longman.

Roy, P. (2005). *A fresh look at follow-up*. Retrieved from http://www.nscd.org/library/publications/ results/res2-05roy.cfm.

Showers, B. (1984). *Peer coaching: A strategy for facilitating transfer of training*. Eugene, OR: Centre for Educational Policy and Management.

Slinger, J. L. (2004). Cognitive coaching: Impact on student and influence on teachers. *Dissertation Abstracts International*, 65 (7), 2567.

Stephens, D., Morgan, D., Donnelly, A., DeFord, D., Young, J. Seaman, M., et al. (2007). The South Carolina reading Initiative: NCTE's reading initiative as a statewide staff development project. Urbana, IL: National Council of Teachers of English.

Truesdale, W. T. (2003). The implementation of peer coaching on the transferability of staff development to classroom practice in two selected Chicago public elementary schools. *Dissertation Abstracts International*, 64 (11), 3923.

Vescio, V., Ross, D., and Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education*, 24(1), 80-91.

Yoon, K. S., Duncan, T., Lee, S. W-Y., Scarloss, B., and Shapley, K. (2007). Reviewing the evidence on how teacher professional development affects student achievement. *Issues & Answers Report*, REL 2007–No. 033. Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest.

Appendix A

Standard IV: Teachers Facilitate Learning for Their Students

Teachers know the ways in which learning takes place, and they know the appropriate levels of intellectual, physical, social, and emotional development of their students.

Teachers know how students think and learn. Teachers understand the influences that affect individual student learning (development, culture, language proficiency, etc.) and differentiate their instruction accordingly. Teachers keep abreast of evolving research about student learning. They adapt resources to address the strengths and weaknesses of their students.

- Know how students think and learn
- Understand the influences on student learning and differentiate instruction
- Keep abreast of evolving research
- Adapt resources to address the strengths and weaknesses of students

Teachers plan instruction appropriate for their students.

Teachers collaborate with their colleagues and use a variety of data sources for short- and long-range planning based on the North Carolina Standard Course of Study. These plans reflect an understanding of how students learn. Teachers engage students in the learning process. They understand that instructional plans must be constantly monitored and modified to enhance learning. Teachers make the curriculum responsive to cultural diversity and to individual learning needs.

- Collaborate with colleagues
- Use data for short- and long-range planning
- Engage students in the learning process § Monitor and modify plans to enhance student learning
- Respond to cultural diversity and learning needs of students

Teachers use a variety of instructional methods.

Teachers choose the methods and techniques that are most effective in meeting the needs of their students as they strive to eliminate achievement gaps. Teachers employ a wide range of techniques including information and communication technology, learning styles, and differentiated instruction.

- Choose methods and materials as they strive to eliminate achievement gaps
- Employ a wide range of techniques using information and communication technology, learning styles, and differentiated instruction

Teachers integrate and utilize technology in their instruction.

Teachers know when and how to use technology to maximize student learning. Teachers help students use technology to learn content, think critically, solve problems, discern reliability, use information, communicate, innovate, and collaborate.

- Know appropriate use
- Help students use technology to learn content, think critically, solve problems, discern reliability, use information, communicate, innovate, and collaborate

Teachers help students develop critical thinking and problem-solving skills.

Teachers encourage students to ask questions, think creatively, develop and test innovative ideas, synthesize knowledge and draw conclusions. They help students exercise and communicate sound reasoning; understand connections; make complex choices; and frame, analyze, and solve problems.

Teachers help students work in teams and develop leadership qualities.

Teachers teach the importance of cooperation and collaboration. They organize learning teams in order to help students define roles, strengthen social ties, improve communication and collaborative skills, interact with people from different cultures and backgrounds, and develop leadership qualities.

- Teach the importance of cooperation and collaboration.

- Organize learning teams in order to help students define roles, strengthen social ties, improve communication and collaborative skills, interact with people from different cultures and backgrounds, and develop leadership qualities

Teachers communicate effectively.

Teachers communicate in ways that are clearly understood by their students. They are perceptive listeners and are able to communicate with students in a variety of ways even when language is a barrier. Teachers help students articulate thoughts and ideas clearly and effectively.

- Communicate clearly with students in a variety of ways
- Assist students in articulating thoughts and ideas clearly and effectively

Teachers use a variety of methods to assess what each student has learned.

Teachers use multiple indicators, including formative and summative assessments, to evaluate student progress and growth as they strive to eliminate achievement gaps. Teachers provide opportunities, methods, feedback, and tools for students to assess themselves and each other. Teachers use 21st century assessment systems to inform instruction and demonstrate evidence of students' 21st century knowledge, skills, performance, and dispositions.

- Use multiple indicators, both formative and summative, to evaluate student progress
- Provide opportunities for self-assessment § Use assessment systems to inform instruction and demonstrate evidence of students' 21st century knowledge, skills, performance, and dispositions.

About the Author
Amy A. Germuth leads EvalWorks which evaluates STEM and other education projects.

Collaboration Between Scientists and Teachers Using Twitter

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INTRODUCTION

When considering how you learned science when you were in school, do you remember participating in authentic science or do you recall memorizing facts? Unfortunately, most of us may say the latter; however, there are changes currently occurring in science education that strive to reconstruct this trajectory. Science education reform has emphasized the partnership between teachers and scientists (Kim & Herbert, 2011) in order to increase authentic scientific inquiry in the classroom. Authentic science has been shown to positively influence students' science identity, allow students to develop critical science skills, and increase student motivation (Chapman & Feldman, 2017; Hellgren, 2017; Tarjan, de Nesnera, & Hoffman, 2015). Therefore, the partnership between scientists and teachers to generate authentic science in the classroom has become increasingly crucial. One way to assist teachers to partner with scientists is through the social media platforms such as, Twitter. Educators have shown increasing interest in using Twitter as a source of professional development and collaboration with others (Xing & Gao, 2018). Considering this, collaboration on Twitter can also play a role in the social capital of teachers. Social capital can be defined as the "relational resources embedded in the cross-cutting personal ties that are useful for the development of individuals in community social organizations" (Tsai & Ghoshal, 1998, p. 404). However, there has been a lack of research that examines the impact of Twitter on teachers' social capital (Rhem & Notten, 2016).

Twitter can provide quality professional development for teachers including the opportunity to collaborate with scientists (Shein & Tsai, 2015). Citizen science, science conducted by regular people (McKenney, Flythe, Millis, Stalls, Urban, Dunn, & Stevens, 2016) has been practiced at least since the 1700s (Raddick, Bracey, Carney, Gyuk, Borne, Wallin, & Jacoby, 2009). In 2009, Raddick and colleagues suggested that citizen science be incorporated into K-12 classrooms. Citizen science allows students to participate in authentic scientific research. Students engaging in citizen science have the opportunity to collect data to send to scientists that could assist them in making new discoveries (Students Discover, 2015). For example, in the Students Discover "The Great Pumpkin Project," students can collect data, such as insect population and how plants change over time, from a local garden and send this data to scientists to assist them in discovering the relationships between insects, plants, and microbes. In return, students are able to learn about items such as plant-insect-microbe interactions and the importance of bees and plant pollination. Another example is the project entitled "Journey North"(journeynorth.org) in which students learn about migration patterns and seasonal changes by collecting data about hummingbirds, monarch butterflies, and other organisms. Students report sightings of these particular organisms, assisting scientists in making discoveries about seasons and migrations. There is evidence of these types of lessons being designed; however, there is less evidence of implementation in the classroom (Students Discover, 2015; SciStarter, 2017). It is possible that this is caused by a lack of communication among scientists involved in the projects and teachers in the classroom.

To address the lack of communication among scientists and teachers, the social media platform, Twitter, could be a useful tool. Over the years, Twitter has become an informal learning space for teachers (Rehm & Notten, 2016). Teachers use hashtags such as #scichat to collaborate with each other, share resources, stay informed about current educational practices, and hold conversations with people and organizations from around the world. Personal learning networks have emerged from these conversations. Twitter could be an excellent platform for science teachers to connect with scientists in order to assist them with their research via citizen science, but are they using it? In this investigation, I explored the extent to which those involved in science teacher social networks are also involved in citizen science social networks. An overarching research question is "In what ways are K-12 science teachers involved in citizen science on Twitter?" The question was investigated with two sub-questions as follows:

a) What kind of overlaps exists between participants using science educator hashtags and citizen science hashtags?
b) What kind of overlaps exists between top influencers using science educator hashtags and citizen science hashtags?

Findings from this study could assist researchers in determining the next steps for Twitter usage among science teachers who are interested in collaborating with scientists and pursuing citizen science in their classrooms.

METHODS

Data were collected over a period of six weeks from five different hashtags on Twitter through NodeXL, an open-source template for Microsoft Excel which allows for the exploration of network graphs. Two of the hashtags are popular citizen science hashtags: #citizenscience, #citsci, and three of them are leading science teaching hashtags: #scichat, #scienceed, and #scienceteacher. Many participants in the citizen science hashtag include scientists that are involved in research involving citizens. Many participants in the science teacher hashtags group are K-12 science teachers. Hashtags were selected based on personal experience as a science teacher who has implemented citizen science in the classroom, as well as, an in-depth internet search of the top science teacher and citizen science hashtags. One limitation of this study is that participants of each hashtag group cannot be confirmed as science teachers or scientists; however, this study assumes that the majority match these definitions. All vertices, which are participants using the particular hashtag, from the science teacher hashtags were collected into one spreadsheet, organized in alphabetical order, and then the duplicates were removed. The same process was conducted with both citizen science hashtags: #citizenscience and #citsci, in the same spreadsheet. In order to determine overlaps among vertices, duplicates were highlighted among both columns.

Graph metrics were calculated in NodeXL in order to determine top influencers for each hashtag. "Betweenness centrality," an indicator of a person's influence in the network, was one of the graph metrics calculated (Newman, 2001). This column was sorted from largest to smallest in order to determine the top influencers of each group. Influencers provide a "bridge" between different parts of the network. Without them, the network could fall apart. "Influencers may only represent a small percentage of an overall conversation; their role does ultimately shape how information spreads. Tapping into close communities makes content shareable, but top-down influence is essential for content to achieve truly viral speed and scale" (Parkin, 2014). NodeXL only allows for one week of data collection at a time; therefore, in this study, there were six different spreadsheets for each of the hashtags, totaling 30 spreadsheets in all. In order to determine top influencers over a period of 6 weeks, the top 10 influencers, determined by betweenness centrality, were documented. The top five vertices that appeared for the greatest amount of time were considered the top five influencers over the six-week period.

FINDINGS

Research Sub-question 1: What kind of overlaps exist in participants in science educator hashtags and citizen science hashtags?

Overall, there were 8,311 unique vertices involved in the citizen science hashtags and 2,980 unique vertices involved in the science teacher hashtags. One-hundred and seventeen of the participants were involved in both sets of hashtags. Out of all the participants using the science teacher hashtags, approximately 4% of them were also involved in citizen science networks.

Research Sub-question 2: What kind of overlaps exist in top influencers in science educator hashtags and citizen science hashtags?

Top influencers are organized in Table 1. There were no overlaps among the citizen science top influencers and science teacher top influencers.

Table 1

Top influencers using Citizen Science Hashtags and Science Educator

#citizenscience	#citsci	#scichat	#scienceed	#scienceteacher
ntxscied	coopsciscoop	garym	beth_heidemann	arludo
coopsciscoop	siobhanleachman	tekieboard	go2science	sciteacheraward
citscioz	citscioz	weareteachers	mtoy2014	wdlorg
scistarter	inaturalist	ericcurts	roisinlaubs	teachinglc
insectmigration	crowdandcloudtv	hatterchatter	sciencemarchpr	spanglerscience

DISCUSSION AND IMPLICATIONS

This study examined the involvement of users of the science teacher hashtags in the use of citizen science hashtags and revealed that only 4% of those using science teacher hashtags were using citizen science hashtags as well. The findings of this study could potentially add understandings to social network and science education literature. First, it suggests that there may be a disconnect between science teachers and the rest of the citizen science community, at least in the "world of" Twitter. Connecting science teachers with members of the citizen science community would greatly contribute to citizen science as well as science teaching and learning. Understanding whether or not there is a disconnect between scientists and science teachers could lead to initiatives that would bring more authentic science into the classroom.

Second, there were no overlaps among the top influencers in each social network. If scientists who are interested in citizen science for youth become involved in science educator hashtags to the extent that they become a top influencer, science classrooms could be impacted in a positive way. Conversations on Twitter can contribute to the formation of social capital for both teachers and scientists which this could be also benefit the educational and scientific communities (Rehm & Notten, 2016).

In order to facilitate greater collaboration between scientists and science teachers on Twitter, future studies could focus on intervention. A possible next step would be to connect the top influencers in each category in order to brainstorm ways in which science teachers and scientists could collaborate.

REFERENCES

Chapman, A., & Feldman, A. (2017). Cultivation of science identity through authentic science in an urban high school classroom. *Cultural Studies of Science Education*, 12(2), 469–491.

Hellgren, J. (2017). Motivating students with authentic science experiences: changes in motivation for school science. *Research in Science and Technological Education*, 35(4), 409.

Kim, H. J., & Herbert, B. (2011). Inquiry Resources Collection as a Boundary Object Supporting Meaningful Collaboration in a Wiki-Based Scientist-Teacher Community. *Journal of Science Education and Technology*, 21(4), 504–512.

Mahoney, B. (2013). Hashtags, Mentions, and Following: Creating a PLN with Twitter. *Middle Ground*, 16(4), 22–23.

McHeyzer-Williams, L. J., & McHeyzer-Williams, M. (2016). Our Year on Twitter: Science in #SocialMedia. *Trends In Immunology*, 37(4), 290–295.

McKenney, E., Flythe, T., Millis, C., Stalls, J., Urban, J., Dunn, R., & Stevens, J. (2016). Symbiosis in the Soil: Citizen Microbiology in Middle School and High School Classrooms. *Journal of Microbiology and Biology Education*, 17(1), 60–62.

Newman, M. (2005). A measure of betweenness centrality based on random walks. *Social Networks*, 27(1), 39–54.

Parkin, R. (2014, April 6). Identifying Influencers with Social Network Analysis. Retrieved from https://www.pulsarplatform.com/blog/2014/identifying-influencers-with-social-network-analysis/

Raddick, J., Bracey, G., Carney, K., Gyuk, G., Borne, K., Wallin, J., & Jacoby, S. (2009). Citizen Science: Status and Research Directions for the Coming Decade. *The Astronomy and Astrophysics Decadal Survey, Position Papers*, 46.

Rehm, M., & Notten, A. (2016). Twitter as an informal learning space for teachers!? The role of social capital in Twitter conversations among teachers. *Science Direct*, 60, 215–223.

Shein, P. P., & Tsai, C.-Y. (2015). Inquiry Resources Collection as a Boundary Object Supporting Meaningful Collaboration in a Wiki-Based Scientist-Teacher Community Impact of a Scientist–Teacher Collaborative Model on Students, Teachers, and Scientists. *International Journal of Science Education*, 37(13), 2147–2169.

Scistarter: Science we can do together. (2017). Retrieved from https://scistarter.com/

Students Discover. (2015). Retrieved from http://studentsdiscover.org/research/microbes/

Tarjan, L. M., de Nesnera, K., & Hoffman, R. (2015). Authentic science investigation in the classroom: Tools for creating original, testable questions and graphical hypotheses. *Science Scope*, 39(4), 42–48.

Tsai, W., & Ghoshal, S. (1998). Social Capital and Value Creation: The Role of Intrafirm Networks. *The Academy of Management Journal*, 41(4), 464–476.

Xing, W., & Gao, F. (2018). Exploring the relationship between online discourse and commitment in Twitter professional learning communities. *Computers and Education*, 126, 388–398.

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