Implementing a Mentoring Program for Beginning Secondary STEM Teachers: Conceptualization and Lessons Learned

innovations.theaste.org/implementing-a-mentoring-program-for-beginning-secondary-stem-teachers-conceptualization-and-lessons-learned

Smetana, L., Millsapp, K., Leider, M., & Johnson, M. (2023). Implementing a mentoring program for beginning secondary STEM teachers: Conceptualization and lessons learned. *Innovations in Science Teacher Education*, *8*(1). Retrieved from https://innovations.theaste.org/implementing-a-mentoring-program-for-beginning-secondary-stem-teachers-conceptualization-and-lessons-learned/
by Lara Smetana, Loyola University Chicago; Krishna Millsapp, Loyola University Chicago; Megan Leider, Loyola University Chicago; & Mark Johnson

Abstract

The importance of attending to teachers' transition from student to teacher (i.e., induction period) is increasingly recognized. This article describes efforts to develop, implement, and iteratively revise a mentoring program for beginning secondary science and mathematics teachers. We explain the conceptualization of the program in terms of four dimensions of teachers' professional practice and varying mentoring approaches and formats. Examples of mentoring program components illustrate the program design. Lessons learned from the first 2 years are explored utilizing participant data as evidence. Plans for our program are discussed as well as implications for other teacher education programs.

Introduction

Much of the literature in this journal and in the field of teacher education is focused on teacher candidates' education coursework (i.e., preservice) or on professional development programming for more experienced teachers (i.e., inservice). There is far less research focused on teachers' induction periods, their transition from preservice to inservice teachers. The term *induction* gained popularity in the 1980s and has been defined as the "entry [into teaching] and . . . the planned support the new teachers receive" as they transition into professional practice (Veenman, 1984, p. 165). Induction is increasingly recognized as a critical point in a teacher's career (Luft et al., 2015; Thomas et al., 2019), which is particularly important in addressing what has been labeled a teacher retention crisis (García & Weiss, 2019a, 2019b).

There have been studies on the development and implementation of induction programs, both formal and informal (e.g., Fantilli & McDougall, 2009), and mentoring, in various forms, has played a predominant role in some of those studies (e.g., Bradbury, 2022; Feiman-

Nemser, 2001; Ingersoll & Strong, 2011; Orland-Barak & Wang, 2021). Given that teacher learning is multidimensional, multicausal, and multi-correlational (Bell & Gilbert, 1994; Opfer & Pedder, 2011), the induction research points to the need for multifaceted approaches that provide a variety of support mechanisms (Bickmore & Bickmore, 2010; European Commission, 2010; Main, 2007; Smith & Ingersoll, 2004). However, questions remain about what makes for successful induction programming.

Gold's (1996) framework for teacher induction programs drew early attention to the importance of simultaneously supporting teachers' personal and professional needs. It is also now well understood that context matters and that a new teacher's school climate and culture are highly influential (Smetana et al., 2016; Wei et al., 2009). Thus, there are multiple aspects of teacher professional learning that induction programs must address, including personal, professional, social, and moral or political dimensions (Akiri & Dori, 2021; Bell & Gilbert, 1994; European Commission, 2010; Murrell et al., 2010; Shoval et al., 2010). Similarly, Orland-Barak and Wang (2021) called for an approach that, among other things, deliberately integrates multiple mentoring approaches as needed. Further, they call for regular, systematic inquiries into one's own mentoring practices to inform future practice and contribute to the professional knowledge base.

In this article, we take up this call and describe our efforts to develop, implement, and iteratively revise induction supports for secondary science and mathematics teachers as part of a larger program designed to encourage and support STEM majors to become high school teachers in high-need school districts. To contribute to the ongoing conversation and growing body of knowledge around teacher induction, we share what we have done, what we have learned, and what we are still pondering.

Background

Multidimensional Teacher Learning

Recent understanding of teacher professional learning recognizes that learning is ongoing through one's career, takes place in a social context, and is related to practice (Louws et al., 2017; Opfer & Pedder, 2011; Webster-Wright, 2009). Learning for teachers takes place formally through coursework and programming but also informally through everyday classroom experiences; interactions with colleagues, students, and families; and experiences outside of work (Webster-Wright, 2009). Clandinin and Connelly (1995) used the metaphor of "professional knowledge landscapes" to describe the breadth and complexity of teachers' practice knowledge, which comprises multiple dimensions. These dimensions include personal, professional, social, and moral or political (Bell & Gilbert, 1994; Clandinin & Connelly, 1995; Orland-Barak & Wang, 2021).

The *personal dimension* is how teachers perceive themselves and their job situations, give meaning to these, and act upon them (Kelchtermans, 2009; Vanassche & Kelchtermans, 2014; Sinha & Hanuscin, 2017). Within this dimension are teachers' emotions, feelings, intentions, attitudes, motivation, well-being, identity, self-image, self-awareness, self-confidence, and interpersonal efficacy. This dimension "is deeply entwined with the moral" and political aspects of teaching (Kelchtermans & Deketelaere, 2016, p. 453).

The *professional dimension* is often considered the how-to dimension and includes the various types of knowledge, skills, competencies, and dispositions teachers possess related to content knowledge, instructional practices, and how to support all students equitably (Wilson, et al., 2015). Understanding of the three-dimensional vision of science teaching and learning put forth in *A Framework for K-12 Education* (National Research Council, 2012) and the related *Next Generation Science Standards* (NGSS Lead States, 2013) certainly falls under this dimension. Furthermore, we agree with Parkhouse et al. (2022) that culturally relevant education is a fundamental responsibility of all educators because "all students deserve schools that are collectively empowering, individually affirming, and structured to promote their success, critical thinking, and civic engagement" (p. 475).

The *social dimension* recognizes that teachers are members of and work within social groups (Grusec & Hastings, 2007) or what Lave and Wenger (1991) refer to as communities of practice. Teachers are engaged in a joint enterprise toward common goals with a shared repertoire of practices (Lefstein et al., 2019). This dimension encompasses educators' collaborative ways of working, such as exchanging knowledge and resources with others and taking on leadership roles.

The *moral or political dimension* specifically emphasizes how teachers' work intersects with social justice issues (Nieto, 2006) and that teaching is a privilege and a responsibility (Apple, 2011). Moral and political values are woven into the daily life of classrooms and schools, both explicitly and implicitly (Cochran-Smith, 2001). Teachers' values, beliefs, and dispositions influence how they think and act (Murrell et al., 2010). Educators must be mindful of the authority they hold, including their authority as policy agents (Clarke, 2009). From the perspective of critical pedagogy (Freire, 1970), teachers are called to critically examine current realities and their own practices and push back against injustices within educational systems, policies, and practices (Apple, 2011; Cochran-Smith, 2001; Cochran-Smith & Lytle, 2009). This involves investigating social contradictions, working individually and collectively to mitigate oppression, and confronting sociopolitical structures that perpetuate injustice (Cochran-Smith, 2001; George Dover, 2009; Ladson-Billings, 1998; McDonald & Zeichner, 2009). To do so effectively, teachers must "strategically navigate [the] institutions" they work within "and genuinely promote critical dialogue" (Philip, 2013, p. 65).

Mentoring Approaches

Just as teaching is multidimensional, so must be mentoring. Orland-Barak and Wang (2021) reviewed various mentoring approaches for preservice teachers, discussing the assumptions about teacher learning, the focus of mentoring, and the affordances and challenges that accompany each approach. They also argued that no one approach is sufficient and that mentoring requires knowledge, understanding, and the deliberate selection and implementation of mentoring approaches based on the situation. In general, the trend has been toward more cooperative and equal mentor–mentee relationships that emphasize supporting equitable student science learning (Bradbury, 2022); such relationships have been termed “educative” (Feiman-Nemser, 2001) or “collaborative” mentoring (Nam et al., 2011). In educative or collaborative mentoring, the mentor takes a coaching stance (Lipton & Wellman, 2007; Miller et al., 2019) by engaging the novice teacher in reflective thinking and problem-solving, supporting them in accessing internal resources and developing capacities for self-directed learning. This contrasts with an approach of providing answers and solutions for the mentee.

Mentoring Formats

There are also multiple formats that mentoring can take. At the *individual* level, a more experienced mentor works one-on-one with a novice teacher, supporting their personal growth, professional expertise development, and induction into the culture of teaching (Aspfors & Fransson, 2015). *Group* mentoring involves multiple teachers working together with one or more mentors. This may consist of offering guidance and perspectives, sharing resources and information, and engaging in learning activities relevant to the group (Byars-Winston & Dahlberg, 2019). A mentoring *network* is a wider environment that brings together a mix of novice and experienced educators to learn from and with one another, sharing challenges and experiences and building collective knowledge and expertise (Tal et al., 2021). Creating a sense of belonging to a community is an important component of what both the group and networking mentoring formats offer (Heredia & Yu, 2017; Navy et al., 2019; Navy et al., 2022).

Our Induction and Mentoring Program

The Need

In this article, we report on a mentoring and induction program that grew out of a National Science Foundation (Award 1660794) Robert Noyce Teacher Scholarship program. Noyce programs are designed to support STEM majors to become well-qualified high school classroom teachers who also commit to teaching in high-need schools and districts.[1] Our Loyola University Chicago-Noyce Scholars (LUC-Noyce Scholars) program began in 2017 and complements our existing teacher education programs for secondary science and mathematics, offered at both the undergraduate and graduate levels. To date, 24 students have graduated from the LUC-Noyce Scholars program, and another six are still completing their licensure programs. Our scholars include individuals with varied backgrounds and life

experiences, and their majors span the content areas of mathematics, biology, chemistry, and physics. Overall demographics are 70% female, 27% male, 3% trans-gender; 68% White, 17% Asian, 6% Hispanic/LatinX, 10% more than one race or other; 20% multilingual. The majority are currently or have already completed their teaching obligations in Chicago Public Schools, the school district in which our university is located. The remaining scholars have gone to work in surrounding suburban school districts that serve a high percentage of students from low-income families, which the exception of one scholar who has moved out of state and works in another large, urban, high-need district. A benefit of NSF's Robert Noyce Teacher Scholarship program, and other programs like it, is that teacher education programs have an avenue to stay connected with their graduates. After completing their teacher education program and earning licensure, scholars complete a multiyear service obligation, which creates opportunities for long-term engagement with program graduates. Over the years, we have consistently stayed in touch with graduates not only to verify that they have fulfilled their teaching obligations but also to share information about conferences, professional development, job openings, and other opportunities.

[1] We used the term *high need* as defined in the Higher Education Act of 1965.

We had not initially planned to offer formal induction programming as part of the LUC-Noyce Scholars program. The decision to launch a mentoring program arose from feedback collected from student teaching supervisors, cooperating classroom teachers, and recent graduates who expressed the need and desire for more support as scholars transitioned into their first year of teaching. This need was likely magnified by the COVID-19 pandemic, which necessitated the move to remote instruction during this group of scholars' student teaching. When asked about ideas for what is important for teacher retention, one cooperating teacher shared,

> I would say, to retain teachers, they need an outlet…. The only thing I can think of is if their cohort, like, continues to have check-ins during the first year. Because I think this group of student teachers is going to have an interesting first year…. Because a lot of them didn't get the ability [opportunity] to teach. So, I think having, sort of, maybe, like, a cohort meeting that they have where they can talk to each other would be helpful.

Having seen this desire expressed in interview data collected from scholars, student teaching supervisors, and cooperating teachers as part of ongoing evaluation of and research into the program's impact, in the spring and summer of 2020 we developed and administered a questionnaire and spoke with scholars informally to better understand their needs and what they would like from a mentoring program. We received responses from 14 scholars who were part of the program at the time (see Figure 1 for example questionnaire responses). As expected, scholars' responses varied based on where they were in their programs and careers. Overall, the respondents who were most vocal about needing support were those who were about to start student teaching or program graduates about to start their first year of teaching. Responses expressed the desire for feedback on lessons that

would help them build their confidence during their first year; support for classroom management, student engagement, and supporting students' socioemotional learning; and resources regarding technology for remote and hybrid teaching settings. Regarding the format of a mentoring relationship, responses indicated that their ideal mentor would be someone who was more like a coach than an evaluator and that the relationship would be supportive rather than stressful. They also desired an opportunity to connect and collaborate with their peers and to have conversations about both school-related and non-school-related topics with more experienced mentors and peers.

Figure 1

Examples of Student Teacher Input on Their Mentoring Needs

"I think it's really cool to have someone be able to come in who doesn't necessarily know your students and give me feedback. Not only on how you're teaching and the lessons you're using, but also on your relationships with students and just things that they noticed as an outsider" to the classroom.

To have someone "just to reconvene, just to reflect and to kind of brainstorm back and forth will be beneficial."

"I would like a lot of support on like lesson planning and just like what I have to get through and the level at which I have to present that information . . . I think that's something I struggle with [teaching all the various class levels]. Not only is the content different, but the way that we grade and expectations are a lot different, so getting guidance on how to properly approach that."

I think "having a bit of a safety net around, that would be beneficial. If I was able to come with a formulated plan to my mentor and say, 'Hey, I have this idea for a lesson or a lab. What are your thoughts on that?' [To have someone] to really nitpick and offer suggestions for improvement, that would be most beneficial."

"I can reach out, and it [can] be like as equals. Understand that we are both teachers; we both have an education, [but] I just have a little bit less experience. And I want someone who I could bounce ideas off of. Someone who is also in the field, but not feel like I'm talking to a teacher or talking to a professor. [Someone] I can bounce ideas off and I will not be judged, not be evaluated."

I'd like "a sounding board almost for, not necessarily venting, but just talking with someone until I get all my feelings out. It's always something I need. It's typically how I process feelings about harder subjects or emotions."

Program Components

We designed the mentoring program with the research literature and feedback from our scholars in mind; however, we also had to be mindful of our budget constraints. Examples of the individual-, group-, and network-level program components and how these components

relate to professional practice dimensions are outlined in Table 1.

Table 1

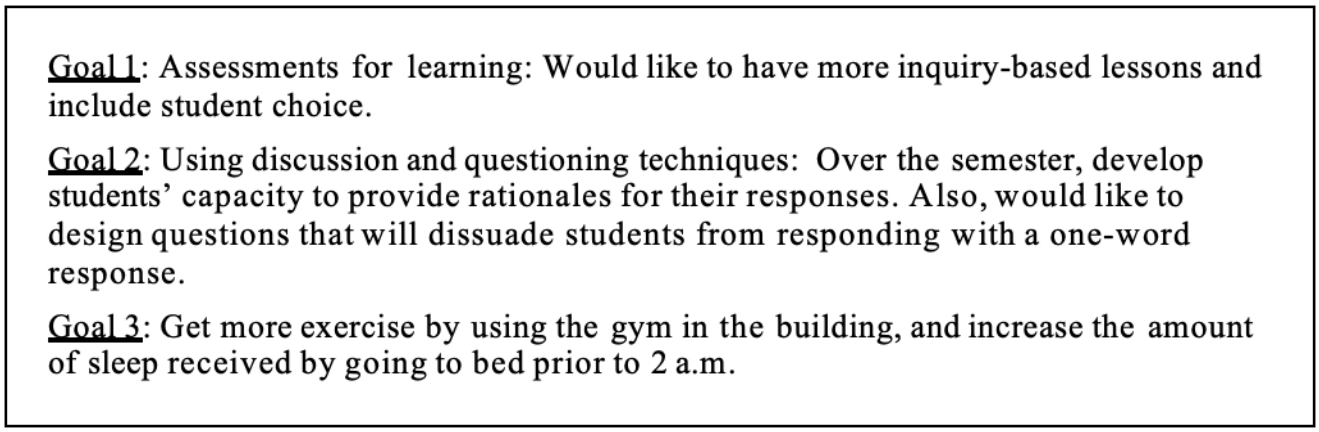
Mentoring Program Components as Related to Mentoring Approaches and Professional Practice Dimensions

Professional practice dimensions	Mentoring approaches		
	Individual mentoring	Group mentoring	Network mentoring
Personal: Perceptions of self within the profession, plus reflections and actions up on these	• Scholars set personal goals, keep reflection journals, meet for regular check-ins with mentors • Mentors take a coaching stance in their work	• Sessions focused on teacher wellness (e.g., stress relief and mindfulness activities, discussion of self-care, and creation of personal wellness plans) • Sessions focused on personal values/teaching philosophies and alignment of these with instructional practices	• Job search support, resume workshops, career fair • Mock interviews with partner school administrators • Meet with CPS Talent Office to learn about Opportunity School Initiative and teaching opportunities
Professional: Knowledge, skills, habits of mind	• Scholars set professional practice goals, keep reflection journals, meet for regular check-ins with mentors • Mentors take a coaching stance in their work	Sessions focused on: • sharing and peer problem-solving of instructional problems of practice • core instructional practices, such as evidence-based argumentation • developing, reflecting upon & revising restorative classroom management practices	• Scholars select PD workshops; sessions at conferences matched to professional needs/goals • Scholars participate in PLCs within their school with specific instructional foci (e.g., multilingual supports in STEM)
Social: Socialization into professional communities of practice	Mentors encourage scholars to take leadership roles within the group & within their larger networks	• Sessions prioritize scholar collaboration and communication • Sessions include time for informal conversation	• Scholars attend & present at Noyce Summit, NSTA, Golden Apple, & within school/district • Scholars access partnerships & networking opportunities
Moral/Political: Critical inquiries into teaching practices and disruption of systemic injustices	Mentors challenge scholars to take a critical perspective when looking at their practice and the consequences of that practice	Sessions focused on: • relationship building, classroom management practices for a cooperative, respectful climate • personal values/teaching philosophies & alignment of these with instructional practices	Scholars participate in Midwest Noyce Regional Conference focused on the theme of *Culturally Relevant Practices for Math & Science Teaching*

At the individual level, each scholar that is completing student teaching or in their first or second year of teaching is assigned an LUC-Noyce Scholar program mentor. The mentors, the second and third authors, are veteran high school science teachers and teacher educators, and they also have school leadership experience. Student teachers also have a student teaching supervisor from the university and a school-based cooperating teacher who provide additional individual mentoring. Most first- and second-year teachers are also assigned school- or district-based mentors who are not affiliated with the LUC-Noyce Scholars program but provide another form of individual mentoring. Scholars meet individually with their Noyce mentor at least twice per semester. During these meetings, time is allocated to providing scholars with a forum in which they can discuss any professional or personal successes as well as challenges and possible ways to address them. These meetings are also used to set and check in on goals throughout the academic year. Scholars are invited to set two professional goals and one personal goal (see Figure 2 for examples). This proved to be an unfamiliar practice for scholars. Therefore, in Year 2, we spent more time helping them not only to articulate goals but also to specify action plans to achieve those goals and identify what evidence would be used to determine the extent to which each goal was met. It should be noted that we had hoped to include classroom visits; however, these were restricted by most partner schools' COVID-19 policies.

Figure 2

Example Goal Statements



At the group level, cohorts come together monthly during the academic year for meetings focused on topics of interest that emerge from the individual mentoring meetings and other informal discussions. These alternate between taking place on campus or via Zoom, with dinner and time for socializing included in the in-person meetings. To illustrate what these sessions have consisted of, we describe two example meetings below.

A focus this past year was on the broad topic of classroom management because it frequently emerged as an area of concern in individual mentoring meetings. Rather than approaching this as sharing a generic set of strategies for maintaining discipline, we wanted candidates to reflect upon the relationship between what Woolfolk Hoy and Weinstein (2006) refer to as three interwoven aspects of teacher practice: classroom management (actions to create a productive, orderly learning environment), discipline (actions to elicit positive changes in students' behavior), and socialization (actions to help students fulfill their responsibilities). We also wanted scholars to consider how their beliefs about teaching, learning, and student development were related to their practice. After dinner and informal conversation, we led scholars through a This I Believe activity in which scholars were placed in small groups with a mix of content areas and years of experience. Together, they discussed a series of questions designed to get them thinking about their core values and beliefs and how well their classroom management plans aligned with these. They also discussed whether their core values and beliefs aligned with their respective school's culture, mission, values, and classroom expectations. Based on the conversations, scholars determined if they would make changes to their existing classroom management plans. After meeting in their small groups and creating summary posters, scholars came back and shared their findings with the larger group and further discussed how their management plans could be improved. At the end of the meeting, we distributed the book *Better than Carrots or Sticks* (Smith et al., 2015), which was recommended as a favorite resource by an alumna of the program. Then, scholars were asked to select sections of the book that resonated with them to share at the next meeting. Later in the semester, we checked back in on goals the teachers set around classroom management and how they had adapted their practices based on the text and their group discussions.

The last meeting of the semester focused on preparation for student teaching. Here, we wanted to draw upon the experience of the more senior scholars and encourage peer mentoring. After dinner and informal conversation, we presented a round-robin activity. Scholars were split into two groups: those who would soon be starting student teaching and those who were in their first or second year of teaching. The new student teachers circulated to talk to different pairs of first- and second-year teachers. A discussion question was projected on the screen, and the groups had about 15 minutes to discuss it before the student teachers rotated to a new table for a new discussion question. These included questions such as the following: If you could go back in time, what would you tell your pre-student-teaching self; what time management and work–life balance tips can you share; and what were your greatest successes and challenges in student teaching? Student teachers were all provided with a journal to take notes in during the activity, which they continued to use as a reflective journal throughout student teaching.

Finally, at the network level, scholars were invited and encouraged to participate in opportunities such as the mentoring network established through their local district, the Midwest Regional Noyce conference, conferences hosted by the National Science Teachers Association (NSTA) and the National Council of Teachers of Mathematics (NCTM), and the national NSF Noyce network. This helps them connect to partnerships and network with other professionals from a range of locations and at varying stages of their careers. It also allows them a space to share their knowledge, experience, and expertise with others. Nearly all the scholars who have completed student teaching were engaged in some sort of broader professional participation this past year. Eighty percent of those who completed the Year 2 end-of-year questionnaire indicated that they networked with their peers formally, via conferences, or informally, via other communication modes. To learn more about this engagement, as part of the first fall group meeting this year, we held a Summer Showcase in which scholars shared what they did over the summer, including participating in research experiences for teachers, developing new curricular materials and sharing them with others, leading workshops for fellow teachers, attending and presenting at conferences, or taking graduate courses to earn additional endorsements.

Lessons Learned

In this section, we report on three key lessons learned from interviews, surveys, written reflections, and observations over the past 2 years: (a) novice teachers serve as an important support for one another; (b) goal-setting can provide a structure for novice teachers' reflective practice; and (c) although virtual meetings offer conveniences, in-person gatherings are preferred when possible.

First, the program has effectively created a space for scholars to feel supported and, perhaps more importantly, to support one another. In their feedback over the past 2 years, scholars have consistently and unanimously shared that they enjoy the community building the program has facilitated. Before the launch of the mentoring program, scholars received

support from cooperating teachers and university supervisors, which is typical during student teaching. They knew the people in their own program, but they rarely had opportunities to interact with other cohorts of STEM teachers. With the mentoring program's monthly meetings, "I got to know other scholars better," shared one scholar in an interview. Comparing the sense of community to prior years before the mentoring program started, one scholar said: "I think that's largely in part to having more regular times to maybe meet with other scholars and meet with our coordinators and things like that to really touch base." Given the small size of our school of education, scholars reported that feeling they are part of a larger STEM education community has been beneficial. As one scholar shared,

> It has been phenomenal . . . seeing kind of the level of engagement this year compared to last year [before the mentoring program started] . . . . It has been phenomenal having the opportunity to speak with other science and math scholars about some of these more specific things in the classroom that are directly related to STEM. [It] has been tremendously impactful for me. (Scholar interview, annual evaluator report)

Overall, scholars reported feeling that the group meetings allowed for connecting with other scholars, sharing challenges and ideas, and learning from others' experiences.

Examples of the feedback collected from questionnaires and interviews include: "I found the connections and hearing other teachers' experiences useful," "I liked meeting together and sharing teaching strategies," and "it was really helpful for me to meet with other teachers in the same cohort who are in the same position as me." As one scholar summarized,

> We're all going through different experiences but similar struggles. I really liked talking in subject groups about problems of practice. It helps to brainstorm ideas about acknowledging an issue in the classroom, how to approach it, and how to recover from it. One solution isn't going to work for everyone. (Year 2 questionnaire response)

These reflections point to the value of conversations between peers at different stages of their careers and recognizing the support that novice teachers can provide to one another. When asked on a questionnaire about the year ahead, those going into their second year of teaching all offered what they hoped to be able to share with those who were just starting, which included sharing advice on the job search, connecting with students, and just being "a listening ear for anyone who is having a tough time getting themselves into a positive headspace." Not only have scholars enjoyed getting to learn from one another, but their questionnaire and interview responses also indicate they enjoy and look forward to being able to serve as a resource for one another.

Second, the practice of goal-setting emerged as an important component of helping scholars develop strategies for problem-solving and coping with challenges. Those who have graduated and are now in their own classrooms participate in some sort of goal-setting in

conjunction with their schools' teacher evaluation and school improvement programs, but it has proven beneficial to introduce a goal-setting practice during the initial teacher education program. We believe that this promotes goal-setting as an essential component of one's own professional learning and continued growth. This past year on the end-of-year questionnaire, 11 out of 12 respondents indicated that they found the structured goal-setting practice in individual mentoring meetings helpful and that it resulted in them being, as one scholar put it, "more reflective on my teaching." As another scholar elaborated, "I did not know what my goals could look like—it was very helpful to sit with someone and go through what personal and professional goals could potentially be." Another scholar expanded upon this sentiment, sharing that they appreciated the discipline that the goal-setting meetings imposed:

> Being able to, like, write those goals down at the beginning [of the year], like have them documented somewhere, was good because, obviously, everyone has goals for themselves. But you can't really track your progress if you don't know what you're trying to measure. (Scholar interview, annual evaluation report)

This statement reflects changes made between Years 1 and 2, when we provided more structure to the goal-setting conversations and reflection process.

Third, we have found that although virtual meetings work well for individual mentor meetings, in-person meetings are preferred for community meetings. When we were not able to meet in person during the program's first year due to the COVID-19 pandemic, all meetings occurred virtually. Initially, scholars were engaged in the programming and individual meetings, but we noticed that the level of engagement in virtual meetings began to wane over the course of the year as Zoom fatigue set in. As one scholar lamented in their reflection, "Zoom does not allow a lot of connection between people." In Year 2, the level of engagement, as indicated by meeting attendance, was more consistent across the year because we were able to meet in person on a more regular basis and include a light meal and informal conversation time as part of the meetings. Going forward, in response to our observations and scholar feedback, we plan to offer the option to join the meetings virtually only for scholars who are not local or for other extenuating circumstances.

Looking Forward

After analyzing scholar feedback, written reflections, and classroom observations, we plan on growing the mentoring program in several ways. First, we intend to support our teachers' development as we delve deeper into the content outlined in Table 1. In the immediate future, this includes examining the role that race, culture, and bias play in our teachers' classrooms through a book-club format. Second, we will place a renewed emphasis on reflective practices, and third, we will foster teacher leadership and participate more intentionally in the mentoring network at large. Although reflective practice and teacher leadership are part of our current program, we feel there is room for improvement. Many of our preservice teachers struggled to critically examine their practice and thus were not

always able to incorporate feedback into their teaching. By explicitly giving our teachers the tools to reflect, we intend to help bridge this gap. With regard to teacher leadership, we would ideally like to have all scholars make their work public through presentations or publications.

We discovered through our teachers' reflective writing that although mentees might have a commitment to social justice upon entering our program, they were uncertain about how to take a "multicultural, antiracist, pro-justice" stance in their mathematics and science classrooms (Watson et al., 2018). In reviewing their journals, we noticed that although they did reference the importance of teaching for equity, some scholars struggled to offer specific details on how they intend to do this. We realize that we need to give more attention to these areas and provide more critical transformative mentoring (Orland-Barak & Wang, 2021). Responding to scholars' book club suggestion, the group will select a book to read together that helps them to further their understanding of what social justice means in the context of mathematics and science teaching and learning, and which in turn helps them to develop more culturally responsive practices in their mathematics and science classrooms. This initiative will attend to the teachers' professional and personal needs using a multifaceted approach. First, the teachers will engage with these ideas individually as they read the text. They will then continue to make meaning in their communities of practice—namely, the other scholars and mentors. Finally, they can take these ideas and explore what they look like in their lived teaching experiences.

We believe that it would be beneficial for the two LUC-Noyce Scholars program mentors (coauthors on this article) to spend more time in novice teachers' classrooms now that pandemic restrictions have been lifted. In doing so, mentors can gain greater awareness of scholars' strengths and areas for growth and help them to engage in more systematic action research processes (Kincheloe, 2012) to make sense of their instructional practices and the consequences for student learning and engagement. Here, we plan to introduce Miller et al.'s (2019) "stoplight model" for reflection, which will direct the focus on student thinking and learning, and guide scholars through a deeper discussion of their practice.

Last, we intend to increase the quantity and quality of leadership opportunities for our scholars. In looking again at Table 1, we have begun to support our teachers in network-level mentoring by inviting and encouraging their participation in the professional community, and we intend to increase these opportunities. The first way we will do this is by having scholars lead more of the group meetings, including book club sessions, so that they begin to see themselves as leaders and realize that we do as well. We believe that the scholars are the ones best equipped to lead discussions and activities that relate to their classroom realities. There is considerable expertise within the group, and the best sessions have been when scholars share with one another. We will also increase the support we give to scholars as they assume leadership roles as presenters at conferences such as NSTA and NCTM. Attending and presenting in these settings will help the new teachers grow in their profession as well as become more active in their larger professional network. As we expand and

strengthen our program, we intend to measure the effectiveness of these changes by observing how our teachers' practice is directly impacted by tackling more moral and political content, engaging in more reflective practice, and increasing leadership opportunities. This impact can be measured through scholar feedback, written reflections, and classroom observations.

Broader Implications

The lessons that we learned in developing the LUC-Noyce Scholars mentorship program could apply to other teacher education programs and external induction programs. The framework for a multidimensional, multiformat approach to novice STEM teacher mentoring that we have presented in this article and summarized in Table 1 can inform the design, implementation, and study of other mentoring and induction programming. We have extended the work of others in this area, specifically of Bell and Gilbert (1994) and Akiri and Dori (2021), by recognizing the moral or political dimension of teacher learning and by providing examples of the ways that various teacher learning dimensions can be supported across different mentoring formats as part of teacher induction efforts. The NSF Noyce award afforded us the time and resources to develop the mentoring program, which may not be the case for other programs. However, programs without the funding for a mentoring program such as this could benefit from sharing the framework with their student teaching supervisors and program faculty. The matrix could serve as a reflection tool for programs to consider how they are supporting candidates' multidimensional learning and what additional formats their programming might take, particularly to connect scholars to one another and to larger alumni and community networks.

It is increasingly clear that teacher induction is a complex phenomenon and that no magic wand exists to ensure success. Rather, what Smith and Ingersoll (2004) refer to as "'packages'" of induction support (p. 704) are likely what is needed (Ronfeldt & McQueen, 2017). These might include professional learning communities and other student-teaching supports that are offered as part of a teacher education program, more formal mentoring programs offered to new teachers by schools and districts, and broader professional learning networks such as those recently described in this journal (see Mercier, 2022). Longitudinal studies into the impacts of these efforts are needed because the significance of various teacher induction supports remains an open question (Fuller & Pendola, 2019).

There have also been calls for advancing pedagogies of connection in teacher education (see Carter Andrews et al., 2021). The multidimensional, multiformat mentoring program we have developed serves as one example of how teacher education programs can nurture the development of social relationships amongst their teacher candidates, alumni, faculty, and partners. These sorts of relationships and collegial links have been found to be likely factors in teacher retention (Larkin et al., 2022) and deserve further attention and study.

We believe that investment in teachers' short- and long-term success is a worthy cause and one that schools of education must be a partner in. As we continue to develop our own program, we also look forward to seeing how the larger body research and practice around teacher induction and mentoring continues to develop.

References

Akiri, E., & Dori, Y. J. (2021) Professional growth of novice and experienced STEM teachers. *Journal of Science Education and Technology*, *31*(1), 129–142. https://doi.org/10.1007/s10956-021-09936-x

Apple, M. W. (2011). Global crises, social justice, and teacher education. *Journal of Teacher Education*, *62*(2), 222–234. https://doi.org/10.1177/0022487110385428

Aspfors, J., & Fransson, G. (2015). Research on mentor education for mentors of newly qualified teachers: A qualitative meta-synthesis. *Teaching and Teacher Education*, *48*, 75–86. https://doi.org/10.1016/j.tate.2015.02.004

Bell, B., & Gilbert, J. (1994). Teacher development as professional, personal, and social development. *Teaching and Teacher Education*, *10*(5), 483–497. https://doi.org/10.1016/0742-051X(94)90002-7

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

Bradbury, L. U. (2022). Recent trends in science education research on mentoring preservice teachers. In J. A. Luft & M. G. Jones (Eds.), *Handbook of research on science teacher education* (pp. 132–144). Routledge. https://doi.org/10.4324/9781003098478-12

Byars-Winston, A., & Dahlberg, M. L. (Eds.) (2019). *The science of effective mentorship in STEMM*. National Academies Press. https://doi.org/10.17226/25568

Carter Andrews, D. J., Richmond, G., & Marciano, J. E. (2021). The teacher support imperative: Teacher education and the pedagogy of connection. *Journal of Teacher Education*, *72*(3), 267–270. https://doi.org/10.1177/00224871211005950

Clandinin, D. J., & Connelly, F. M. (with Craig, C., Davies, A., He, M. F., Hogan, P., Huber, J., Whelan, K., & Young, R.). (1995). *Teachers' professional knowledge landscapes*. Teachers College Press.

Clarke, M. (2009). The Ethico-politics of teacher identity. *Educational Philosophy and Theory, 41*, 185–200.

Cochran-Smith, M. (2001). Learning to teach against the (new) grain. *Journal of Teacher Education*, *52*(1), 3–4. https://doi.org/10.1177/0022487101052001001

Cochran-Smith, M., & Lytle, S. L. (2009). *Inquiry as stance: Practitioner research for the next generation*. Teachers College Press.

European Commission. (2010). *Developing coherent and system-wide induction programmes for beginning teachers: A handbook for policymakers.* European Commission Staff Working Document. \ https://www.efvet.org/wp-content/uploads/2016/08/ind-pol-hbk-sec2010538-final.pdf

Fantilli, R. D., & McDougall, D. E. (2009). A study of novice teachers: Challenges and supports in the first years. *Teaching and Teacher Education*, *25*(6), 814–825. https://doi.org/10.1016/j.tate.2009.02.021

Feiman-Nemser, S. (2001). Helping novices learn to teach: Lessons from an exemplary support teacher. *Journal of Teacher Education*, *52*(1), 17–30. https://doi.org/10.1177/0022487101052001003

Freire, P. (1970). *Pedagogy of the oppressed* (M. Bergman Ramos, Trans.). Herder and Herder.

Fuller, E. J., & Pendola, A. (2019) *Teacher preparation and teacher retention: Examining the relationship for beginning STEM teachers* (2019 AAAS ARISE Commissioned Paper Series). American Association for the Advancement of Science.

García, E. & Weiss, E. (2019, March 26). The teacher shortage is real, large and growing, and worse than we thought. https://www.epi.org/publication/the-teacher-shortage-is-real-large-and-growing-and-worse-than-we-thought-the-first-report-in-the-perfect-storm-in-the-teacher-labor-market-series/

García, E. & Weiss, E. (2019, April 19). U.S. schools struggle to hire and retain teachers. Economic Policy Institute. https://www.epi.org/publication/u-s-schools-struggle-to-hire-and-retain-teachers-the-second-report-in-the-perfect-storm-in-the-teacher-labor-market-series/

George Dover, A. (2009). Teaching for social justice and K-12 student outcomes: A conceptual framework and research review. *Equity & Excellence in Education*, *42*(4), 506–524. https://doi.org/10.1080/10665680903196339

Gold, Y. (1996). Beginning teacher support: Attrition, mentoring, and induction. In J. P. Sikula, T. J. Buttery, & E. Guyton (Eds.), *Handbook of research on teacher education: A project of the Association of Teacher Educators* (2nd ed., pp. 548–594). Macmillan Library Reference.

Grusec, J. E., & Hastings, P. D. (Eds.). (2007). *Handbook of socialization: Theory and research*. Guilford Press.

Heredia, S. C., & Yu, J. H. (2017). A matter of choice: Opportunities for informal science institutions to support science teacher induction. *Journal of Science Teacher Education*, *28*(6), 549–565. https://doi.org/10.1080/1046560X.2017.1388085

Higher Education Act of 1965, Pub. L. No. 89–329 (1965).

Ingersoll, R. M., & Strong, M. (2011). The impact of induction and mentoring programs for beginning teachers: A critical review of the research. *Review of Educational Research*, *81*(2), 201–233. https://doi.org/10.3102/0034654311403323

Kelchtermans, G. (2009). Who I am in how I teach is the message: Self-understanding, vulnerability and reflection. *Teachers and Teaching: Theory and Practice*, *15*(2), 257–272. https://doi.org/10.1080/13540600902875332

Kelchtermans, G., & Deketelaere, A. (2016). The emotional dimension in becoming a teacher. In J. Loughran & M. L. Hamilton (Eds.), *International handbook of teacher education* (Vol. 2, pp. 429–461). Springer. https://doi.org/10.1007/978-981-10-0369-1_13

Kincheloe, J. L. (2012). *Teachers as researchers: Qualitative inquiry as a path to empowerment* (Classic ed.). Routledge. https://doi.org/10.4324/9780203801550

Ladson-Billings, G. (1998). Just what is critical race theory and what's it doing in a *nice* field like education? *International Journal of Qualitative Studies in Education*, *11*(1), 7–24. https://doi.org/10.1080/095183998236863

Larkin, D. B., Carletta, L., Patzelt, S. P., & Ahmed, K. (2022). Making sense of science teacher retention: Teacher embeddedness and its implications for new teacher support. In L. Manier, T. T. York, & B. Calinger (Eds.), *Research in practice: Preparing and retaining K–12 STEM teachers in high-need school districts* (pp. 275–319). American Association for the Advancement of Science. https://doi.org/10.1126/aaas.add8022

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355

Lefstein, A., Louie, N., Segal, A., & Becher, A. (2020). Taking stock of research on teacher collaborative discourse: Theory and method in a nascent field. *Teaching and Teacher Education*, *88*, Article 102954. https://doi.org/10.1016/j.tate.2019.102954

Lipton, L., & Wellman, B. (2007). How to talk so teachers listen. *Educational Leadership*, *65*(1), 30–34.

Louws, M. L., van Veen, K., Meirink, J. A., & van Driel, J. H. (2017). Teachers' professional learning goals in relation to teaching experience. *European Journal of Teacher Education*, *40*(4), 487–504. https://doi.org/10.1080/02619768.2017.1342241

Luft, J. A., Dubois, S. L., Nixon, R. S., & Campbell, B. K. (2015). Supporting newly hired teachers of science: Attaining professional teaching standards. *Studies in Science Education*, *51*(1), 1–48. https://doi.org/10.1080/03057267.2014.980559

Main, S. (2007). Toward a pedagogical framework: New Zealand induction. *Journal of In-Service Education*, *33*(2), 237–240. https://doi.org/10.1080/13674580701293093

McDonald, M., & Zeichner, K. M. (2009). Social justice teacher education. In W. Ayers, T. Quinn, & D. Stovall (Eds.), *Handbook of social justice in education* (pp. 595–610). Routledge.

Mercier, A. (2022). STEM Teacher Leader Collaborative: A responsive professional learning network with radical hope. *Innovations in Science Teacher Education*, *7*(3). https://innovations.theaste.org/stem-teacher-leader-collaborative-a-responsive-professional-learning-network-with-radical-hope/

Miller, M., Hanley, D., & Brobst, J. (2019). The impacts of a research-based model for mentoring elementary preservice teachers in science. *Journal of Science Teacher Education*, *30*(4), 357–378. https://doi.org/10.1080/1046560X.2019.1573127

Murrell, P. C., Jr., Diez, M. E., Feiman-Nemser, S., & Schussler, D. L. (Eds.). (2010). *Teaching as a moral practice: Defining, developing, and assessing professional dispositions in teacher education*. Harvard Education Press.

Nam, J., Seung, E., & Go, M. (2011). The effect of a collaborative mentoring program on beginning science teachers' inquiry-based teaching practice, *International Journal of Science Education*, *35*(5), 815–836. https://doi.org/10.1080/09500693.2011.584329

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press. https://doi.org/10.17226/13165

Navy, S. L., Luft, J. A., & Msimanga, A. (2022). The learning opportunities of newly hired teachers of science. In J. A. Luft & M. G. Jones. (Eds.), *Handbook of research on science teacher education* (pp. 245–256). Routledge. https://doi.org/10.4324/9781003098478-22

Navy, S. L., Maeng, J. L., & Bell, R. L. (2019). Learning from a state professional development conference for science teachers: Beginning secondary science teachers' experiences. *Journal of Science Teacher Education*, *30*(4), 409–428. https://doi.org/10.1080/1046560X.2019.1584512

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press. https://doi.org/10.17226/18290

Nieto, S. (2006). *Teaching as political work: Learning from courageous and caring teachers* (Occasional Paper Series). Child Development Institute, Sarah Lawrence College. https://www.sarahlawrence.edu/media/cdi/pdf/Occasional%20Papers/CDI_Occasional_Paper_2006_Nieto.pdf

Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research*, *81*(3), 376–407. https://doi.org/10.3102/0034654311413609

Orland-Barak, L., & Wang, J. (2021). Teacher mentoring in service of preservice teachers' learning to teach: Conceptual bases, characteristics, and challenges for teacher education reform. *Journal of Teacher Education*, *72*(1), 86–99. https://doi.org/10.1177/0022487119894230

Parkhouse, H., Bennett, E., Pandey, T., Lee, K., & Wilson, J. J. (2022). Culturally relevant education as a professional responsibility. *Educational Researcher*, *51*(7), 474–480. https://doi.org/10.3102/0013189X221092390

Philip, T. M. (2013). Experience as college student activists: A strength and liability for prospective teachers of color in urban schools. *Urban Education*, *48*(1), 44–68. https://doi.org/10.1177/0042085912461509

Ronfeldt, M., & McQueen, K. (2017). Does new teacher induction really improve retention? *Journal of Teacher Education*, *68*(4), 394–410. https://doi.org/10.1177/0022487117702583

Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. Jossey-Bass.

Schussler, D., Feiman-Nemser, S., Diez, M. E., & Murrell, P. (2012). Swimming in deep waters [A response to "A review of *Teaching as a Moral Practice*"]. *Democracy & Education*, *20*(2), Article 11. https://democracyeducationjournal.org/home/vol20/iss2/11

Shoval, E., Erlich, I., & Fejgin, N. (2010). Mapping and interpreting novice physical education teachers' self-perceptions of strengths and difficulties. *Physical Education and Sport Pedagogy*, *15*(1), 85–101. https://doi.org/10.1080/17408980902731350

Sinha, S., & Hanuscin, D. L. (2017). Development of teacher leadership identity: A multiple case study. *Teaching and Teacher Education*, *63*, 356–371. https://doi.org/10.1016/j.tate.2017.01.004

Smith, D., Fisher, D., & Frey, N. (2015). *Better than carrots or sticks: Restorative practices for positive classroom management*. ASCD.

Smith, T. M., & Ingersoll, R. M. (2004). What are the effects of induction and mentoring on beginning teacher turnover? *American Educational Research Journal*, *41*(3), 681–714. https://doi.org/10.3102/00028312041003681

Tal, M., Herscovitz, O., & Dori, Y. J. (2021). Assessing teachers' knowledge: Incorporating context-based learning in chemistry. *Chemistry Education Research and Practice*, *22*(4), 1003–1019. https://doi.org/10.1039/D0RP00359J

Thomas, L., Tuytens, M., Moolenaar, N., Devos, G., Kelchtermans, G., & Vanderlinde, R. (2019). Teachers' first year in the profession: The power of high-quality support. *Teachers and Teaching*, *25*(2), 160–188. https://doi.org/10.1080/13540602.2018.1562440

Vanassche, E., & Kelchtermans, G. (2014). Teacher educators' professionalism in practice: Positioning theory and personal interpretative framework. *Teaching and Teacher Education*, *44*, 117–127. https://doi.org/10.1016/j.tate.2014.08.006

Veenman, S. (1984). Perceived problems of beginning teachers. *Review of Educational Research*, *54*(2), 143–178. https://doi.org/10.3102/00346543054002143

Watson, D., Hagopian, J., & Au, W. (Eds.). (2018). Teaching for black lives. Rethinking Schools.

Webster-Wright, A. (2009). Reframing professional development through understanding authentic professional learning. *Review of Educational Research*, *79*(2), 702–739. https://doi.org/10.3102/0034654308330970

Wei, R. C., Darling-Hammond, L., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the U.S. and abroad*. National Staff Development Council. https://edpolicy.stanford.edu/sites/default/files/publications/professional-learning-learning-profession-status-report-teacher-development-us-and-abroad.pdf

Wilson, S., Schweingruber, H., & Nielsen, N. (Eds.). (2015). *Science Teachers' Learning: Enhancing opportunities, creating supportive contexts*. National Academies Press. https://doi.org/10.17226/21836

Woolfolk Hoy, A., & Weinstein, C. S. (2006). Student and teacher perspectives on classroom management. In C. M. Evertson & C. S. Weinstein (Eds.), *Handbook of classroom management: Research, practice, and contemporary issues* (pp. 181–219). Erlbaum.