

The Recruitment and Retention of Mathematics Teachers in High-need Schools

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One potential avenue to address the STEM teacher shortages reported internationally is to offer scholarships paired with targeted preparation experiences for high-performing STEM majors and professionals to become K-12 teachers. In the study reported in this paper, the influence of the Robert Noyce Teacher Scholarship Program on the recruitment and retention of mathematics teachers in high-need schools was investigated. The research found the Noyce Scholarship and program activities to be an effective mechanism for recruiting high performing college students as mathematics teachers and to retain them in the critical first few years of teaching. Discussed in this paper is how the Noyce Program made these impacts through financial incentives, as well as the scholars' participation in the program and interactions with others.

Keywords · mathematics teacher education research · recruitment · retention · STEM teachers · high-need schools

Teacher shortages are an international phenomenon (Ingersoll et al., 2018a; Nguyen et al., 2022; Sibieta, 2020), and the recruitment and retention of teachers worldwide is a serious concern (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2015). UNESCO (2016) reported massive international teacher shortages at the primary and secondary levels. UNESCO (2016) estimated that by 2030 countries must recruit a total of 68.8 million teachers to ensure sustainable development goals in relation to primary and secondary education are met. This highlights the need to identify strategies for retaining teachers and reducing attrition. This also has implications for teacher education programs that prepare prospective teachers and develop their competencies for teaching in international programs, such as the International Baccalaureate (Ingersoll et al., 2018a).

Over the last ten years, Science Technology, Engineering, and Mathematics (STEM) teacher shortages have been reported every year by almost every state in the United States (Dee & Goldhaber, 2017). An Economic Policy Institute report suggested the teacher shortage, particularly in STEM fields, was growing (García & Weiss, 2019). Moreover, schools and districts reported difficulty in filling STEM positions three to four times more frequently than for other positions (Dee & Goldhaber, 2017). A recent survey of practicing teachers indicated substantial numbers of teachers were thinking of leaving the profession, with many citing the impact of COVID-19 as a major contributing factor (e.g., Steiner & Woo, 2021). This will exacerbate further the teacher attrition problem, a perennial challenge as a significant portion of new teachers leaves the profession every year (Nguyen, 2021). Data indicate between 30% and 50% of new teachers leave the profession within their first five years of teaching (Ingersoll et al., 2018b), and the supply of new teachers has dwindled over the past decade as enrollment in teaching programs has dropped precipitously (Carver-Thomas & Darling-Hammond, 2017). Previously, studies examining teacher attrition found that nationally STEM teachers leave their school and the profession

at comparable rates to non-STEM teachers, but this national trend masks differential attrition for STEM teachers in high-need schools, particularly high-poverty and high-minority schools (Carver-Thomas Darling-Hammond, 2017; Ingersoll & May, 2012; Nguyen & Redding, 2018).

This leakage of the teacher pipeline has strong implications for student learning and equity as decades of evidence indicate teachers are critical to student achievement. Research has shown the most disadvantaged schools have difficulty recruiting and retaining highly qualified and effective teachers (Boyd et al., 2011; Guarino et al., 2006). Further, high-poverty schools are more likely to struggle with mathematics teaching vacancies as they experience higher turnover and find it harder to fill vacancies (García & Weiss, 2019; Strizek et al., 2006). An additional concern related to STEM teachers is that historically underserved students often have less access to high quality teachers than their more advantaged peers. Low-income and minority students are much more likely to be taught by out-of-field teachers who have neither certification, nor a degree related to the subject matter (Almy & Theokas, 2010). A continual lack of high-quality teachers in high-need areas has created a cycle of ineffective teaching with detrimental implications for student achievement (Darling-Hammond, 2007; Ferguson, 1991). As the United States becomes increasingly more diverse ethnically (United States Census Bureau, 2021), teachers can expect to teach students whose backgrounds and experiences differ from theirs.

To combat these challenges, educators and policy makers at the state, national, and international level have spent a tremendous amount of time and resources to recruit highly qualified teachers and to diversify the teaching workforce (Hanushek et al., 2004; Ingersoll & Smith, 2003; Loeb et al., 2005). A review of international efforts to recruit and retain teachers suggested that monetary incentives help to recruit teachers (See et al., 2020). The authors, however, concluded that the amount of money must be considered large enough to compensate for working in disadvantaged schools. One such initiative in the United States was the *Robert Noyce Teacher Scholarship Program* (<https://www.nsfnoyce.org/>), which targets STEM teacher shortage specifically in high-need schools and districts by awarding large non-need-based scholarships. It focuses on recruiting candidates with strong academic STEM backgrounds into teaching careers in high-need schools; to retain them, it provides ongoing support to them while novice teachers. Candidates are offered a generous scholarship and in return make a commitment to teach in a high-need school for a year for each semester they accept the scholarship. Little empirical evidence, however, has been collected to indicate if the Noyce Program successfully recruits and retains STEM teachers (Ticknor et al., 2017). Similarly, international reforms to recruit and retain teachers do not have clear evidence of effectiveness. Although money can be used to recruit teachers, it may not keep them in the teaching profession (See et al., 2020). One of the few studies that examined the effects of the Noyce Program at one institution found that, while the perceptions and attitudes of Noyce Scholars who received the scholarship were positive, most of the scholars were not initially influenced to enter the teaching profession based on the Noyce Program (Whitfield et al., 2021).

The qualitative study reported in this paper adds to this small but growing literature base by examining the effects of the Noyce Program, particularly with respect to the scholars' ability to work in high-need schools. The study explored the influences that a Noyce Program, embedded within a teacher education program grounded on sociocultural theory (Steele, 2001), had on their preparation to teach mathematics in high-need schools. Two questions propelled the study:

- (1) *What factors contribute to the success of recruiting and retaining mathematics teachers in high-need schools?*
- (2) *To what extent do targeted activities contribute to mathematics teacher candidates' perceptions of their ability to work in high-need schools?*

Conceptual Framework

The framework guiding the design of the teacher education program activities and the subsequent research efforts used to investigate its impact, rests on a sociocultural perspective where learning is seen as a social activity (Rogoff, 1990; Shabani, 2016), specifically, the ways in which teacher development is linked to core tenets of Vygotsky's developmental theories (Shabani, 2016). According

to Vygotsky, knowledge is an internalisation of social activities using a process of mediation in which the individual and the social mutually shape each other (as cited in Shabani, 2016). It is a dynamic process where individuals change through their involvement in knowledge building within the community. In teacher education, this perspective informs the creation of communities of practice where preservice teachers, classroom teachers, and mathematics education faculty join together through a common purpose and joint social activity (Lave & Wenger, 1991).

Rogoff (1990) called participation involving socially relevant interactions and meaningful activities that transform an individual's way of thinking and acting, *participatory appropriation*. The concept of participatory appropriation can provide insight into how past experiences lend themselves to current behaviours. In theory, as individuals participate in activities their understanding and sense of responsibility grows (Rogoff, 1990). The construction of an identity of practice and development of professional dispositions involves engaging in the practice of teaching and by doing so gain knowledge about teaching (Adler, 2000). Research indicates, however, this type of learning is not straightforward and is much more complex than Lave and Wenger suggested (Maynard, 2001).

Having content knowledge, pedagogical skills, understanding of learner development, and appreciation for learning contexts are essential components of an effective educator. Without the dispositions to do so, there are no assurances that a teacher will apply these components effectively in a learning environment. The Council for the Accreditation of Educator Preparation (CAEP) defined dispositions as "the habits of professional action and moral commitments that underline an educator's performance" (Council of Chief State School Officers [CCSSO], 2013, p. 6). Dispositions have been shown to impact student outcomes both negatively (Sztajn, 2003) and positively (Boaler, 2008; MacFarlane et al., 2007; White, 2003). They are situation-specific, requiring an understanding of the cultural contexts of diverse school settings (Schussler & Knarr, 2013). Developing professional dispositions is a sociocultural process involving interactions with peers, university faculty, instructors, program advisors, and classroom teachers (Tomlinson, 1995). Therefore, addressing dispositions requires context beyond the university classroom setting. Carroll (2007) offered recommendations to support the development of dispositions in teacher education programs (TEP), and four are shared here.

First, the TEP can enact a culture of caring. This involves modeling for teacher candidates the caring relationships they are expected to establish with their learners. Research indicates that participants who felt supported by teacher preparation faculty were more likely to stay in high-need schools (Nguyen et al., 2020). Kirchhoff and Lawrenz (2011) found that teacher candidates value regularly occurring professional and personal interaction and support from both peers and faculty. In addition, they found candidates "who had a strong social network during teacher preparation and early in their careers were positive about their experiences" (p. 258).

Second, the TEP can scaffold learning opportunities for constructing identities of practice (Shabani, 2016). The development of a professional identity is how participants become full members in a community of practice (Lave & Wenger, 1991). Education faculty, classroom teachers and other education professionals can model dispositions and support teacher candidates as they observe and participate in professional conversations and activities. Preservice teachers benefit from support as they negotiate existing personal beliefs and developing professional ethics. The TEP can leverage critical reflection as a means for processing experiences. Critical reflection enables teacher candidates to intensely examine their teaching style and use these perceptions to discern what actions they can take to become more effective as a teacher (Shandomo, 2010). The need for critical reflection also applies to issues of diversity. Research indicates that lack of cultural understanding by teachers impacts the effectiveness of instruction and leads to lower expectations for students of colour (Gershenson et al., 2016).

Third, the TEP can help candidates interpret classrooms as contexts for enacting educational values and purposes. Classroom learning environments are shaped by many things including the physical location, community, context, culture, and students' interests for example. Altan and Lane (2018) identified and studied sixteen habits of mind and found learning environments, specifically experiences related to family environment, had the most impact on the development of dispositions. The TEP can leverage life experiences as strategies for developing dispositions (Altan & Lane, 2018). In addition, the

TEP can help candidates process the overlap between the learning environment they grew up in and the one they want and need to foster as a teacher. The TEP can support candidates as they transition from student to teacher and come to view learning environments through a new lens.

Fourth, the TEP can provide mentoring support. Engaging in professional experiences promotes growth in teaching expertise. There are times, however, when there are setbacks in teaching proficiencies until knowledge and skills are adjusted for new situations and new proficiencies are mastered (CCSSO, 2013). Therefore, preservice teachers and novice teachers need support as they navigate new classroom contexts and to address students' needs. Smith and Ingersoll (2004) found that beginning teachers with access to mentors who participate in induction activities were less likely to exit the field or transfer schools during their first year. Mentoring of preservice and novice teachers by university faculty and experienced classroom teachers is an essential component to constructing a teacher identity, establishing expertise, and developing dispositions as new teachers master new contexts. Lave and Wenger (1991) referred to this as *legitimate peripheral participation*, where learning occurs as newcomers participate in simple and low-risk peripheral roles alongside more experienced or competent members of the community and gradually their participation involves roles more central to the functioning of the community. In addition, the TEP can model the building of "horizontal relationships" among new teachers by structuring learning experiences that focus on building peer relationships, that create cohorts for field experiences where candidates reflect on practice together, and that incorporate effective forms of communication including technological tools (Korthagen et al., 2006). Teacher candidates benefit from mentoring support as they develop dispositions and learn how to navigate interpersonal challenges and professional relationships.

The sociocultural perspective and how TEP can support the development of dispositions inform both the Noyce Program itself as well as this study. In the next section we describe how the Noyce Program creates and nurtures a culture of caring, how various learning opportunities are provided for Scholars to practice connecting pedagogy with mathematics contents, how courses and experiences provide time and space to engage and enact the values and purpose of mathematical education, and the comprehensive approach the program provides to support these novice mathematics teachers. Additionally, we created interview questions that would probe at how social activities and the TEP may have influenced scholars' experiences during the program and in their first years of teaching, which we describe in more details in the Data and Methods section.

Teacher Education Context and Noyce Program Activities

Components of the TEP at a Midwest public university in the United States into which a 4-year Noyce Program is embedded, were situated firmly in the sociocultural perspective (Steele, 2001). The goal was to engender the appropriate dispositions in mathematics and for mathematics teaching in the Noyce scholars. Recognising the importance of content knowledge in the preparation of teachers, one goal of the TEP was to streamline the pathway to the dual degree. This included addressing the advising process in both the Mathematics Department and in the College of Education (COE). Undergraduate dual majors have advisors in both departments. The program coordinators arranged opportunities to bring advisors together to enable them to support one another, to ensure students received the same message from both departments, and to model for preservice teachers how professionals work together. These relationships demonstrated a culture of caring. Research indicates that participants who feel supported by teacher preparation faculty were more likely to stay in high-need schools (Kirchhoff & Lawrenz, 2011).

Opportunities afforded by the programming in the COE enabled potential Noyce scholars to connect early in the program with mathematics education faculty. In their first semester, all preservice teachers in the teacher education program enrolled in the course, "Orientation to Teacher Education," were assigned the task of meeting with the faculty in charge of their content area major to discuss the teacher education program and opportunities for them to engage in valuable learning experiences. This was organised as a small group activity where preservice teachers could be introduced to each other so they might recognise each other in classes. The meeting also provided the project Principal Investigator

(PI) an opportunity to talk about dual majors, scholarship opportunities, service-learning projects, and upcoming field experiences.

In the COE, courses were designed to address pedagogical knowledge and diversity. Four significant field experiences were integrated into the program to enable candidates to apply coursework in practical ways and address dispositions. Recognising and valuing that what preservice teachers learn is influenced in large part by their field experiences, a mathematics education faculty member (the PI) assisted in making field experience placements for mathematics education students. Before taking on the role of student teacher, preservice teachers complete three significant field experiences successfully. In the first year of the program, preservice teachers participate in an Early Field Experience, which is designed to provide students with a broad perspective on the teaching profession. They then participate in a field experience that focuses on core teaching skills and general pedagogy. This is followed the next semester by a field experience practicum that focuses on content pedagogy and involves planning and teaching mathematics lessons. Placements were made purposefully to provide a variety of experiences: middle school level, high school level, rural, urban, lower-level courses, upper-level courses, and diverse student populations. Research on preparing teachers to work with diverse learners demonstrated that when teachers used knowledge about culturally and linguistically diverse students' lives to connect to the subject in meaningful ways, academic achievement increased (López et al., 2002). This is significant because a lack of understanding of culture is a major reason for the achievement gap (Becerra, 2012; García et al., 1995).

Relationships, peer interactions, and faculty support have been identified as important aspects of teacher preparation (Dinsmore & Wenger, 2006; Koeppen et al., 2000; Putnam & Borko, 2000). Therefore, weekly seminars were designed for Noyce scholars specifically to build relationships, to engage in critical reflection and discussion, and to support the development of a mathematics teacher's dispositions. A needs assessment survey was administered to gather information to inform the topics for the seminar. In some sessions, scholars began by reading a short article or watching a purposely selected video to illustrate best mathematics classroom practices, and to launch a discussion about that practice. Teachers, mathematics coaches, mathematics specialists, and administrators often served as guest speakers. The scholars were also encouraged to ask questions and share ideas. Research indicates that past and present K–12 school experiences impact the development of preservice teachers (Eick & Reed, 2002; Furlong, 2013) and as a result, preservice teachers bring with them primitive constructions of their mathematics teacher identities. Weekly seminar activities enabled scholars to reflect on their past and present K–12 experiences, bringing them to the surface to ponder and discuss.

Seminars provided an opportunity for scholars to interact with each other, and this, along with the classes they were in together, enabled them to develop a sense of community. A sense of community enhances teacher preparation. Relatedness to peers and faculty as well as participation in community learning have been found to increase student retention, academic success and job preparation (Beachboard et al., 2011; Fontana & Manuti, 2016; Koeppen et al., 2000; Tinto, 1997; Tinto et al., 1994; Summers & Svinicki, 2007). Krause et al. (2003) found a significant relationship between regular out-of-class interaction with peers and level of satisfaction with academic progress. A sense of community also shifts future teachers away from a model of academic and professional isolation that often exists in the teaching field and enables teachers to work together more effectively (DuFour & Eaker, 1998; DuFour et al., 2008; Koeppen et al., 2000; Nehmeh & Kelly, 2018).

Data and Methods

Context of the Study

In keeping with the sociocultural research approach adopted (Steele, 2001) interviews were employed to identify and understand: (1) the factors that contribute to the success of recruiting and retaining mathematics teachers in high-need schools, and (2) the extent targeted activities contribute to the mathematics teacher candidates' perceptions of their ability to work in high-need schools. The research activities reported in this paper were part of the research project that examined the recruitment and

retention of pre-service mathematics teachers who participated in a 4-year Noyce Scholar program embedded in a TEP program at a Midwest public institution in the United States from 2017–2019. Each scholar received between \$9,000 to \$20,000 annually to go towards their tuition and living expenses, which covered half to the full cost of attending the public institution at that time. The participants, six Noyce scholars, all women, completed the Noyce Program prior to the summer of 2020 when interviews were conducted. They received their initial teaching certification for secondary mathematics and were actively teaching in their first or second years in high-need schools at the time of the interview. To be eligible, participants had to pursue a double major in mathematics and education and participate in a weekly seminar with other Noyce scholars for each semester they received the scholarship. The weekly seminar topics included how teaching mathematics varied by urbanicity, by school poverty status, by students' English as a Second Language (ESL) status, different school technology policies, and different types and purposes of assessment. As part of the scholarship, they also agreed to teach a year in a high-need school for every semester that they received the scholarship. These Noyce scholars were highly qualified and motivated students who wanted to teach in high-need schools.

Data Collection and Analysis

Semi-structured interviews of six Noyce scholars were conducted over the summer of 2020 (see Appendix Table 1 for interview protocol). Interviews lasted between 30–60 minutes each. Leveraging the sociocultural perspective, the questions were crafted to probe at how the scholars' experiences in the TEP and in the Noyce Program reflected a culture of caring, learning opportunities, enacting educational values, and the importance of mentoring and support. Specifically, Questions 6–8, 12–15, 18, 20, and 25 targeted these ideas and other question targeted programmatic elements of the Noyce Program. The interviews were transcribed verbatim, and one interview was coded by members of the research team using the framework of factors relevant to the overall mission of the Noyce Program to establish reliability. The framework leveraged social activities as the core of learning and development. It included the importance of the Noyce Scholarship to the scholars, the extent to which formal and informal relationships matter in initial recruitment and retention, the extent to which Noyce Program features influence scholars' views and experiences, exposure to high-need schools and preparation to teach in such schools, reliance on informal and formal connections to other teachers and Noyce scholars as a teacher, and issues concerning rural teaching. As part of the first round of coding, a research team consisting of five members coded the same interview and coded a second interview to check for reliability. The coding was iterative with researchers comparing their coding to each other to ensure consistency and accuracy (Corbin & Strauss, 2008). Once it was established the research members were coding for the same or very similar information, the remainder of the interviews were coded individually by two researchers.

Following coding, the research team met to discuss findings and resolve any discrepancies or uncertainties between the two main coders through consensus. Using grounded theory (Corbin & Strauss, 2008), the coded interviews, the iteratively developed codes by the research team, and emergent themes were examined. The themes that emerged from this process were: 1) stress and anxiety with the cost of college, 2) the value of personal connections for success, 3) the contributions of the weekly seminars, 4) the importance of exposure to high need schools, and 5) the influences of informal and formal connections. Finally, we employed case dynamics matrix analysis (Miles & Huberman, 1994) to examine the five themes and how they varied from scholar to scholar. This enabled the identification and tracking of patterns and themes within and between scholars. Excerpts from the transcripts are used as evidence of each of the themes in the Results section. To maintain privacy and anonymity, each participant was assigned a unique code for reporting purposes (e.g., Scholar Z).

Results

Reducing Stress and Anxiety with the Cost of College

The Noyce Scholarship facilitated a level of financial security, giving scholars more time to focus on their coursework and teacher preparation. Five out of the six Noyce scholars agreed the scholarship helped reduce stress and anxiety related to the monetary aspects of attending college. In one case involving a non-traditional student (Scholar F: mature-aged student), the scholarship was certainly a game-changer with respect to debt because she had college-aged children. She stated that it was “essential, because my husband had told me since I have kids that are going into college, I could not take on student debt. That was the bottom line, there will be no student debt.” Scholar B, who was looking to pursue advanced studies, indicated that,

It was really nice to have [graduated] without debt, and it actually helped me jumpstart my master’s, because I always said I would start my master’s when I paid off my student loans. And since I didn’t have those, then I was able to start my master’s a lot earlier than I had initially anticipated.

In addition to reducing stress on the financial side, Scholar C felt like the funding was “a great motivator to keep going” forward with the program itself. For these scholars, the Noyce Scholarship funding was crucial to alleviating the stress of uncertainty with regard to tuition. The scholarship also opened new opportunities that would have otherwise taken longer, or possibly, not have even been considered.

With respect to gaining additional time in their schedules, Scholar A noted that without the funding, she would have had to take on extra hours as a student worker. In particular, the extra time opened opportunities to participate in various activities, thus broadening the overall collegiate educational experience, instead of “just stressing about the money.” Scholar A also indicated she could focus her attention on building relationships and “[learning] more to talk to people,” a vital skill for teachers. Scholar E indicated that

knowing that the funding was already done, that I could kind of go out on a limb for myself, and take more difficult classes because I didn’t really have to worry about ... [How] was I going to be able to pay for this?”

Having tuition taken care of motivated this scholar to challenge herself and enrol in more difficult classes, allowing her to gain more content area expertise and knowledge. As these scholars’ feedback reveals, the Noyce Scholarship resulted in a variety of positive outcomes, allowing them to explore new opportunities, build relationships, and acquire additional content knowledge.

Critical Personal Connections for Success

A particularly strong finding that resonated across all the Noyce scholars was that personal connections and relationships played a critical role in their success. These personal connections, sometimes formal and sometimes informal, contributed to various steps in the pipeline, from scholars applying to the program and how they responded to the seminars as scholars, to how they perceived opportunities once they became teachers.

First, while both the Mathematics Department and the Curriculum and Instruction Department advertised the Noyce Scholarship, many scholars applied due to their relationships with their advisors and professors in those departments. For instance, Scholar A noted she was made aware of the Noyce Program through her advisor in the COE. The Noyce Program provided her with the money, advising and support so that she could become a dual major in Mathematics and Education. Others have applied to the program due to their personal connections with the Noyce Program director, Dr. Martinie (first author). Moreover, the relationship between each scholar and Dr. Martinie was critical to all the scholars in how they experienced the program as scholars and beyond. This was in part due to her role as the program director, but mostly it was due to her personal relationships with the scholars. For example, when Scholar B wanted to know more details about getting her master’s degree, she did not directly

contact different departments, but rather, she contacted Dr. Martinie first to learn more about the whole process.

Personal connections helped students beyond just applying to the Noyce Program. The connections contributed to the scholars' learning as well as providing experiences they would not have otherwise had. For instance, scholars expressed how Dr. Martinie placed learning within their grasp and showed there is always a way to learn and improve. Scholar F said that it was a

very truly tremendous benefit to have Dr. Martinie as my mentor because she's just got so much information and a way of presenting it that it makes everything, "Oh, I can do that." She really makes it something that's attainable I think for everybody. And that is, is a very valuable skill that she has and brings to encourage people, in such a positive way.

When asked to describe the supports that helped scholars through the education program, Scholar A said,

One of the biggest things that helped was just having Dr. Martinie and just getting to know her the whole time. We became honestly more friends than anything and I got to know her really well. Because of this, I helped with the family STEAM nights ... Then attending the Noyce Summit conference and also getting to really dive into some research as an undergrad ... I think that was really cool.

When asked about the kind of support the COE continued to provide for them after they graduated, multiple scholars, A, B, E and F, indicated they continued to rely on their relationship with their former advisors and with Dr. Martinie, for information and on-going support. For instance, Dr. Martinie provided mathematics resources and opportunities at the right time to support scholars. Scholar C, who had graduated, added that:

Dr. Martinie, like, did a lecture series. In June, and she sent that out to the Noyce scholars, and I went to a few of them. That was good. It was on math leadership or education leadership, and I found that interesting and helpful and kind of like to a spark. After going through school and in the in the way we did this last year [referring to changes due to COVID-19] was refreshing to hear other people and what they're doing and education to improve it. And yeah, so that's something Dr. Martinie did, [which] I wish there was more of.

At times, the scholars did consider whether teaching was the right career for them after they experienced challenges in the classroom. When this occurred, the scholars were reassured that they were capable teachers who could continue. Scholar D had this to say,

I've reached out to Dr. Martinie a couple times, and I was actually considering quitting mid-year this year after first semester. After that really terrible class I was just, like, I can't do this. And I'm glad that I didn't, but I saw, like, I reached out to her. She's been helpful.

This scholar just needed a nudge and reassurance to keep her going. It was her personal relationship with Dr. Martinie that made her feel comfortable and vulnerable enough to voice her concerns about teaching. The established relationship facilitated Dr. Martinie providing the support and encouragement required for the scholar to continue in the program.

In sum, throughout various parts of the education program and beyond, the personal relationships and connections scholars had with their former advisors and the Noyce Program director played critical roles. Some scholars applied to the program due to these relationships, and others found these relationships provided them with the support and mentorship needed to finish the education program. Others relied on these relationships for more professional development opportunities and encouragement to stay in the profession. These findings strongly suggest the personal connections were oftentimes the driving force that nudged and pushed scholars to continue the program and supported them in their teaching career. In particular, Dr. Martinie's proactive and nurturing approach, her regular engagement with the scholars during and after the program, and her consistent effort to provide current scholars with learning and teaching opportunities were critical to the program's success.

Contributions of Weekly Seminars

Another finding was an appreciation for weekly seminars, particularly when scholars were provided an opportunity to hear from and talk with experienced and new teachers. Seminars were planned based on input from scholars. Surveys were conducted to gather information about the scholars' needs and interests, and from the information gathered, seminar topics were selected. Each month a specific topic, relevant to teaching in high-need schools, was highlighted. Weekly seminar activities included reading articles, viewing videos of teacher actions in the mathematics classroom, small group discussions, and hearing unique perspectives on topics from guest speakers. Scholars reported this allowed for insights into teaching and exposure to situations and ideas they might not otherwise have had until entering the classroom.

First, all six scholars found the seminars important to their development as teachers. Scholar A stated the best part of the seminar was talking with teachers around the country and gaining insight into what the career would be like before she graduated. This helped scholars approach student teaching with a unique lens and a keen ability to notice details. Scholars also noted that seminars enabled them to spend valuable time with the other scholars who were on the same track and allowed them to reach out to each other whether it was help with a class or some other purpose. It provided an avenue for scholars to feel better connected and part of a community. Scholar A reported the scholars participated in group chats to exchange ideas and stay connected beyond completing the program. She said, "This program definitely just connected me more to not just future teachers or teachers that [sic] were already in the field, but some people that were at my same level. So that was nice."

Second, scholars reported that the seminar impacted their views of high-need schools/districts. Scholar B stated that before attending seminars she did not have the insight into real teachers who taught mathematics in high-need schools. Scholar F said she really liked hearing students talk about teachers who make an impact, and this motivated her to seek out the answer to the question, "How do you become that teacher who makes an impact on high-need kids?" It was important for scholars to hear that teaching mathematics and making an impact could vary greatly by the school environment and working conditions. For instance, mathematics resources, such as calculators and manipulatives, may be more limited in high-need schools, particularly those in rural communities or serving minority students.

Third, in terms of preparation to teach in high-need schools, scholars reported the seminars were an impactful part of their preparation. Scholar A said talking with teachers who were already in the field was a "big thing." Teachers shared experiences that scholars had not considered and provided advice and tips about teaching mathematics they had not heard previously; for instance, information related to different school policies on technology use, or different types and purposes of assessment in mathematics. They valued hearing these things from practising teachers, and this encouraged them to focus on those things while student teaching. In the end, they felt less surprised and more prepared when they began teaching.

While scholars appreciated the content and connections seminars provided them as preservice teachers, they also appreciated the continuation of this after they graduated. Each semester, one of the seminars with a panel of Noyce old-scholars who had graduated. They shared with the current Noyce scholars details about their position and talked about what they felt prepared and unprepared for during their first years as a mathematics teacher. They shared stories about things that surprised them and about the impact they had on their students and school. These findings suggest that making connections, building community, exposure to current teachers, and hearing classroom stories have an impact on the preparation to teach mathematics in high-need schools.

Exposure to High-need Schools

All six scholars feel the Noyce Program enabled them to have exposure to teaching conditions at high-need schools, and this encouraged them to expand their understanding of traditionally disadvantaged schools, helped them identify tools they can use when they start teaching, and armed them with an ability to provide adaptations for their students. They reported feeling relatively well prepared. First,

scholars reported exposure to teaching experiences at traditionally disadvantaged schools expanded their perception of a high-need school. In the beginning of the program their understanding of these schools focused on serving communities with high poverty rates. Through their exposure to different types of schools, they experienced the diversity that exists in these settings and the unique services required to meet students' needs. They also came to realise high-need schools struggle to attract and retain the qualified teachers that students deserve. They recognised these schools may include a high percentage of students who receive free or reduced lunch. One scholar stated, "I know that like the technical definition is they have around 50% free and reduced lunch, and our school is around, I don't know, 60 or 70 percent, so we have a pretty high poverty rate." Scholar A acknowledged schools can have high needs in different ways, but "most of them obviously have a diverse population and a high percentage of students who are on free and reduced lunch and things like that." In terms of diversity, scholars noted characteristics such as racial/ethnic diversity, background, socioeconomic status, and having a larger population of English Language Learners (ELL).

Scholars also noted high-need schools often needed to be prepared to address specific sets of students such as those requiring special education or those from military-connected families.¹ One scholar said, "We also [had] a decent special education program. We [had] a lot of kids that [had] physical as well as learning disabilities." Unfortunately, scholars also reported some schools lacked resources to assist with students with exceptionalities. In one case, a large school had one special education teacher for the whole school, and the scholar shared how students' accommodations were outdated. She reported she often discussed them with the student and the parents, but fortunately, she felt equipped and prepared to do this. In general, the scholars felt prepared enough to address most students' needs.

Although the scholars felt the Noyce Program helped to prepare them to teach in high-need schools, they acknowledged that they had more to learn. For example, Scholar A said she was exposed to many different things. She said,

I'm still so new that I don't think I'm really prepared for anything too crazy, but I was definitely given tools and resources into what an urban school looks like [and] how to work with students who are connected to the military.

She also recognised that while she felt prepared on a basic level, she had more to learn. She said, "So I think I learned about them and was exposed, but I definitely have room to grow in all of those areas and could learn more about all of them, for sure."

Another finding was how scholars often started their teaching experience by anticipating what they experienced as a student when they were not sure what to expect from their new school setting. Through their exposure to high-need schools, they quickly learned not all students viewed school the same way they did and not all families engaged with schools in the same way their family did. Exposure to high-need schools enabled scholars to connect with teachers and students to gain a deeper understanding of the culture and climate of high-need schools. For example, Scholar A said,

I think my view was pretty similar to what it is now, but I just didn't have the insight into real teachers who taught at those schools. So, after going through this [program], I had more connections and experiences to what it's like to actually teach in one of those schools.

In contrast, for Scholar B, her views changed as she compared it to her experience as a student. She said,

I went to school in an area that is not really a high-need district. I mean, there are very, very few kids who are in poverty. We had tons of resources, a really nice school and everything. I didn't really know much besides that, just from growing up there, so I got to learn a lot more about that and different programs that are implemented.

¹ Many of the high-need schools in this Midwest state are located near military bases, so they serve many military families.

Being immersed in a culture that was different than their personal experience of schooling growing up enabled them to expand their views and understand their learners.

Overall, while exposure to high-need schools helped them gain a better sense of what to expect, they still were not always able to anticipate what their teaching experience would be like, and they were surprised by things being easier or harder than expected. However, they generally felt prepared to address their students' needs, to make use of available resources, and in areas where they did not feel as prepared, they were eager to learn more.

Informal and Formal Connections

Another theme that emerged was the desire for more informal and formal connections with other educators as both preservice and novice teachers. As preservice educators, five of the Noyce scholars expressed the need and value of connecting with current classroom teachers and the benefits of connections made with Noyce scholars as undergraduates. Once in the field, Noyce scholars noted the importance of their continuing connections with other Noyce scholars as novice teachers, collaboration with other educators, and of their mentorship program.

In reflecting on their experience as preservice educators, the Noyce scholars recognised the benefit of speaking with teachers already in the field. One scholar remarked, "just talking with teachers who are already in the field was a big thing," while another scholar spoke of Dr. Martinie inviting the Noyce scholars to her graduate course Zoom sessions.

She invited us during June to join her grad class over Zoom and listen to math educators speak, and I joined in when I could, and I really enjoyed that. So, I felt very supported, and I think that really changed my view of teaching.

Scholar B wished to be able to give back to future Noyce scholars: "We can still be a part of it ... even [when] graduated, I [could] serve other things like that." Wishing to give back demonstrates the great value she saw in speaking with teachers in the field in a preservice educator role. The Noyce scholars also identified the importance of the connections they made with one another while in the program. Scholar B said:

I feel like I got to know people I knew a lot of, obviously the six of us who graduated at the same time, but I got to know other Noyce scholars like Scholar F or and Scholar G who I wouldn't have met, really. So that was kind of cool to get to know them through Noyce as well. So, I have other resources and other people I can talk to, which is nice.

The significance the scholars placed on the connections they made as preservice teachers in the Noyce Program was shown in how they kept in contact to support one another. Along with being connected with other Noyce scholars was feeling supported by the informal relationships that teachers establish with one another. Scholar E remarked on the value of social media teacher groups, "I'm in a group on Facebook. I'm in a teachers' group, and it's actually very interesting to kind of see what different people are doing."

These informal and formal connections were identified in practice when the Noyce scholars reported collaborating with other educators. Scholar C went into detail about collaboration with other teachers: "They are definitely willing to help to help out. If you need help ... I hope to do more collaboration this next year." Scholar E expressed similar views, "I would say just the ability to collaborate with the other people is really a huge resource for me." Scholar D recognised the value of working with other departments, in particular working with special education teachers, "If you contact any of their IEP [Individualised Education Plan] managers or anything like that, they're very helpful."

A final way in which the scholars felt supported was the informal and formal mentor relationships established in their first year of teaching. Scholar B described an informal mentoring relationship that supported her in her first year of teaching, involving an elementary principal and three new middle school mathematics teachers (including the scholar). The principal spent a whole day at the beginning of the school year with the new mathematics teachers and showed them how she would go through the manual. She worked through teaching material with them, shared how she planned lessons, and

planned student learning experiences with them. Then she observed them teaching two or three times and gave feedback and made recommendations. Scholar B stated, "That was huge. Um, and that was really cool because she's not even my principal."

Scholar C had both informal and formal mentorship that supported her first year of teaching. She described how her department head functioned as an informal mentor:

My department head is really great. She checked in on me and another new teacher that[sic] I shared a classroom with. She made sure we knew exactly what we were doing. She always thought ahead, she would answer questions before we even knew we had questions.

In sum, scholars recognised the informal and formal connections they made through the Noyce Program and in their first year of teaching as critical to supporting their development and practice as teachers. As preservice educators, scholars acknowledged the value of talking with current teachers as an essential part of the Noyce Program. Furthermore, scholars noted the value of the relationships they formed with other Noyce scholars, not just as preservice educators but continuing into the beginning of their teaching career. More specific to supporting teacher practice as first-year educators, the Noyce scholars strongly identified collaboration as a critical need. In addition, the informal and formal relationships the Noyce scholars established with mentors in their first year of teaching were vital in supporting their development and practice as educators.

Discussion

Teacher education programs have the responsibility to prepare preservice mathematics teachers to work with learners from traditionally disadvantaged households, in a variety of contexts, regardless of the preservice teacher's background. Towards this end, through a sociocultural lens, the factors that contributed to the success of recruiting, preparing, and retaining mathematics teachers to teach in high-need schools, the perceptions of high-need schools held by mathematics teacher candidates and how they changed over the course of their preparation as a result of participating in the program activities was investigated. Moreover, as novice teachers need to be prepared to meet the demands of the job on Day 1, the researchers examined how well-prepared candidates felt when they began teaching.

Five critical factors emerged from the analysis. First, the Noyce Scholarship created a level of financial security, enabling scholars to focus on their coursework, teacher preparation and relationship building. Second, personal connections and relationships with faculty and advisors played a critical role in their success. Third, weekly seminars, many of which were mathematics-focused, were impactful, particularly when scholars are connected with new and experienced teachers. Fourth, when scholars are exposed to teaching conditions at high-need schools, their understanding of high-need schools increased. This exposure also helped them identify mathematics resources and tools that they leveraged when they started teaching, as well as equip them with appropriate adaptations for their learners. Fifth, as undergraduates and later as novice teachers, scholars thrived on informal and formal connections with other educators and want to continue these relationships. As undergraduates, scholars articulated the need and recognised the value of connecting with other mathematics education preservice teachers as well as practising classroom teachers. As novice teachers in the field, scholars spoke to the significance of building ongoing relationships with other Noyce scholars and continuing to collaborate with other mathematics educators.

Several connections to sociocultural perspective emerged. First, the scholarship itself had an impact on scholars. While prior research on Noyce Scholarship programs has suggested that the Noyce Scholarship may not heavily influence scholars' decisions to enter the teaching profession (Whitfield et al., 2021), the results presented in this paper suggest that the Noyce scholarship can have positive effects and that formal and informal relationships can be leveraged to recruit candidates into the teaching profession. By removing financial stress or barriers to teaching, scholars' anxiety related to the cost of college can be alleviated, thereby allowing a greater focus to be on learning and on making meaningful relationships and connections with fellow scholars. The grant and subsequent removal of financial stress

along with the improved time spent on learning and developing social connections are likely to help these scholars persist and graduate (Nguyen et al., 2019).

Relatedly, informal and formal connections with their peers represent horizontal relationships in their community of practice. Horizontal relationships are complemented by several vertical relationships meant to induct scholars into the community of practice by assisting in the development of their professional dispositions (Lave & Wenger, 1991; Tomlinson, 1995). Scholars valued these vertical relationships. These relationships were built using formal and informal methods including connections to cooperating teachers in their field experiences, speakers at weekly seminars, and mentor-mentee relationships with the program director, Dr. Martinie.

The development of Noyce scholars' professional dispositions is represented through multiple findings, which connect to the four recommendations for the TEP discussed in the theoretical framework (Carroll, 2007). From induction into the TEP, throughout the program, and into the early years as novice teachers, Dr. Martinie played a critical role in the scholars' development; the relationships the scholars reported with Dr. Martinie demonstrate the essential role of creating a "culture of caring." This culture enabled the development of identities of practice through scaffolded learning experiences (Kirchhoff & Lawrenz, 2011). Both exposure to high-need schools and the weekly seminars provided the Noyce scholars support in interpreting classrooms as contexts for enacting educational values and purposes. Scholars were provided an avenue for critical reflection as a means for processing their field experiences and professional conversations (Garcia, 2020; Shandomo, 2010). Critical reflection also enabled them to better process how the learning environment they need to foster as a teacher may look very different from the one they grew up experiencing. Finally, the scholars emphasised the importance of the mentoring support they received in their first year as a teacher from multiple sources: Dr. Martinie, their administrators, and teacher induction programs at their schools.

Even though many of the Noyce activities stemmed from or were connected to the sociocultural perspective (Steele, 2001) and were well-integrated into the TEP, there were still limits to what was provided to the Noyce scholars. For instance, the program activities did not specifically address how teachers can develop adaptability skills to adjust to different teaching circumstances or specifically how to adapt teaching in rural and urban environments as recommended by the CCSSO (2013). Teachers who are more adaptable are less likely to become disengaged at work and have greater job commitment (Collie et al., 2018). Addressing these limitations may increase programmatic success.

Implications and Future Research

National and international programs and initiatives like the Noyce Program should build from these findings as they have implications for recruiting and retaining STEM teachers, and in particular teachers of mathematics. First, scholarships can be an enticing opportunity for many students who may not enter the teaching profession. Moreover, scholarships can lessen anxiety and stress related to the cost of college and provide time and opportunities for scholars to improve their social networks and take on more challenging mathematics courses to further develop their own education. Second, for program directors and advisors in charge of initiatives like the Noyce Programs, leveraging formal as well as informal connections are critical in recruiting students into the program, and these connections serve as entry points into providing them additional support and guidance once scholars become teachers. Stated otherwise, the results suggest the human element (i.e., leveraging personal connections), is needed.

Third, it would be advantageous for programs to include intentional opportunities for scholars to engage with teachers in the field. Dispositions are situation-specific; therefore, addressing them requires context beyond the university classroom setting. Supporting connections with current teachers through field experiences helps to not only increase exposure to high-need schools but also to develop relationships with mentoring figures, build a community of practice, and expand the culture of caring established by teacher education faculty. Moving forward, this could be done by connecting each scholar with a mentor at the beginning of the program and setting time aside during seminars for the scholars to meet with their mentors on a regular basis throughout the program. Scholars' exposure to

high-need schools in field experiences provides them the opportunity to reflect on and consider their teaching practice—a critical part of enacting values and developing professional dispositions (Carroll, 2007). Ongoing conversations with a trusted mentor teacher will support critical reflection. These supports and opportunities can be provided on a regular basis as part of a class or in a weekly/monthly seminar. Weekly seminars that provide mathematics-specific contents, such as how to deal with resource constraints, the variations in working conditions, or the various types and purposes of mathematics assessment, can be transformational for preservice mathematics teachers as they learn how to teach mathematics in different contexts.

Fourth, the program must continue supporting scholars in developing relationships with their peers. Relationships with fellow scholars prove critical in the scholars' development of professional dispositions, and feeling supported enabled them to continue in difficult times. When asked for suggestions to improve the program, several scholars suggested facilitating connections between current and former scholars. This could be done by establishing mentor-mentee relationships within the Noyce Program between current and former scholars in various stages of their career to create a community of mentors or "mentor family" (Zygmunt et al., 2020). Although the implications have been presented in relation to specialised programs, such as the Noyce Scholarship Program that targets the recruitment of mathematics teachers, it is proposed that all pre-service teachers would benefit from the strategies implemented. Future research can further explore these relationships to understand their impact on the development of professional dispositions.

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Ethics Declarations

Ethical approval

Ethical approval for the research was granted by Kansas State University Institutional Review Board (IRB-08626), and informed consent was given by all participants for their data to be published.

Competing interests

The authors declare there are no competing interests.

Appendix 1

Interview Protocol

1. Tell me what sparked your interest in teaching or led you into teaching.
2. What drove your decision to become a teacher in a high-needs school? (e.g., finances, rewards associated with teaching, mentors, past experiences, personal interest, etc.)
3. How did you hear about the Noyce scholarship?
4. Were you recruited or encouraged to apply to the Noyce scholarship by anyone?
5. When did you receive the Noyce scholarship/stipend?
6. What experiences during your teacher preparation program, if any, were extra because you were a Noyce Scholar?
7. In comparison to your math classmates not on the teaching track, how would you describe the academic preparation in the Noyce Scholar program? (e.g., is it stronger, weaker, or comparable academic preparation?)
8. Please describe any activities or supports that helped you through your education program.
9. In your view, what are the characteristics of high-needs schools?
10. What were your views of high-needs schools/districts prior to your teacher preparation program?
11. How, if at all, have your views changed during the program?
12. How, if at all, did the Noyce scholarship influence your views?
13. How has your teacher preparation program prepared you to teach in high-needs schools/districts?
14. How did the Noyce scholarship prepare you to teach in high-needs schools/districts, if at all?
15. Do you feel prepared to teach in urban/rural, ELL, SPED, military-connected, etc?
16. How long do you foresee teaching in a high-needs school?
17. What factors will influence how long you continue teaching in a high-needs school?
18. What kind of support or resources would you like to see from your teacher preparation program or Noyce?
19. Are there other resources outside of the Noyce scholarship, or your school that have supported you in teaching?
20. How do you feel your content area preparation affects your teaching experience?
21. How has the Noyce funding played a role in your decisions throughout the process (e.g., becoming a teacher, finishing their degree/leaving the program)?
22. Have you considered other careers that would use your content area training?
23. Why did you or did you not change careers?
24. What, if anything, did you find challenging or surprising during your first year of teaching?
25. What kind of support does the College of Education at Kansas State University continue to provide for you?
26. What kind of support and resources are there at your school to help you do your job during the school year?
27. How did the COVID-19 pandemic affect your teaching?
28. How did or does the pandemic affect your career?
29. Finally, sometimes we do not know how to ask the most important questions about your experience as a Noyce Scholar and as a teacher. Is there anything else important you think we have left out?