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RESEARCH PAPER – INTEGRATED STEM EDUCATION

The impact of co-teaching on the professional practices of veteran, novice, and potential science and mathematics teachers

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Abstract

A university-school district partnership program designed to increase recruitment and retention of science and mathematics teachers in schools identified as low performing by the school district, paired potential or novice teachers with veteran teachers in elementary or secondary schools. All participants received mentoring to build instructional practice in science and mathematics, enhance their science and mathematics skills, and increase the achievement of students in key areas of mathematics and science through co-teaching practices. Pairs of veteran and novice/potential teachers co-taught for a semester. All participants were interviewed during and after the co-teaching experiences. We found that: (1) all participants perceived that shared collaborative practices were professionally important; (2) co-teaching for both potential and novice teachers made them feel valued as educators; (3) both potential and novice teachers described plans to pursue or remain in teaching; and (4) veteran teachers described their perception of an expanded professional role as teacher recruiters. These findings have implications for the intervention of co-teaching as a means to address teacher shortages, particularly in science and mathematics.

KEYWORDS

math/math education, science/science education, teacher education < teachers and teaching, teachers and teaching

1 | INTRODUCTION

Teacher shortages in science and mathematics threaten goals of graduating students who are scientifically and quantitatively literate. Shortages in the United States are most apparent in rural and urban schools that serve students from low socioeconomic backgrounds (Guarino et al., 2006; Sutcher et al., 2016). Teachers who leave describe being frustrated with expectations regarding accountability, class size, paperwork, student attitudes, lack of parental and administrative support, perceptions of the low status of the profession, and low salaries (Kersaint et al., 2007). In short, teachers who leave do not always feel valued or supported. Many teacher education programs are exploring strategies to recruit future teachers by highlighting how the benefits outweigh the limitations of this profession. Indeed, feeling valued as a member of a professional community may help convince early career teachers to remain (Achinstein & Ogawa, 2006; Balgopal, 2020). This article describes a co-teaching program, supported by a university-school district partnership, that was designed to encourage (1) undergraduates to consider entering the teaching profession (i.e., potential teachers) and (2) recently licensed science and mathematics

teachers (i.e., novice teachers) to remain in a school district through supportive professional relationships.

1.1 | School and university partnerships: Co-teaching

Innovative and successful strategies to recruit and retain high-quality science and mathematics teachers often involve collaborations between practitioners and academics (NCATE, 2010). Partnerships can be valuable for reforming teacher education when they reinforce nonhierarchical cooperation (Van Scoy & Eldridge, 2012) and integrate theory to practice (Heinz & Fleming, 2019). As an example, co-teaching during pre-service teacher preparation, such as field experiences, internships, and student teaching, increases teacher identity and confidence in classroom management (McCall et al., 2018; Soslau et al., 2018; Wassell & LaVan, 2009), reflection and cogenerative dialogue (Gallo-Fox, 2015), and collaboration and communication (Ruben et al., 2016). Co-teaching also increases PK-12 student performance (Solis et al., 2012). Bacharach et al. (2010) reported that students with disabilities, those who qualified for free and reduced lunch, and English language learners who were in co-taught classrooms outperformed counterparts in single, veteran teacher classrooms. Students in co-taught classrooms benefit because they are more likely to have their questions answered and are more engaged in class discussions (Hurd & Weilbacher, 2017). Teachers in co-teaching pairs bring different perspectives, modeling for students how to critically think about complex issues, especially when the topics are interdisciplinary (Flannery & Hendrick, 1999).

Although co-teaching has been shown to benefit both early career teachers and PK-12 students, its (1) promise as a recruitment strategy for potential teachers who are first and second-year undergraduate students, and newly licensed teachers, and (2) impact on veteran teachers' perceptions of their role in promoting their profession, has been underexplored. The current study addresses this gap in the literature. Student teachers, who learn about co-teaching in their education courses and often, but not always, co-teach with cooperating teachers during internship or field experiences, were not included in this study.

2 | THEORETICAL FRAMEWORK

Teacher agency and social cognitive theories both explain how environmental context (such as co-teaching with veteran teachers) affect professional choices. We, therefore, used both theories to study perceptions of potential and novice teachers and their professional choices.

2.1 | Teacher agency

The capacity to act on beliefs about one's actions and circumstances is broadly explained by the concept of agency. Agency is achieved when one is not only reflective about the past and present, but also when one anticipates how future behaviors can potentially result in desired outcomes (Emirbayer & Mische, 1998). People who have achieved agency are able to understand the role that context played in their past actions; this can then help them work to change or shape their subsequent circumstances (Biesta & Tedder, 2007). For teachers, the environmental context includes interactions that can influence their sense of agency (Priestley et al., 2013). The spatial and social context shapes opportunities for teachers to look both backward as they identify professional dilemmas and then work to resolve these in the future drawing on their present resources (Balgopal, 2020; Emirbayer & Mische, 1998). Resources may be structural (e.g., curricula, technology) or personal (e.g., content knowledge, social and professional networks, beliefs). Balgopal (2020) found that the agency demonstrated by science, technology, engineering, and mathematics (STEM) teachers who initiated and sustained successful integrated curricular reform was strengthened by supportive professional mentors (administrators, teacher leaders) and their own professional resilience (shaped by their beliefs in whole child education and the value of risk taking). These STEM teachers, as Biesta et al. (2015) theorized, achieved agency in an emergent way within their environment, rather than a result of being in their environment. In other words, the classroom and school settings enable teachers to achieve agency, rather than to just have agency (Biesta & Tedder, 2007). Achieving agency requires both reflective and reflexive work on the part of the teacher, which can be fostered by professional collaborations.

2.2 | Social cognitive theory

Teacher beliefs can explain, and sometimes predict, their professional choices because perceptions about the past drive decisions they make in the future (Biesta et al., 2015). Woodbury and Gess-Newsome (2002), drawing on social cognitive theory (SCT), studied how teacher beliefs are shaped by both environmental and personal attributes (Bandura, 1997). SCT is often used in studies of behavior change, and likewise, is informative when trying to identify how teachers' backgrounds and teaching context drive their instructional choices (e.g., Graves et al., 2016). SCT explains that each teacher's practice is influenced by their thinking specific to

beliefs and knowledge about teaching and teaching roles, students and learning, schooling and schools, content being taught, and sense of satisfaction or dissatisfaction with current practice (Czerniak & Chiarelott, 1990). These beliefs, however, are shaped by personal factors including teacher characteristics such as demographics, experiences, preparation as a teacher, and professional development. Contextual factors at the classroom, school, district, and policy levels also affect teachers' choices. For example, the socio-economic level of a teacher's school can predict their classroom management and instructional strategies (Rubie-Davies et al., 2012). Co-teaching is another contextual, or environmental, variable that can affect teachers' instructional choices and self-perception as mentors (Guise et al., 2017). Pre-service science teachers' practices teaching inquiry-based science is shaped by not only their beliefs about inquiry and content knowledge, but by their mentor teacher (Crawford, 2007).

To study the impact that co-teaching had on potential, novice, and veteran STEM teachers' professional choices, we used both teacher agency and social cognitive theories to answer the following questions: How did co-teaching experiences affect (1) potential teachers' intentions to become a teacher? (2) novice teachers' intentions to seek a job in the district? and (3) veteran teachers' perceptions of their role in recruiting and retaining future teachers?

3 | METHODS

This phenomenological study was conducted in a single school district in the western United States. Phenomenological studies seek to uncover and describe the lived experiences of participants (Creswell, 2018). We recognize that our own perspectives influence how we interpret the experiences of participants, especially when coding their perceptions. All three of us are former PK-12 teachers (two in special education and one in science); two of us are administrators (a former assistant principal of a STEM middle school and a co-director of a teacher licensure program); two of us identify as teacher educators (in science education and in general education); and all of us identify as teacher education researchers.

Our state appealed to teacher education programs to collaboratively address the teacher shortage, which has been consistently documented in mathematics and science since 2005, by offering grant support, which we received. The participating school district serves >30,000 students in 57 schools in eight cities and has a close relationship with a licensure program at a neighboring university. The long-running collaboration between the school district and university is formalized through a Professional Development School model allowing teachers to co-teach with university instructors during early field experiences of pre-service teachers.

3.1 | Participants

3.1.1 | Veteran teachers

Veteran teachers were recruited in the pre-identified schools in which students had not demonstrated sufficient growth on state assessments in mathematics and science, according to school district administrators. A total of 12 teachers participated from two elementary schools ($n = 8$), one middle school ($n = 3$), and one alternative high school ($n = 1$). Veteran teachers ranged in teaching experience from 2 years to more than twenty and were either paired with a novice teacher or with a potential teacher.

3.1.2 | Novice teachers

Recent graduates from the university's teacher education program were hired by the school district as long-term substitutes (LTSs). The LTSs ($N = 6$) were licensed in either mathematics or general science and were partnered with a veteran teacher in a similar discipline. LTSs expressed interest in securing a permanent teaching position after the study, including in the district in which the study took place.

3.1.3 | Potential teachers (UG STEM assistants)

Undergraduate STEM students ($n = 12$) were recruited to apply for paid positions. Those who demonstrated strong content performance through review of transcripts, experience with any form of teaching, like coaching, tutoring, or camp counselor through review of resumes, and interest in working with learners through review of letters of interest were invited to participate in an interview. Through interviews, we assessed students' possible intentions in become a teacher, ability to be adaptable and patient in classroom settings, and interest in meeting diverse student needs. They were partnered with veteran teachers based on shared disciplinary interests and schedule to co-teach and were mentored by our project coordinator (author JH) after registering as a school district volunteer.

3.2 | Intervention: Co-teaching professional development

Veteran-novice teacher pairs were expected to participate in a three-hour professional development workshop on co-teaching led by university teacher educators. During workshops, pairs discussed co-planning and co-teaching strategies modified from the list of seven strategies described by Bacharach et al. (2010): one teach/one observe; one teach/one assist, station teaching, parallel teaching, supplemental teaching, alternative/differentiated teaching, and team teaching. An existing co-teaching pair attended each workshop to share lessons learned. In total, twenty-nine teachers were trained. Follow-up support was provided by university faculty members through email messages and school visits. The school district's professional development coordinator also visited each team to offer support and guidance during the 15-week semester. Other district educators trained in co-planning and co-teaching included English Language Development teachers, Integrated Services teachers, and Interventionists. Based on principal requests, all teachers at two campuses received co-teaching training.

STEM Assistants did not participate in formal co-teaching workshops but were mentored in methods of collaboration. STEM Assistants were not required to attend workshops because we did not want to project the expectation that they were required to enter the licensure program. We wanted to ensure that if these participants chose to pursue teaching that it was a self-driven decision, and that the co-teaching classroom experience was the primary intervention. Instead, they met bi-monthly over 4.5 months with the project coordinator, a former teacher and school administrator with over 40 years of experience. The project coordinator organized informal lunch gatherings to allow STEM Assistants, as a group, to share their concerns, questions, and insights of the co-teaching experience. The project coordinator visited potential teachers' schools while they were in the classroom to conduct observations and reached out through email to touch base with both veteran and potential teachers. Through regular contact, the project coordinator established a mentor–mentee relationship with the undergraduate participants.

3.3 | Data collection

Three sources of data were collected: interviews, classroom observations, and email correspondences. In phenomenological studies, interviews serve as the primary data source, while the other data help triangulate final propositions. For example, if participants described positive or negative experiences in the classroom, we reviewed observational notes and email messages to identify what events may have explained the perceptions.

3.4 | Interviews

All participants were interviewed once at the end of the semester. These formal semi-structured interviews were conducted with veteran, novice, and potential teachers during respective focus group meetings at schools with veteran or novice teachers or on the university campus with potential teachers. Participants who could not attend focus group meetings were interviewed separately. We developed an interview protocol (Appendix) that consisted of six questions about participants' perceptions of co-teaching and classroom practices.

3.5 | Informal and email correspondence

All participants were in email correspondence with members of our team, especially the project coordinator. Initial correspondences centered on scheduling and administrative issues around placement of co-teachers in veteran teachers' classrooms, and subsequent communication reflected the activities and outcomes of the partnerships.

3.6 | Classroom observations

The project coordinator regularly visited schools and classrooms because of our team's awareness of the possible lack of familiarity that undergraduate students may have with the practices in public schools. The project coordinator was a mentor and was prepared to mediate if there were any misunderstandings between veteran and potential teachers, but there were none.

3.7 | Data analysis

Interviews and focus groups were audio-recorded and transcribed. Through iterative readings, we used thematic coding methods (Braun & Clarke, 2006) informed initially by a priori codes (i.e., personal factors, school context, teacher beliefs, and teaching practice) reported by Woodbury and Gess-Newsome (2002). After subsequent analysis, we modified the codes: role in school (personal), student outcomes (school) emergent beliefs (informed by someone else's practice), and emergent practices (informed by someone else's practice). These slightly revised codes aligned with both social cognitive theory and teacher agency because they took into account environmental and

personal attributes as well as how these enabled participants to reflect on past experiences, explain the current experiences, and inform their intended future actions. We determined that emergent thinking and emergent practices were indicative of participants' abilities to reflect on the past and be reflexive about future actions. Using these four themes, we identified patterns across roles of the participants—potential, novice, and veteran.

To establish trustworthiness, classroom observations and informal correspondences with all participants were used to triangulate findings, strengthening support for final propositions. Observations of how participants interacted with their partner teacher and/or students, for example, reinforced claims that a novice teacher made about wanting to become a teacher or not. Independent coding of a randomly selected set of interviews, resulted in 100% agreement in coding, which we attribute to regular peer debriefing during the study. Our initial findings were shared with another STEM teacher education researcher who was not part of this study, which prompted us to clarify the explanations of methods and interpretation of our findings.

4 | FINDINGS

We examined the perceptions of potential teachers and novice teachers, and the veteran teachers who mentored them in their classrooms for a semester. We found that: (1) all participants perceived shared collaborative practices were professionally important; (2) both potential and novice teachers perceived that co-teaching made them feel valued as educators; (3) both potential and novice teachers described plans to pursue or remain in teaching; and (4) veteran teachers described their perception of an expanded professional role as teacher recruiters.

4.1 | Ways of collaborating

All participants were aware that collaboration can be disaggregated into various activities. Participants with more teaching experience more often identified multiple collaborative activities, while those with the least amount of experience identified fewer collaborative activities. Veteran, novice, and potential teachers all found co-planning and co-instruction to be collaborative activities. When describing co-planning, novice teachers described the benefits: "The conversations we've had showed you what is possible ... a way to structure the day, another way to approach your work with kids" and "Teachers, new teachers, have to understand that it's not all about you, your kids, and your closed classroom." Veteran and novice teachers, however, also perceived co-assessment to be collaborative, and only veteran teachers thought co-reflection was collaborative. This finding reinforced our assumption that veteran teachers are more familiar with pedagogical practices needed to improve lessons.

The types of co-instruction practices that the three types of participants described overlapped, but they slightly differed. This may be a reflection of what classroom activities the participants helped design. Veteran teachers described co-instructional practices to include one teach/one assess, parallel teaching, station teaching, and supplemental teaching. Novice teachers described co-instructional practices to include 'one teach/one assess,' parallel teaching, station teaching, differentiated instruction, and team teaching. As one novice teacher explained, co-instruction was tied to assessment and differentiated instruction:

> For math, we did the coach-teaching model with two teachers giving the lesson, one teacher evaluated students, and then we broke the students up based on a pre-assessment of what they needed, and we broke the kids up by ability of what they could do that day.

> For novice teachers, in particular, being able to co-teach provided opportunities to observe veteran teachers. Novice teachers shared with us that they adopted their collaborating teachers' style, either wholesale: "I've switched to her style" or in subtle ways: "... just watching her teach, being in the same room all day long, it's easier to pick up the little novelties of what someone else does and adapt."

In other words, co-teaching allowed novice teachers to reflect on and test practices.

Potential teachers only described two co-instructional approaches: one teach/one assess and supplemental teaching. Again, the difference in their responses likely reflects the roles that these participants played in the classroom setting. For example, although veteran teachers may have employed various pedagogical strategies, potential teachers may not have designed these or may not have been aware of the subtle differences between various instructional approaches. "With literacy, we went to a station model, where teachers took on different aspects of literacy, whether it be guided reading, writing, and literature skills," explained a potential teacher.

Both veteran and novice teachers described the value of co-assessment, working together to design and administer assessments, and then evaluating students' needs, so they could be met. For example, one novice teacher shared:

"Every kid was held accountable at their level. Even our higher kids that we were able to push them even further ...." Another novice teacher agreed:

> the most rewarding thing as a teacher that the experience had on me, is that I strongly feel that every kid was met at their level and that there was growth... and that's hard to say as a teacher, to say that confidently you have met every student's need in your classroom.

Although all participants identified co-planning and co-instruction as collaborative approaches, and both veteran and novice teachers engaged in co-assessment, only veteran teachers identified co-reflection as a collaborative activity. Reflection is an important professional practice that neither novice, nor potential teachers described. Here veteran teachers described self-reflection as being (a) open to feedback; (b) making meaning of feedback; (c) making a plan to do something different, if needed; and (d) implementing that plan (McLeod, 2015). Veteran teachers were more metacognitive of their instructional practices than the potential and novice teachers and drew on their experiences when engaging in self-reflection. They identified reflection as a collaborative experience, illustrating the value that co-teaching had for them. For novice teachers, who did not identify this practice, it demonstrates an opportunity where co-teachers can mentor those just entering the profession.

4.2 | Feeling valued

Feeling comfortable in a professional setting can be reinforced by affirming comments from and actions of peers or mentors (Kelly & Antonio, 2016; Yim & Waters, 2013). Likewise, for both potential and novice teachers, feeling valued by their mentor teacher was important. Novice teachers described being supported as they tried something new, illustrated below:

> Somebody said to 'run with it,' so that's what everybody did. We didn't have somebody standing over us and saying, 'Well, what are you doing now?' ... I would say that also the professional trust as a team. Also, being able to say, 'Let's try something and if it doesn't work, then we'll scrap it; we'll try something different.

Taking risks can be challenging for those whose professional identity is still malleable. Being a novice teacher in a classroom environment that supports experimentation can be rewarding, especially as those early in their careers are trying to determine what instructional strategies work best: "The modeling, the different models to use, was very helpful for us to be able to say we can be flexible in our thinking and to just try something new out," a novice teacher explained.

All potential teachers described the importance of feeling welcomed and needed in classrooms by both veteran teachers and the students. For potential teachers, who had not committed yet to becoming teachers, the feedback from their students was what they described the most, illustrated by a potential teacher who was helping in an elementary school during mathematics instruction:

> These two girls who had grown pretty close to me. They were struggling, at least at the beginning and so I spent more time with these two, but they bonded with me in the time that we did spend together. And at one of the passing periods between classes, they just grabbed my hand and pulled me down to the principal's office and begged the principal to hire me on as a full-time tutor for their school.

The potential teacher repeated this story and others similar to this, prompting her to consider a career in teaching. Although she ultimately chose to stay in the natural sciences, she decided to seek employment that would allow her to engage with the public. In some cases, the co-teaching experience convinced potential teachers to pursue a post-bachelor teaching license, as was the case for the following participant who was in a middle school science classroom:

> I worked with a couple of students, but I didn't really get to know a lot of the other ones. But when some of the girls found out I was leaving, they were like, "No, you're leaving. Don't leave so soon." It was interesting to see how much value I had to other students that I didn't really work with, but just being a presence. Helping out made it more fun, and they'd be like, "Oh, there's this new person in the classroom."

This potential teacher decided to join professional development workshops being organized for pre-service STEM teachers, even though she was not in the licensure track. She ultimately finished her degree in chemistry and returned to seek her teaching license. Part of feeling valued was that novice teachers gained a deeper understanding of what teaching entails, as the following participant explained:

> I guess in high school, I always thought of 'You know the teacher, yeah, sure they have to do lesson plans and they have to put everything

> together.' But I never really thought of the thought that the teacher puts into it. The way they shape their class in order for their students to succeed. Being on the opposite side really helped me see that and it's really, really cool.

Hence, by feeling like both an insider—seeing how teachers make purposeful decisions in what and how to teach, assess, and manage classroom dynamic—and an outsider—not having committed to becoming a teacher or being in teacher education courses—novice teachers were able to reflect on the profession of teaching prior to committing.

Veteran teachers described a sense of feeling valued that was tied to an expanding perception of their professional role. A couple of the veteran teachers in the elementary schools talked about what they believed was their students' perceptions of the potential teachers, especially as role models in STEM. "I felt that it was a great way for kiddos to see women understanding math and using math, and it's gonna be part of their career. So, I thought that was cool." Another teacher who hosted two potential science teachers shared that:

> I think seeing women in science is important and the fact that I had two women who are advocates showed my women that they can be scientists too. There's a lot of inequity involved in science and so the ability to have women up here in the forefront in teaching science was, I think, really beneficial for a lot of my students.

Even novice teachers, who had already chosen teaching as a profession, felt that co-teaching experiences allowed them to continue developing skills while feeling affirmed by veteran teachers. Here, a novice science teacher, who has found employment as a teacher, shared her initial experiences co-teaching:

> ... my mentor teacher treated me as a complete equal .... she introduced me as a teacher rather than as a student teacher. Especially with the population of students we were working with, she wanted them to have a perception of me as having full authority, and not trying to look down on me in any way. So, I was treated as a teacher by the students, and then my co-teacher completely respected any and all of my ideas. She was willing to give me advice if I needed it, but if she felt I didn't need it, she was happy to let me kinda run with what I was doing ... It was a really neat experience.

4.3 | Expanded perception of professional role

4.3.1 | Recruiting future teachers

Veteran teachers explained their renewed perception of their professional role in addressing the national teacher shortage. They shared with us a new realization in either recruiting potential teachers to consider entering teacher licensure programs or retaining novice teachers who were just entering the profession. One veteran teacher shared, "So, just reminding me back to the beginning of my teaching years and kind of renewing that, where that light was kind of starting to go a little more dim than it was before." These participants described feeling reenergized to promote their profession to those just considering or entering teaching, as the following quote illustrates:

> ... it is definitely a team. It's a team effort, so I think that it renewed the flame that I can do this, because after years and years, you're sometimes like, "Am I being effective? Am I really doing the best for kids? This re-energizes it and re-energizes my love of teaching.

Veteran teachers also explained that the co-teaching experience was a way to introduce and excite potential teachers into the profession:

> I think being in the trenches actually, seeing what it is. You hear about things; you have an idea what it might be. And actually, getting into the classroom, seeing how kids affect you, seeing how you affect kids, see how you do make a difference in other people's lives is pretty empowering. So, I think it's a good way to get [potential teachers] in and get them exposure [thinking] 'Wow. I make a difference to these little ... Little kiddos' lives, and they count on me and they depend on me.'

Another veteran teacher reflected on co-teaching with potential teachers as a way to help with recruitment into the profession:

> I think [co-teaching] is awesome. I think there are a lot of people who love science and don't think of teaching as a possibility. I know we were looking at nationwide shortages in science teachers. More avenues to get them into science classrooms, the better and ... yeah, I

> think it's a great opportunity to get people into teaching.

Veteran teachers described the importance of authentic experiences for potential teachers by allowing them to see all the work needed to prepare and implement lessons for a variety of learning needs. In one case, the veteran teacher described an email that a potential teacher, who co-taught with her, sent to the class after she graduated.

> And in that email, she really talked about how it was a great experience and it truly inspired her to go into the classroom, the experiences that she had had with our students in our classrooms, and also just inspired her, I think, to become a teacher. And I shared that with the kids, and they thought that was just a really kind of ... They're all just like, 'Wow!' ... I think it was a great way to immerse her into a classroom setting, and to give her the opportunity to see what it's like to teach students of diverse academic and emotional [needs], and I think it was a great way to recruit someone into teaching.

This enlightened understanding of veteran teachers' role in recruiting future teachers is an important and novel finding in our study. In addition to expressing renewed excitement about teaching, veteran teachers described the positive impacts on their students.

> [We] saw enormous growth in math... our lower kids, making phenomenal on their end of year MAPS. I mean we're talking 20-30 points that these kids have from the beginning from the beginning of the year to the end.

Another teacher described similar outcomes:

> I've seen student experience success in terms of the increased differentiation that we're able to provide with two teachers, that we're able to not only see success in terms of meeting learning targets or even from assessments on a unit of math but also the accountability part of holding students accountable for their learning.

4.3.2 | Pursue or remain in teaching

The outcomes of our co-teaching intervention were positive. At the end of the one-year program, of training and engaging in co-teaching experiences, 50% (8/16) novice teachers had found jobs as full-time teachers in probationary roles; half of these jobs were in the school district in which this study was conducted. Of the 12 potential teachers, four (33%) intended to switch into teacher licensure educational tracks; and a follow-up the next year indicated that all four had indeed followed their intentions. One participant explained: "I know a lot more about what it takes to be a teacher." Such sentiments are important for undergraduates who may not choose to pursue a teacher career because they are not confident about the teaching profession. Taking education courses, being a near peer teaching assistant, or shadowing professional teachers may not be sufficient for some potential teachers, who valued being in the classroom as a co-teacher. This finding presents another approach that may address a successful path to recruiting and retaining future teachers.

5 | DISCUSSION

We examined a model of co-teaching along the professional continuum to address recruitment of potential teachers and retention of novice teachers in a district experiencing science and mathematics teacher shortages. Participants' perceptions of their professional roles as science and mathematics teachers were attributed to co-teaching and feeling valued.

5.1 | Potential of co-teaching in different contexts

Co-teaching is a model for the preparation of pre-service teachers that differs from the traditional observe-teach solo model (Roth & Tobin, 2002). Co-teaching benefits both teacher apprentices and their cooperating teachers, who observe new instructional and assessment approaches (Hurd & Weilbacher, 2017). Likewise, our participants described learning from observing colleagues, including veteran teachers, who in turn exclaimed learning new ways to teach content from those earlier in their professional path. Because both teachers can observe one another during co-teaching, they both have opportunities to reflect on past, consider present contexts, and decide how to respond to student needs. In this manner, co-teaching allowed all participants to achieve agency. Because hierarchical barriers are reduced, paired science and mathematics teachers could support one another as they learned how to support students.

Co-teaching has long been associated with special educators teaching in the same physical space as general

education classrooms to meet the needs of students with learning disabilities (Scruggs et al., 2007). More than a classroom assistant, both co-teachers should be perceived as professionals with respective expertise in disciplinary education and engage in co-planning and co-instruction (Cook & Friend, 1995). In practice, though, mentor teachers in co-teaching pairs may perceive their role differently. Guise et al. (2017) described co-teaching practices that ranged from traditional student teaching, blended experience (co-teaching mixed with traditional student teaching model), forward momentum (mentors becoming comfortable with co-teaching), and scaffold and grow (both teachers and student teachers demonstrating personal growth mind-sets). Co-teaching should allow increased time for planning, teaching, and assessing, and an increased respect for peers. Therefore, when it is intentional, co-teachers make time to collaborate and co-reflect on what practices worked and or did not. Reflecting on past and present experiences is necessary for teachers to develop professional agency (Biesta & Tedder, 2007); e.g., teachers' ideas about and comfort with co-teaching likely shift as their experience with it increases (Guise et al., 2017).

Both veteran-novice and veteran-potential pairs in our study engaged in collaborative partnerships, evidenced by various co-teaching pedagogical strategies participants employed (Bacharach et al., 2010). We observed our participants engaging in co-reflection, asking questions of one another. Because classroom environments can shape teacher beliefs, identity, and their professional decisions, supportive collegial communication within teaching spaces is important (Biesta et al., 2015; Tao & Gao, 2017). Therefore, we surmised that pairs of participants co-constructed the classroom environments that enabled both individuals to develop professional agency (Oolbekkink-Marchand et al., 2017), affecting their perceptions of their professional roles as teachers and/or as teacher recruiters.

5.2 | The importance of affirmation and feeling valued by colleagues

Feeling capable and valued affects people's sense of agency and professional aspirations (Bacq & Alt, 2018). Being professionally supported was particularly important during the recent COVID pandemic, reinforcing some teachers' professional commitments (Kim & Asbury, 2020). For teachers, achieving agency is dependent on not only their beliefs about the profession, but on the environmental context, including social interactions with peers and what is expected of them (Parker, 2016). Biesta et al. (2015) found that if individual teachers' beliefs are mismatched with institutional goals, then teachers may not achieve agency in that school. In turn, when teachers feel disenfranchised or non-agentic, they are at risk of leaving the profession. It is not surprising, therefore, that schools that are collegial and supportive affect if teachers feel valued or not, and whether they remain or leave the profession (Waddell, 2010). Participants in our study, overall, described the co-teaching experience in positive terms and expressed feeling valued, which we believe contributed to the positive outcomes related to plans to pursue teaching careers.

University and school district partnerships can enhance novice teachers' feelings of being supported by providing continuous mentoring, coaching, and professional network (Achinstein & Ogawa, 2006; Bickmore & Bickmore, 2010; Guha et al., 2016). In our study, potential and novice teachers were mentored by not only the veteran teacher with whom they were paired, but by their university mentors. We posit that co-teaching helped our participants feel valued because they could engage in constructivist, bidirectional support of one another (Richter et al., 2013). Because feeling valued and having agency are related to teacher retention (Kayi-Aydar & Steadman, 2019; Oolbekkink-Marchand et al., 2017), we conclude that teacher education programs must consider both of these issues.

5.3 | Perceptions of professional roles

Some participants in our study described a revised perception of their professional roles. For potential teachers, this meant deciding to enter the teaching profession (33% chose to enter teacher licensure programs). For novice teachers, this meant staying in the teaching profession (50% found employment as teachers in the district). For veteran teachers, this meant seeing themselves as recruiters for the teaching profession. Although one might argue that novice teachers had already chosen to become teachers, potential teachers had not yet made this commitment. Because acculturation, or socialization into an occupation can influence people's career paths (Bert & Richards, 2018), veteran teachers can be positive advocates for the profession by helping potential teachers feel welcomed and encouraging novice teachers to also remain in the district (Podolsky et al., 2016). Co-teaching in schools allows socialization of early career teachers into the profession. Finding those who may not have yet committed to the profession and who are willing to co-teach is one creative strategy that school districts

might consider using to recruit new science and mathematics teachers.

6 | CONCLUSION

The partnership that supported co-teaching experiences in our study was a promising intervention that addressed science and math teacher recruitment and retention; albeit our findings are limited to our study. Participating veteran teachers volunteered after being invited by their school administrators; hence, self-selection may explain some of their positive perceptions of co-teaching. Participants may have shared only some of their perceptions of co-teaching with us, knowing that we are engaged in teacher education research. Yet, our findings are compelling, demonstrating the value of co-teaching as a science and math teacher recruitment strategy. Those interested should consult Bacharach et al. (2010), often referenced in co-teaching workshops, to learn more about co-teaching approaches.

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CONFLICTS OF INTEREST

We have no conflicts of interest to disclose.

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REFERENCES

Achinstein, B., & Ogawa, R. (2006). (In) fidelity: What the resistance of new teachers reveals about professional principles and prescriptive educational policies. *Harvard Educational Review*, *76*(1), 30–63. https://doi.org/10.17763/haer.76.1.e14543458r811864

Bacharach, N., Heck, T. W., & Dahlberg, K. (2010). Changing the face of student teaching through coteaching. *Action in Teacher Education*, *32*(1), 3–14. https://doi.org/10.1080/01626620.2010.10463538

Bacq, S., & Alt, E. (2018). Feeling capable and valued: A prosocial perspective on the link between empathy and social entrepreneurial intentions. *Journal of Business Venturing*, *33*(3), 333–350. https://doi.org/10.1016/j.jbusvent.2018.01.004

Balgopal, M. M. (2020). STEM teachers as innovators: Motivations for curricular changes. *Science Education*, *104*, 762–785.

Bandura, A. (1997). *Self-efficacy: The exercise of self-control*. Freeman.

Bert, G., & Richards, K. A. R. (2018). Developing a future teachers' club to facilitate physical education teacher recruitment: Do you hear the call? *Journal of Physical Education, Recreation & Dance*, *89*(7), 9–15.

Bickmore, D. L., & Bickmore, S. T. (2010). A multifaceted approach to teacher induction. *Teaching and Teacher Education*, *26*(4), 1006–1014. https://doi.org/10.1016/j.tate.2009.10.043

Biesta, G., Priestley, M., & Robinson, S. (2015). The role of beliefs in teacher agency. *Teachers and Teaching*, *21*(6), 624–640. https://doi.org/10.1080/13540602.2015.1044325

Biesta, G., & Tedder, M. (2007). Agency and learning in the lifecourse: Towards an ecological perspective. *Studies in the Education of Adults*, *39*(2), 132–149. https://doi.org/10.1080/02660830.2007.11661545

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Cook, L., & Friend, M. (1995). Co-teaching: Guidelines for creating effective practices. *Focus on exceptional children*, *28*(3), 1–16.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, *44*(4), 613–642. https://doi.org/10.1002/tea.20157

Creswell, J. W. (2018). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (6th ed.). Merrill Prentice Hall.

Czerniak, C., & Chiarelott, L. (1990). Teacher education for effective science instruction—A social cognitive perspective. *Journal of Teacher Education*, *41*(1), 49–58.

Emirbayer, M., & Mische, A. (1998). What is agency? *American Journal of Sociology*, *103*(4), 962–1023. https://doi.org/10.1086/231294

Flannery, M. C., & Hendrick, R. (1999). Co-teaching and cognitive spaces: An interdisciplinary approach to teaching science to nonmajors. *Science & Education*, *8*(6), 589–603.

Gallo-Fox, J. (2015). Studying secondary science student teaching experiences within a cohort community of practice: A sociocultural methodology. In C. Milne, K. Tobin, & D. Degenero (Eds.), *Sociocultural studies and implications for science education: The experiential and the virtual*. Springer Publishing.

Graves, L. A., Hughes, H., & Balgopal, M. M. (2016). Teaching STEM through agriculture: Implementation of an edible plant curriculum at an elementary school. *Journal of Agricultural Education*, *57*(3), 192–207.

Guarino, C. M., Santibañez, L., & Daley, G. A. (2006). Teacher recruitment and retention: A review of the recent empirical literature. *Review of Educational Research*, *76*(2), 173–208. https://doi.org/10.3102/00346543076002173

Guha, R., Hyler, M. E., & Darling-Hammond, L. (2016). *The teacher residency: An innovative model for preparing teachers*. Learning Policy Institute.

Guise, M., Habib, M., Thiessen, K., & Robbins, A. (2017). Continuum of co-teaching implementation: Moving from traditional student teaching to co-teaching. *Teaching and Teacher Education*, *66*, 370–382. https://doi.org/10.1016/j.tate.2017.05.002

Heinz, M., & Fleming, M. (2019). Leading change in teacher education: Balancing on the wobbly bridge of school-university partnership. *European Journal of Educational Research*, *8*(4), 1295–1306.

Hurd, E., & Weilbacher, G. (2017). You want me to do what? The benefits of co-teaching in the middle level. *Middle Grades Review*, *3*(1), 1–14.

Kayi-Aydar, H., & Steadman, A. (2019). Teacher agency in the context of teacher retention. In C. R. Rinke & L. Mawhinney (Eds.), *Opportunities and challenges in teacher recruitment and retention* (pp. 173–195). Information Age Publishing Inc.

Kelly, N., & Antonio, A. (2016). Teacher peer support in social network sites. *Teaching and Teacher Education*, *56*, 138–149. https://doi.org/10.1016/j.tate.2016.02.007

Kersaint, G., Lewis, J., Potter, R., & Meisels, G. (2007). Why teachers leave: Factors that influence retention and resignation. *Teaching and Teacher Education*, *23*(6), 775–794. https://doi.org/10.1016/j.tate.2005.12.004

Kim, L. E., & Asbury, K. (2020). 'Like a rug had been pulled from under you': The impact of COVID-19 on teachers in England during the first six weeks of the UK lockdown. *British Journal of Educational Psychology*, *90*(4), 1062–1083. https://doi.org/10.1111/bjep.12381

McCall, M., Rogers, R. M., Gasaway, J., & Veselka, M. (2018). Clinical experiences in middle and high schools: Results of a one-year implementation of the co-teach model. *School-University Partnerships*, *11*(1), 26–35.

McLeod, N. (2015). Reflecting on reflection: Improving teachers' readiness to facilitate participatory learning with young children. *Professional development in education*, *41*(2), 254–272.

National Council for Accreditation of Teacher Education. (2010). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers*. Blue Ribbon Panel on Clinical Preparation and Partnerships for Improved Student Learning.

Oolbekkink-Marchand, H. W., Hadar, L. L., Smith, K., Helleve, I., & Ulvik, M. (2017). Teachers' perceived professional space and their agency. *Teaching and Teacher Education*, *62*, 37–46. https://doi.org/10.1016/j.tate.2016.11.005

Parker, G. (2016). An ecological approach to teacher agency: A theoretical overview. *Annual Review of Education, Communication & Language Sciences*, *13*, 1–14.

Podolsky, A., Kini, T., Bishop, J., & Darling-Hammond, L. (2016). *Solving the teacher shortage: How to attract and retain excellent educators*. Learning Policy Institute.

Priestley, M., Biesta, G. J. J., & Robinson, S. (2013). Teachers as agents of change. In M. Priestley & G. J. J. Biesta (Eds.), *Reinventing the curriculum: New trends in curriculum policy and practice* (pp. 187–206). Bloomsbury Academic.

Richter, D., Kunter, M., Lüdtke, O., Klusmann, U., Anders, Y., & Baumert, J. (2013). How different mentoring approaches affect beginning teachers' development in the first years of practice. *Teaching and Teacher Education*, *36*, 166–177. https://doi.org/10.1016/j.tate.2013.07.012

Roth, W., & Tobin, K. (2002). *At the elbow of another: Learning to teach by coteaching*. Peter Lang.

Ruben, B., Rigelman, N., & McParker, M. (2016). Analysis of stakeholder perceptions of a clinical model involving co-teaching and extended-field experiences in an inclusive middle-grades setting. *Research in Middle Level Education Online*, *39*(6), 1–18. https://doi.org/10.1080/19404476.2016.1171571

Rubie-Davies, C. M., Flint, A., & McDonald, L. G. (2012). Teacher beliefs, teacher characteristics, and school contextual factors: What are the relationships? *British Journal of Educational Psychology*, *82*(2), 270–288. https://doi.org/10.1111/j.2044-8279.2011.02025.x

Scruggs, T. E., Mastropieri, M. A., & McDuffie, K. A. (2007). Co-teaching in inclusive classrooms: A metasynthesis of qualitative research. *Exceptional Children*, *73*(4), 392–416. https://doi.org/10.1177/001440290707300401

Solis, M., Vaughn, S., Swanson, E., & Mcculley, L. (2012). Collaborative models of instruction: The empirical foundations of inclusion and co-teaching. *Psychology in the Schools*, *49*(5), 498–510.

Soslau, E., Kotch-Jester, S., Scantlebury, K., & Gleason, S. (2018). Coteachers' huddles: Developing adaptive teaching expertise during student teaching. *Teaching and Teacher Education: An International Journal of Research and Studies*, *73*(1), 99–108. https://doi.org/10.1016/j.tate.2018.03.016

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2016). *A coming crisis in teaching? Teacher supply, demand, and shortages in the U.S*. Learning Policy Institute.

Tao, J., & Gao, X. (2017). Teacher agency and identity commitment in curricular reform. *Teaching and Teacher Education*, *63*, 346–355. https://doi.org/10.1016/j.tate.2017.01.010

Van Scoy, I. J., & Eldridge, D. B. (2012). NCATE's blue ribbon panel report and NAPDS: Working together. *School-University Partnerships*, *5*(1), 7–12.

Waddell, J. H. (2010). Fostering relationships to increase teacher retention in urban schools. *Journal of Curriculum and Instruction*, *4*(1), 70–85.

Wassell, B., & LaVan, S. K. (2009). Tough transitions? Mediating beginning urban teachers' practices through coteaching. *Cultural Studies of Science Education*, *4*(2), 409–432. https://doi.org/10.1007/s11422-008-9151-8

Woodbury, S., & Gess-Newsome, J. (2002). Overcoming the paradox of change without difference: A model of change in the arena of fundamental school reform. *Educational Policy*, *16*(5), 763–782. https://doi.org/10.1177/089590402237312

Yim, L., & Waters, L. (2013). The role of interpersonal comfort, attributional confidence, and communication quality in academic mentoring relationships. *Education Research & Perspectives*, *40*(1), 58–85.

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APPENDIX

INTERVIEW QUESTIONS FOR VETERAN, NOVICE, AND POTENTIAL TEACHERS

1. In what, if any, ways did the co-teaching experience change your practice?
2. In what ways, if any, did the co-teaching experience support (hinder) your decision to pursue teaching (as a career)?
3. How did you implement information learned from the training provided at the beginning of the experience?
4. What effect, if any, do you think the co-teaching experience had on your students?
5. How did this experience affect your interest in remaining in teaching?
6. How likely are you to participate in co-teaching in the future, even if this were to mean combining two classrooms?