

Mentoring Student Teachers for Teaching in Culturally Diverse Schools to Promote Inclusive Science Teaching

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Abstract

Educating highly qualified science teachers requires careful collaboration among teacher preparation programs, college or university supervisors, school partners, and especially effective cooperating secondary science teachers. Mentoring student teachers is a complex yet crucial part of the teacher preparation program. In this case study of a science teacher preparation program at a large four-year Great Plains university, we envisioned key aspects of strong mentoring of student teachers in science by cross-referencing a model of intersectional equity developed by the Advancing Coherent and Equitable Systems of Science Education project, the 2020 NSTA science teacher preparation standards, and Campbell and Brummett's (2007) teacher coaching model. These documents have informed our teacher preparation program and interactions with our preservice teachers. One such decision has been to couple coursework promoting instructional strategies to support diverse learners with the strategic clinical placement of over 75% of our preservice teachers in high-need schools. These choices have yielded positive results. When we reviewed the 10-year employment history of our secondary science teacher alumni post-pandemic, 70-75% of undergraduate and master's program alumni were still employed as science teachers. Approximately 70% of those teachers have been employed in high-need schools. In this article, we provide specific guidelines and a tool for effective mentorship of preservice science teachers. We hope that science teacher educator teams find this tool useful, clear, and practical to share with mentor teachers to empower them to implement these strategies with their student teachers to accelerate their journey toward inclusive science teaching.

Introduction

As science teacher educators, we hope that our efforts to prepare new secondary-level science teachers positively affect their uptake of ambitious and inclusive science teaching. But how do we know our programmatic goals will translate into new science teachers' practices? What types of clinical experience mentoring activities support grades 6-12 students' equitable learning opportunities, and how can we assist in-service mentor teachers working with our student teachers? In this article, we offer a review of selected elements from a self-study of our teacher preparation program, including some findings from a larger

longitudinal study of our science teacher alumni. As a resource, we also developed a new tool for conducting one's own program inventory and for use in professional development with partnering cooperating teacher mentors and supervisors.

Rationale

In the United States (U.S.), science teachers have often been in short supply. The COVID-19 pandemic has exacerbated this situation, especially with many early retirements (Gecker, 2021; Walker, 2021). According to a 2022 survey, 20% of teacher respondents reported that they were “very likely” to leave the profession, some to pursue other careers (Heubeck, 2023). Over the last decade, nationally, there have also been fewer newly certified teachers available to hire because of declines in teacher education program enrollment (Partelow, 2019). Thus, it is more important than ever to provide new science teachers with critical learning experiences and strong mentorship before starting their first teaching position. Longer, supervised teacher preparation internships have been linked to higher retention rates of new teachers (Carver-Thomas & Darling-Hammond, 2017). However, due to the higher retirement rates, there are fewer master science teachers and science teacher leaders to mentor preservice teachers (Ebby, 2023). Therefore, it follows that teacher educators must not only focus on the learning needs of their preservice teachers but also act to collaboratively develop the strengths and mentorship capabilities of the less experienced cooperating teachers who mentor them daily.

Larkin et al. (2022) found that while 65% of New Jersey first-year science teachers remain in the profession after five years, only 38% stay with the same employer, with higher turnover rates occurring in communities with higher poverty. This trend parallels Carver-Thomas and Darling-Hammond's (2017) finding that Title I schools have a 70% higher national turnover rate than non-Title I schools. It also speaks to the long-standing mismatch between teacher and student demographics. The teacher workforce is overwhelmingly white, middle class, and female, but it teaches an increasingly racially and ethnically diverse student population. Additionally, the national priority for equitable science education has been an elusive goal but one that has gained more attention and recognition, especially with the greater involvement, voices, and valuable insights shared by scholars of color (e.g., Moore Mensah & Bianchini, 2023; Buxton & Lee, 2023; Ogunnai, 2023). Guided by these scholars' work, science teacher educators and program coordinators should continue to integrate culturally responsive-focused activities to educate future teachers who can enact inclusive science teaching.

In 2020, the *National Science Teaching Association* (NSTA) updated its science teacher preparation standards. Well-prepared science teachers should have strong content knowledge and pedagogical skills to “plan learning units of study and equitable, culturally responsive opportunities for all students,” in addition to a rigorous understanding of cognitive learning theory and principles, classroom learning environments, safety, and have cultivated a positive attitude toward ongoing professional development (NSTA, 2020, p. 2). Problematically, “teachers who lack comprehensive preparation are two to three times more

likely to leave teaching in their early years than those who are fully prepared” (Carver-Thomas & Darling-Hammond, 2017, p. 14). Pragmatically, educating highly qualified, equity-minded science teachers requires careful collaboration among teacher preparation program leaders, university supervisors, and school partners, especially related to the daily mentoring by experienced cooperating science teachers in classrooms.

We have employed what we have learned from a long-term self-study of our teacher preparation program (TPP) and experiences with our preservice science teachers (PSTs) in the field to inform our teacher education foci and practices. We have adjusted our TPP curriculum using our observations to establish which instructional practices have been both easier and more challenging for new science teachers to integrate into their teaching. With a specific equity focus on multilingual learners, we specifically investigated the relationship of course in teaching ELLs in the content area and those PSTs who had and had not completed one. To show the long-term positive effects of our TPP we also share the pre- and pandemic/post-pandemic retention rates of our teacher alumni from undergraduate- and masters-level programs. Finally, for others’ TPPs’ self-assessment and innovation, we offer a new mentoring tool with recommendations for strengthening PSTs’ equitable and inclusive teaching practices. The tool includes research-into-practice action items for program coordinators, teacher educator teams, and cooperating teachers.

Research Questions

As this was a TPP improvement-oriented case study that investigated programmatic changes for effective science teacher preparation, we crafted the following research questions:

1. In what ways has our TPP aligned with the NSTA science teacher preparation standards and ACESSE model of equitable science learning?
2. How have programmatic and clinical placement changes over time affected science teachers’ inclusive instructional practices?

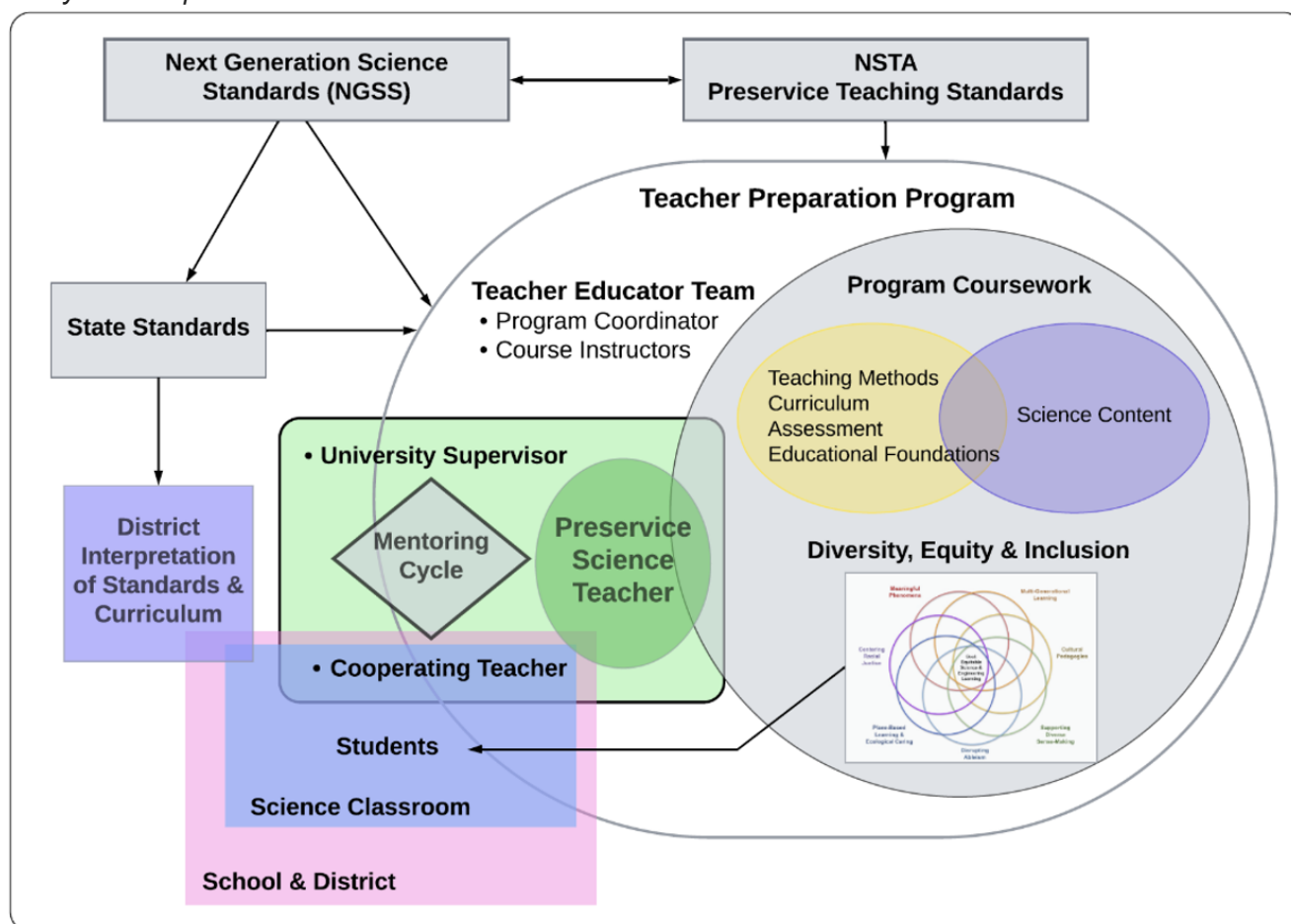
To situate our self-study in the context of teacher preparation, we developed a conceptual framework described in the next section with an associated literature review.

Conceptual Framework and Literature Review

Study’s Conceptual Framework

Our conceptual framework (Figure 1) centrally attends to the critical mentoring cycle and relationships among the PST, CT, and clinical supervisor. It also shows the mentoring cycle situated within programmatic design factors and state and national documents that influence TPP design. Science TPPs are complex, consisting of a team of teacher educators, including the program coordinator, a wide variety of course instructors (i.e., science, science teaching

methods, curriculum design, assessment, and other educational equity courses), and supervisors. A program may be organized and composed of a large or smaller group of individuals who must fulfill multiple roles. As a team, we have served in all of these teacher educator roles. Regardless of how many roles a teacher educator may be responsible for, the cycle of mentoring PSTs is strongly relational-based, and the immediate goal is to balance critical feedback and positive empowerment in these apprenticeship placements.

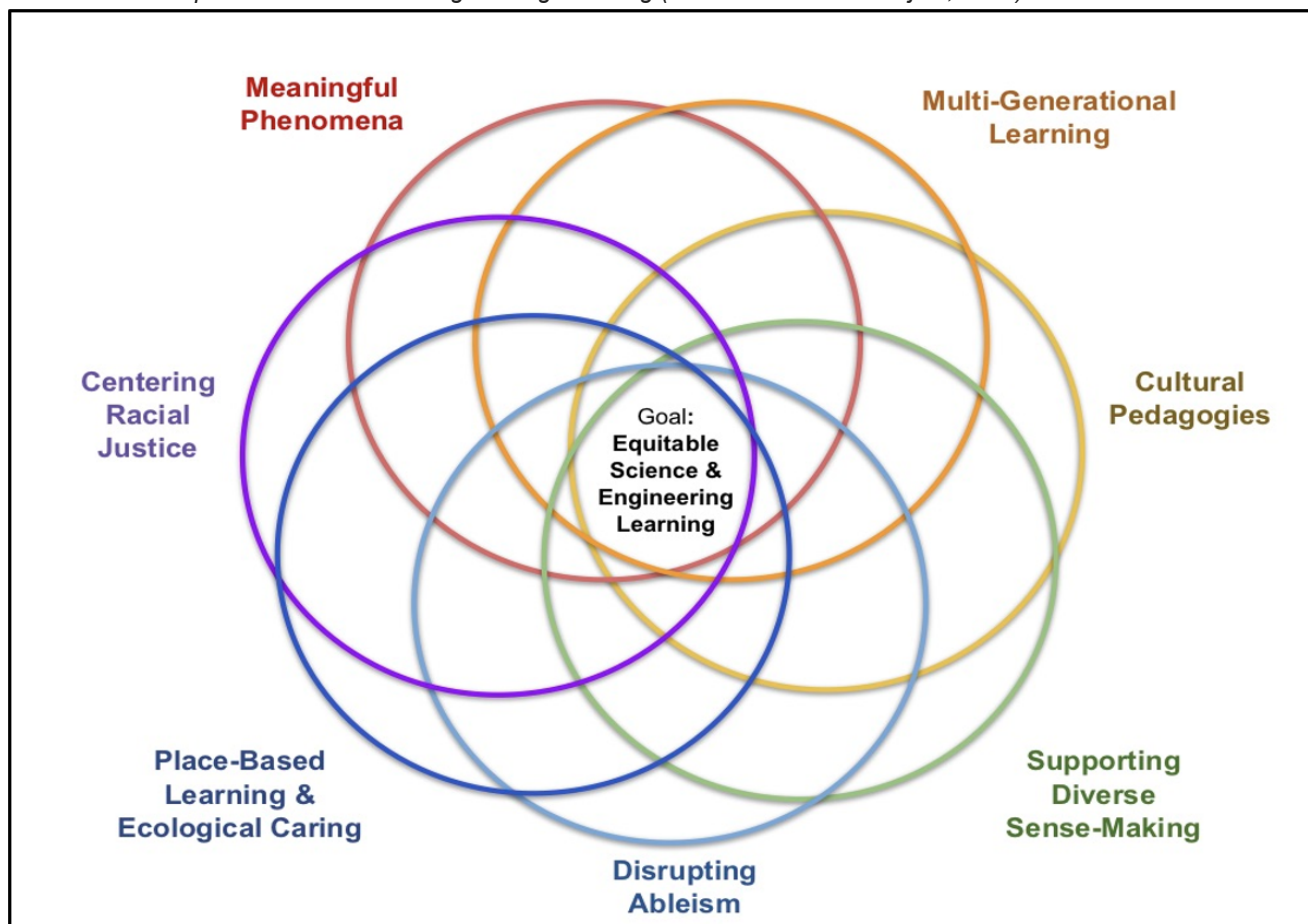
Figure 1*Study's Conceptual Framework*

A key programmatic component of formal teacher education programs is the clinical placements of PSTs in grades 7-12 science classrooms with an experienced CT. Supervisors act as liaisons between the field placement and TPP; this individual is, or has been, a science teacher and may also be a TPP course instructor. At the same time, the clinical placement in the CT's classroom is also influenced by school and district priorities, as well as students and their families.

In terms of external factors, both TPP and clinical placements are informed by national and state science education standards, which in the U.S. are typically the *Next Generation Science Standards* (NGSS). The field placement and CT's mentorship are also influenced by how that school and district interpret their state science education standards. While the overall TPP design should be in alignment with the NSTA preservice teaching standards (2020), specific coursework, like a teaching methods course, should also be driven by a vision of scientific literacy and current science education standards. In our program's case, we also have prioritized culturally relevant pedagogy, equitable learning opportunities, and inclusion of all students. Our focus on equity is in alignment with the *Advancing Coherent and Equitable Systems of Science Education* (ACESSE) project (2020), which is an NSF grant-funded collaboration between the Council of State Science Supervisors, the University of Washington, and the University of Colorado-Boulder (Figure 2). Its goal is to advance equity in science instruction and identify seven facets of equitable science learning. We used these facets to ground our self-study and make recommendations for other science TPPs to consider how they frame their mentoring of preservice teachers for equitable science learning.

Figure 2

Framework for Equitable Science and Engineering Learning (from the ACESSE Project, 2020)



Literature Review

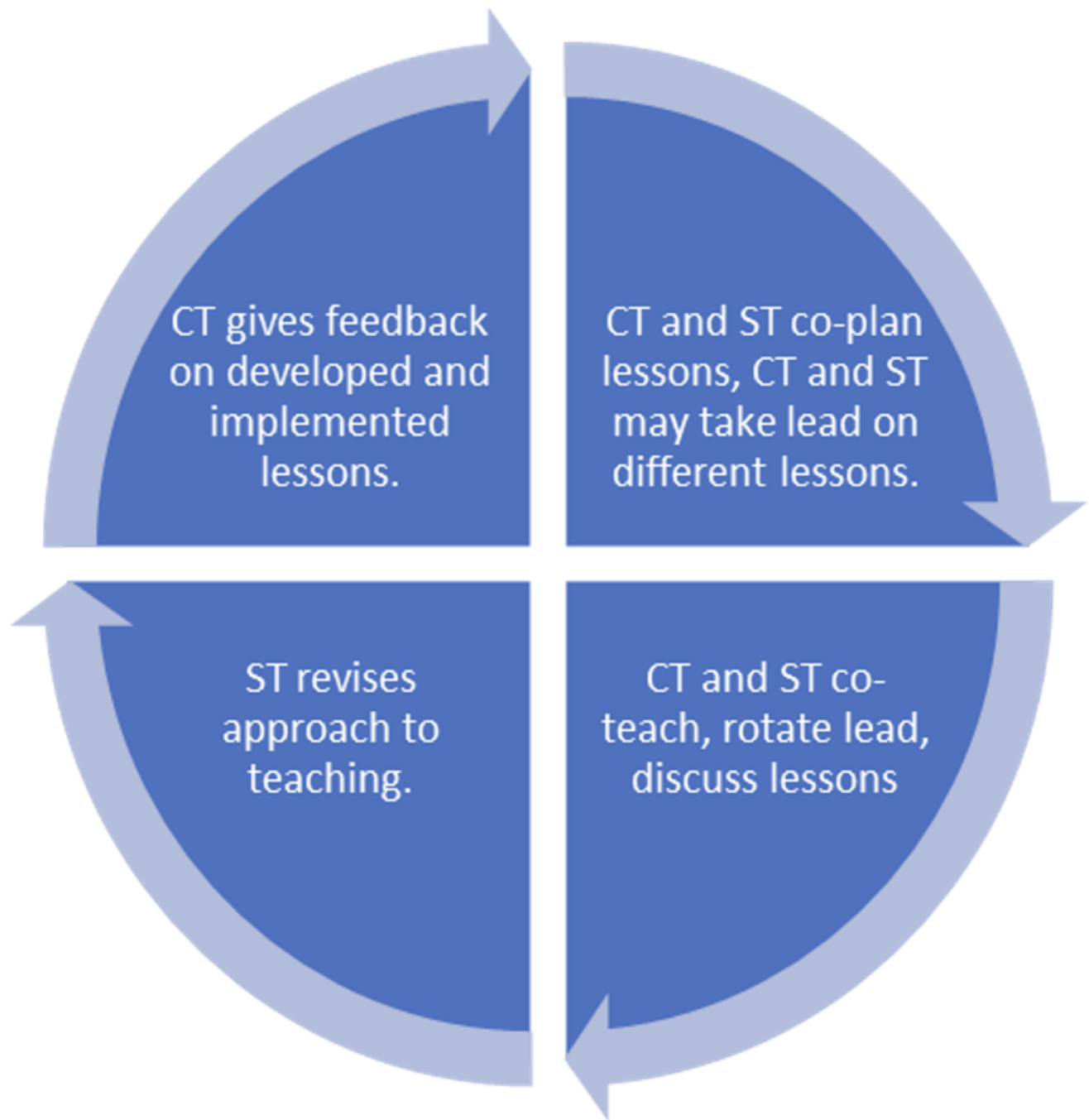
We reviewed research in three categories in line with our conceptual framework: (a) a constructivist approach to the mentoring cycle; (b) programmatic factors that informed our design of our TPP; and (c) national science education teacher preparation documents and leading frameworks for equitable and inclusive science teaching and learning.

Mentoring Relationships: Mentoring Cycle and Mentor and Mentee Roles

Campbell and Brummett (2007) provide a constructivist approach to mentoring preservice music teachers that we adapted for a science TPP (Figure 3). In this approach, PSTs are mentored through four stages: (a) *Beginning teaching*, (b) *Supervised teaching*, (c) *From teaching to learning*, and (d) *Autonomous teaching*. These stages correspond to the mentoring roles of *Model*, *Coach*, *Critical Friend*, and *Co-inquirer* (Campbell & Brummett, 2007). Over the course of PSTs' field experiences, their mentors' roles adjust as PSTs endeavor to build reflective teaching dispositions. At first, PSTs may focus more on classroom routines; however, by the end, they should develop their teaching to include best practices to meet learners' diverse needs. The mentoring cycle is an iterative process in which CTs model a strategy, and then the PST practices it with students. As the PST gains confidence with modeled instructional strategies, they should be encouraged to try other approaches as their CT provides ongoing coaching.

Figure 3

Coaching and Critical Friend Cycle (Adapted from Campbell and Brummett, 2007)



Throughout this process, the CT supports the PST as they translate what they have learned in their courses into practice. CTs need to break down daily instructional and classroom management tasks that they have likely internalized in their own teaching practice for PSTs, such as organizing students into cooperative groups and evaluating which topics or scientific concepts need to be retaught if misconceptions persist (Stanulius et al., 2019).

Programmatic Design Factors

Science TPPs contain various components, such as pedagogy courses, the number and type of science credits required, and field placements in secondary science classrooms. Early on, Shulman (1987) emphasized the importance of teachers having strong subject matter knowledge (SMK). Science teachers need deep content knowledge in the area in which they are teaching so as not to pass misconceptions to their students (Sadler & Sonnet, 2016). For example, educational researchers Lewis et al. (2021) further defined this

when they found that, on average, chemistry teachers needed 30 credit hours of college-level chemistry with a 3.2 average GPA to pass a high school test of common chemistry misconceptions. This elaborates upon similar research findings by Kind (2014) and Nixon (2016), who also argued that science teachers need strong content knowledge.

State and National Guiding Documents

NGSS and Equitable Science Learning. Along with the *Next Generation Science Standards* (NGSS) (National Research Council [NRC], 2013), there has been more focus on diversity, equity, and inclusion in STEM education. A key aspect of mentoring new science teachers is to foster (inter)cultural competence to better support underrepresented students and multilingual learners, in addition to the foundational work of transforming subject matter knowledge into specialized knowledge for teaching (e.g., developing lessons to dispel common misconceptions). Planning and implementing culturally responsive curricula is challenging, even for experienced teachers who have already mastered the complexities of inquiry-based science instruction (Bybee, 2009), never mind PSTs who are often more concerned with learning how to effectively manage a classroom, enact school policies, district- and school-level administrator directives, and communicate with students' parents/guardians (Meister & Melnick, 2003).

Much essential scholarship has promoted culturally responsive teaching (e.g., Freire, 2018; Buxton & Lee, 2023). Ladson-Billings (2014) revisited this concept that she had advanced several decades before and recommended a shift from *culturally responsive* to *culturally sustaining pedagogy*, which “allows for a fluid understanding of culture, and a teaching practice that explicitly engages questions of equity and justice” (p. 74). These educational priorities, along with many other scholars' works (*Sidebar A: Suggested Readings*), have encouraged greater inclusiveness in science education. In our study, we asked ourselves, as teacher educators, clinical supervisors, and CTs, “In what ways can we work more closely together to support preservice teachers to meet the goals and vision of inclusive science education?”

Science Teacher Preparation, Standards, and Certification. While there are the NSTA (2020) science teacher preparation standards, there is no national science teacher preparation curriculum. Therefore, the NSTA standards alone do not ensure that all teacher certification programs are standards-based or similarly aligned. Additionally, there is a lack of common evaluation methods at program and state levels to determine if student teachers have met these standards. Due to the local nature of U.S. education, each state has its certification process for teachers, including minimum requirements of college credits in each subject area and a licensing exam. At the time of this study, PSTs were required to complete the Praxis Core and subject-specific Praxis II exams. Multiple states use Praxis tests but also set and use different cutoff scores, and other states have developed their own tests (e.g., Massachusetts and New York), which is yet another inconsistency across teacher preparation and assessment.

Methodology: Research Approach and Questions

We used a single case study research approach to engage in a self-study of our TPP (Yin, 2017). While there were some meaningful differences between the undergraduate and graduate levels of science teacher preparation (Table 1; Lewis et al., 2020), in our definition of the case, we elected to treat the associated clinical work as a single case (Creswell & Poth, 2018). Our rationale is that we have the same goals for all our future science teachers (i.e., to be successful as inclusive and well-qualified content area practitioners), and they were all required to have at least 650 hours of clinical practicum and student teaching prior to certification. Thus, the research questions that we addressed in this study are: (1) *In what ways has our TPP aligned with the NSTA science teacher preparation standards and ACESSE model of equitable science learning?* and (2) *How have programmatic and clinical placement changes over time affected science teachers' inclusive instructional practices?* In the following sections, we describe data sources, collection, and analytic methods. We then use the research questions to guide our discussion of results and share the tool we developed to support CTs in their mentor role for inclusive teaching practices.

Table 1

Comparison of Teacher Preparation Program Paths

Program	Undergraduate	MA (NSF Noyce-supported)
Science Coursework	<i>Prior and concurrent to acceptance:</i> Sufficient science coursework for state's secondary science teaching endorsement (24 credit hours in one area with another 12 hours among other 3 areas).	<i>Prior to Acceptance:</i> Undergraduate major in one area of science (36+ credit hours; and 12+ ancillary hours in other areas); some MA students have graduate-level science coursework or advanced degree in science.
Education Coursework	<i>Pre-professional Education Coursework:</i> Foundations of Education; Adolescent Development & Practicum (6 cr.)	<i>Required MA Coursework:</i> Intro to Educational Research; Curriculum Theory; Teacher Action Research Project (9 cr.) <i>Optional MA Coursework (3 cr.):</i> Reading in the Content Area; History and Nature of Science
Common Coursework (18 credits)	Accommodating Exceptional Learners; Adolescent Development / Human Cognition; Science Teaching Methods and Science Curriculum & Assessment (each with a practicum experience); Multicultural Education / Pluralistic Society; Teaching ELLs in the Content Area	
Resulting Degree (+ Science Teaching Certification)	BA Education (Major: Secondary Science)	MA Education

Context and Clinical Placement Demographic Data

The TPP's university is situated in a largely suburban city of nearly 300,000 people, and its public school district is the second largest in the state. Most of our PSTs are mentored by middle and high school teachers in this district for their practicum placements. For their student teaching placements, most of our PSTs are hosted in the state's two largest school districts; however, some PSTs prefer a rural setting, and a few go out of state. Thus, we offer a comparison of student demographics in these two cities with state and national numbers (Table 2). We had clinical placement records for 216 PSTs, who were 52% female and 95% white, from our undergraduate and MA-level cohorts between 2012 and 2024. Of these, the MA-level PSTs ($n = 100$) with at least an undergraduate science degree, 57% were female and 92% white.

Table 2
Comparison of Student Demographic Data (2021-2022 School Year)

	Second Largest School District	Largest School District	State	National
N	41,747	51,626	327,055	47,305,808
ELL (%)	6.48	20.52	7.76	10.3
<u>SpEd</u> (%)	17.16	18.12	15.92	15.0
FRL (%)	42.73	68.69	41.31	48.6
BIPOC (%)	37.11	76.60	35.87	54.66

Most CTs were selected to mentor our preservice science teachers because of their willingness to serve as a CT, and there was a match to their main content area expertise and teaching assignment. This information was available from an annual survey administered by our main school district partner. Other CTs in other school districts were usually nominated because they were teacher alumni of our institution and were then contacted by our office of field placements to see if they were willing and available to mentor.

Methods

We used national documents (i.e., the NSTA preservice teacher education standards and the ACESSE project) and our own PST placement records, observations, interviews, and experiences to evaluate our own program and make connections to mentoring student teachers as they learn to teach science. Details of these data sources and analyses follow.

Data Collection and Analysis

In this case study, we used multiple TPP data sources, including (a) science methods instructors and syllabi, (b) our records of practicum and student teaching placements (i.e., the specific districts, schools, CTs, and university supervisors involved), and (c) selected field notes from classroom observations and feedback to PSTs by university supervisors throughout the TPP program (Miles et al., 2020). Field notes were taken during practicum, and student teaching observations were made by their university supervisor for all PSTs. Our post-TPP data included selected related findings from our four-year longitudinal study of TPP undergraduate- and MA-level program alumni, that included over 800 classroom observations (Lewis et al., 2020; Benzoni & Lewis, 2024). These observations of science teacher alumni's lessons were also coded using a classroom observation instrument (Baker et al., 2009) called the *Discourse in Inquiry Science Classrooms* (DiISC).

Analytic methods included tallying practicum placements and employment in high-need schools. Retention rates were calculated from TPP alumni teachers' employment history. To calculate retention rates at a range of school districts, we used data from our annual teacher employment surveys to construct their employment history and accessed student demographic information and free and reduced lunch (FRL) rates from public state Department of Education websites. Quantitative data (e.g., preservice and alumni employment data) were analyzed using descriptive statistics. Additional statistical tests (i.e., MANCOVA) were used with the classroom observation coded data to analyze the program level and teaching experience effects on alumni's use of academic language development strategies to support multilingual learners.

We used an interpretive phenomenological approach (Beck, 2021) to analyze our qualitative data, which included a review of ongoing program feedback and revision memos regarding historical changes made to the program, and field notes for examples of mentoring in clinical placements. Alumni teachers who were interviewed for annual grant reports and a public report regarding the effectiveness of our teacher education program were also included in our review and content analysis of qualitative feedback statements.

Results and Discussion

The first question we posed was, "*In what ways has our TPP aligned with the NSTA science teacher preparation standards and ACESSE model of equitable science learning?*" Our participants were students in a secondary science TPP at a large 4-year, research-intensive Great Plains university in its college of education.

Teacher Preparation Program Alignment with NSTA Standards

As we evaluated our program, we triangulated several data sources and generated a list of 10 core science TPP foci. We then aligned the 2020 NSTA teacher preparation standards along with common mentoring activities we had observed in CTs' classrooms. In Table 3, we elaborate on how science-specific mentorship roles are aligned with the preservice teacher preparation standards. Topics range from science content and practices to working with students with special needs and talents, assessment practices, and reflective teaching practices.

Table 3

NSTA-informed Program Foci and Mentoring Cycle with Preservice Science Teachers

Teacher Education Program Focus	Mentoring Cycle with Preservice Science Teacher (CT = cooperating teacher, US = university supervisor)	NSTA Preservice Teacher Preparation (PTP) Standard(s)
1. DCIs, subject matter knowledge	Accessing and discussing (common) student scientific misconceptions (CT = daily; US = periodically).	Developing one's content knowledge and how to guide instruction. (PTP Standard 1 & 2)
2. Methods and strategies for instruction: e.g., Inquiry-based learning, 5E, phenomenon-based lessons, NGSS storylines	Modeling effective instruction and then providing opportunities for ST to practice with support and providing constructive feedback (CT = daily; US = periodically).	Learning how to provide students with active learning opportunities. (PTP Standard 2)
3. Making curriculum relevant	CT encourages ST to stay current by using news articles and other media to find the engagement piece for lesson.	Student engagement (PTP Standard 2)
4. Culturally relevant pedagogy and culturally responsive teaching	Learning about local community resources ("funds of knowledge"), topics, events, etc., to connect the science curriculum. Using diverse scientists and engineers as examples.	Inclusive equity stance to support diverse students in developing a science identity. (PTP Standard 3)
5. ELLs/MLLs teaching strategies	Demonstrate multimodal learning within the curriculum and how to access students' funds of knowledge. Provide resources and time for ST to talk with ELL teachers and get to know students.	Supporting diverse learners' learning needs (PTP Standard 3)
6. Making science accessible to all: Special needs and talents	Have the student teacher attend IEP and PLC meetings, set meetings with ELL and SPED teachers and specialists for specific students, and brainstorm strategies for gifted students.	Cultivating a professional disposition and how to effectively work as a team in support of students. Being able to differentiate learning/lesson plans and activities. (PTP Standards 2, 3, 5)
7. Formative and summative assessment	Provide assessment examples and help ST create their own assessments.	Measurement of effectiveness of instruction. (PTP Standard 5)
8. Science materials, equipment, and technology resources	Modeling best practices for hazardous chemicals and specialized equipment use. Orientation to the actual technology platforms and resources that your school uses to help them get familiar with these. Provide trouble-shooting scenarios in advance of actual teaching.	Laboratory and student safety, effective lesson presentation, and student engagement. (PTP Standard 4)
9. Reflective practice, e.g., Problem-solving instructional challenges/"failures"	Listening to preservice teachers. How did the PST think the class went? What would they do differently? Student teachers reflecting on their teaching and/or journaling about their lessons.	To develop a regular practice of teaching self-analysis and change. (PTP Standard 6a)
10. Maintain professional development	Attend team/departmental meetings, get involved with school activities with CT. Attending science teacher conferences, etc. to improve science content and discipline-specific pedagogy.	Developing a professional disposition as a teacher. (PTP Standard 6a, 6b, 6c)

All science content coursework taken by undergraduate students across various majors was provided by science faculty teaching in discipline-specific content departments in our College of Arts and Sciences and/or College of Agricultural Sciences and Natural Resources. The TPP science teaching-specific coursework had long been aligned with the six NSTA science teacher preparation standards (Lewis et al., 2020) to focus on transforming science SMK for teaching, often referred to as specialized knowledge. For example, to address NSTA Standard 2, our course assignments require that PSTs prepare two lesson study projects that incorporate inquiry-based curricular plans for lessons, units, and year-long plans for science courses. All curricular materials that these PSTs designed were required to include instructional strategies for accessing multilingual students' funds of knowledge and attending to neurodiverse students, as well as other students with special learning needs. Their lesson study projects required planning, teaching, and self-evaluation using formative assessment protocols, as presented in *Understanding by Design* (Wiggins & McTighe, 2011). These assessment practices are in alignment with NSTA Standard 5. Most PSTs' practicum and student teacher placements were located within high-need schools, and they also took educational foundations coursework that focused on strategies for supporting multilingual learners and using culturally responsive pedagogy, which aligns with NSTA Standard 3.

The PSTs' assignments in both of their science teaching courses prior to student teaching had associated practicum placement components, specifically their lesson study assignments. These activities were also supervised by their CTs. In a review of these graded assignments across several years of the placements, some PSTs struggled to meet the full expectations of the assignment because they were limited by their CT's adherence to a curriculum package, their own beliefs and view of effective science teaching, and/or their lack of familiarity with effective mentoring practices.

Clinical Placement Mentoring Tool for Teacher Educators: Mentoring for Equitable Science and Engineering Learning Matrix

Finally, to support the mentoring of future science teachers, we focused on the role of the cooperating teacher and the university supervisor and asked ourselves: how can preservice science teachers be better mentored to teach diverse students using what they learned from their TPP in their instructional practices? By cross-referencing the model of intersectional equity developed by the ACESSE project authors and the coaching model, we envisioned key aspects of strong mentoring of student teachers in science (Appendix, Handout #1). Using examples provided by CTs and supervisors, we generated empirical examples of these activities. While each example focuses on one of seven specific facets of the ACESSE model, there is a strong relationship across multiple factors. For each priority within the model, we provide an example of how our teacher educators have engaged in specific mentoring activities in our school partners' cooperating teachers' classrooms. The examples below the table matrix can be used as part of mentor CTs' professional development to improve any aspects of inclusive teaching with their preservice science teacher.

Science Teacher Preparation Program Successes due to Program Redesign

The second question we posed to ourselves in our case study was, *"How have programmatic and clinical placement changes over time affected science teachers' inclusive instructional practices?"* We were awarded two Robert Noyce Track 1 (Phases 1 and 2) preservice teacher preparation grants (2011-2021). Per NSF's requirements, we needed to shift our two- to three-year long post-baccalaureate teacher education program to a 14-month certification program, and we used a master's degree program format to do so. Over a 10-year period, we supported 90 individuals' MA plus teacher certification as highly qualified science teachers with these grants; other post-baccalaureate students also sought their teacher certification as well but did not have a scholarship. In return for financial support to become science teachers, Noyce scholars were required to teach in a high-need school or school district for two years. Table 4 highlights our TPP results regarding preparation and retention rates. As is described in the next sections, this also accelerated the need to have in-field practicum and student teaching placements within one's single-subject science certification to improve mentorship by knowledgeable CTs.

Table 4
Program Design Review and Adjustments

Program Element	Description
<i>Prioritizing a Single-subject Science Teaching Endorsement</i>	- Recruitment of MAT program teachers with science degrees. - Require UG teachers to have single subject endorsement with at least 24 credit hours in a single science subject.
<i>Coursework Designed to Attend to Students' Identities and Cultural Diversity</i>	Require a teaching ELLs course for both UG and MAT PSTs.
<i>Science Methods Course Design Shifts</i>	- A greater focus on instructional strategies for multilingual learners. - Resources designed to leverage students' cultural diversity and funds of knowledge. - Field trips to experience place-based phenomena instruction. - Introduction of strategies that promote reflection and metacognition. - Increased exposure to lesser-used NGSS SPs, e.g., argumentation.
<i>Practicum Placement Shifts</i>	- Attend to single-subject endorsement content area for practicum and ST placement. - Placement in classrooms that use <u>OpenSciEd</u>. - Requirement of and placement with CTs that align to program goals and curriculum.

Prioritizing a Single-subject Science Teaching Endorsement

To meet NSTA Standard #1 (Science SMK) and address the problem of out-of-field teachers replicating science misconceptions with their students, we changed the college's mandate from a general science endorsement to a single-subject endorsement (24+ credit hours) for both the MA and undergraduate programs. An undergraduate science degree was a requirement for the NSF Noyce grants; thus, we only recruited science majors to become science teachers. This credential became the norm for our MA-level future science teachers, and they typically chose one of four single-subject secondary (grades 7-12) science endorsements (biology, chemistry, physics, and Earth and space science) rather than the general science endorsement. Some teachers with a strong biochemistry background were able to be endorsed in biology and chemistry, and they were mentored in both content areas. The increased SMK related to single-subject endorsement also correlates with greater use of inquiry-based science teaching strategies (Lewis et al., 2020).

Additional Coursework to Attend to Students' Cultural Diversity

While our state still does not require a course on teaching multilingual learners (MLLs) for teacher certification, when we originally designed our new (as of 2011-12) NSF Noyce-supported 14-month MA-level teacher certification program, we required all of these PSTs to take *Teaching ELLs/MLLs in the Content Area*. For many years, this meant that most of our undergraduate PSTs did not take such a course as it was not required. However, in the science teaching curriculum course assignments, we began to see the benefits of the MA-level certified science teachers' improved knowledge of MLL teaching strategies. By ensuring that these PSTs were also placed in diverse schools, they could then also be supported by mentor teachers to practice all types of inclusive teaching strategies.

In an ancillary longitudinal study of our TPP science teacher alumni and their in-service teaching practices, we focused on their use of academic language development strategies (Benzoni & Lewis, 2024). Teachers were observed and scored on their use of academic language development (ALD) strategies using the *Discourse in Inquiry Science Classroom* (DiISC) instrument (Baker et al., 2009; Lewis et al., 2025). We found that our MA-level teacher alumni used more of these inclusive instructional strategies than those undergraduate teacher alumni who had not had such a course. We coded for eight ALD strategies from the DiISC instrument. One-way MANCOVA was

used as an omnibus test to examine the effect of the TPP on teachers' use of ALD strategies while controlling for teaching experience. We then used two-way MANCOVA to investigate specific ALD strategy use based upon which of the two TPPs they graduated from. We found that MA-level teacher alumni (with a MLL course), regardless of their teaching experience, used the following four strategies significantly more often than the undergraduate-level program alumni: (a) *Teacher uses clear instruction throughout lesson by modeling expectations*; (b) *Using visual aids and gestures to communicate with students*; (c) *Teacher addresses multiple levels of academic language proficiency (differentiated instruction and/or assessment)*; and (d) *Teacher provides instruction for interactions among students* (Benzoni & Lewis, 2024). After we conducted this study, our teacher education department decided to require an ELL/ MLL course for all its future K-12 teachers in their preparation programs.

From an interview for a public report, one MA-level certified high school chemistry teacher alumna at a high-need, racially and culturally diverse school commented about equity and the use of formative assessment in her TPP. She specifically mentioned her final project, which focused on the effect of feedback and revision on multilingual learners' scientific writing and stated that: "Through this [the TPP] experience, I gained the skills necessary to be a reflective teacher. I learned how to use assessment data to revise my lessons to improve learning outcomes for all students and increase access to all students, including those from marginalized groups."

Individual Course Curriculum Modifications.

Science Teaching Methods and Curriculum Design Courses. Throughout the NSF Noyce-funded TPP activities, we used our annual reports' findings, as well as evidence from our experience in the field, to update the two science teaching courses in the program, the UG and MA cross-listed courses, *Learning and Teaching Principles and Practices* and *Curriculum Principles and Practices*, which were focused specifically on science teaching. Some updates we made included adding more place-based phenomena and modeling lessons that incorporated diverse students' funds of knowledge (Table 5). The two largest school districts that typically hire our alumni classify 20.5% and 6.5% of their students as English language learners (ELLs)/MLLs, with over 100 different languages spoken. Even before adding a teaching ELLs/MLLs course in the UG TPP coursework, we had focused on MLLs' learning needs in the science teaching methods courses. We modeled culturally relevant pedagogy and phenomenon-based curriculum and instruction, which also connected with some PSTs' rural backgrounds and introduced them to indigenous scientific traditions.

Table 5
Examples of TPP Activities to Model Inclusive Curriculum

Focal Area	Examples
Multilingual Learners	1. PSTs were tasked to complete a lab where verbal and written materials are only in Spanish to understand the situation in which many multilingual learners find themselves. In this way, they had to contemplate how to provide multilingual learners with specific instructional scaffolds, including providing their students with access to digital and printed translation dictionaries and permitting students to use home language, and facilitating collaboration among students who share the same home language. 2. We introduced evidence-based approaches to facilitate students' vocabulary acquisition, emphasizing multimodal and in-context vocabulary instruction to promote language acquisition over time. 3. PSTs were exposed to multimodal instructional strategies that included jigsaw, reading annotation, gallery walks, and infographics aimed at enhancing students' comprehension of scientific texts. 4. Teaching methods instructors also fostered discussions based upon PSTs' clinical placement experiences to consider how these and other strategies could be effectively employed to support all students' learning.
Culturally Relevant Pedagogy	1. We used the "Three Sisters" framework that originated from multiple Native American tribes to engage students in a discussion about biodiversity and interdependence. 2. Example lessons were modeled with the PSTs using materials from the Howard Hughes Medical Institute (e.g., skin color) and local place-based resources. 3. PSTs were tasked with crafting units showcasing phenomena-based lesson plans, expanding their perspectives beyond standard Western Modern Science curricula.
Phenomenon-based Learning	1. Every year, during the two-course sequence, PSTs take multiple field trips, one to the state's natural history museum and another to a restored prairie. Through both, they experience prairie ecosystem phenomenon-based instruction, led by informal educators. 2. Using resources they learned about from each site, PSTs were tasked to develop multi-disciplinary, place-based lessons and projects with rubrics. 3. We moved to place science students in the local middle schools for one of their three field placements, preferably the first. One reason is that the local school district has adopted the Open Sci Ed curriculum, which incorporates phenomenon-based learning along with the 5E model of inquiry-based learning.

Adjustments to Clinical Placements.

Two adjustments to clinical placements supported improved mentorship of PSTs. First, as described previously, with the awarding of teacher preparation grants, we changed our post-baccalaureate program to focus on single-subject endorsements. Before this change, the science teacher certification had been focused on completing a general science endorsement, so commensurately, their clinical placements were not purposely selected for singular expertise in biology, chemistry, Earth/space, or physics. With an emphasis on educating highly qualified discipline-specific teachers, we changed our priorities for selecting CTs to ensure that, for example, chemistry teachers were having opportunities to teach chemistry, and so forth. NSF Noyce grant recipients were required to teach for two years in a high-needs school or district, defined at the time as having 40+% of students enrolled in the federal free or reduced lunch (FRL) program. To prepare future science teachers for success, we prioritized practicum and student teaching placements in high-needs schools (Table 6). The average percentage of high-need school-level placements for the MA-level PSTs was higher than the undergraduate program PSTs to better support the Noyce service requirements when those teachers become in-service teachers. The average student teaching placement in high-need schools was also higher than the practicum placement as these placements were prioritized from the same pool of cooperating teachers. There have been occasions where the subject matter specialty took priority because of a smaller pool of discipline-specific cooperating teachers (i.e., physics), and this lowered the average high-need placement rate. In an associated study of teachers' use of NGSS science practices (Tankersley et al., 2024), we found that by placing PSTs in high-need schools and districts, there were no significant long-term differences in inquiry-based teaching strategies used by teacher alumni in their own classrooms based on SES. In other words, regardless of school-level SES, our science teacher alumni equitably provided their students with comparable social constructivist opportunities to learn.

Table 6

Summary of TPP practicum and student teaching clinical placements for cohorts 2016-2019, 2021.

Program	Placement Type	# of placements	% of placements in a high need school (FRL >40%)	% of placements in a high need district (FRL >40%)
MA	Practicum	37	59	89
UG		55	42	91
MA	Student Teaching	36	64	83
UG		49	55	78

The second aspect of the clinical placements that supported improved CT mentoring was when our main school district partner adopted the 5E inquiry-based instructional model for its science teachers to develop their lessons in the 2015-16 academic year. Shortly afterward, the state also adapted the NGSS as its official science education standards in 2017-18. Prior to 2015, many of our PSTs questioned why we were using the 5E model in the science teaching methods course because many of their CTs themselves had not adopted inquiry-based teaching approaches. Thus, their lesson plans and studies were almost always academic exercises to become certified. Unfortunately, in those earlier years, some of these CTs' beliefs and close mentorship undermined our efforts to prepare future science teachers whose views aligned with national science education priorities.

Over time, through more careful observation, record-keeping, and CT recruitment, we were able to become more selective in our placements of our PSTs with CTs whose beliefs about how students learn, and constructivist instructional strategies better aligned with our program. Despite initial challenges, district-level professional development and their knowledgeable and committed science curriculum specialist led to more successful reform in their science teachers' practices. Our TPP is now recognized for leading these efforts, which reflects better alignment with the state's science education standards that use the NGSS three-dimension design.

In-service Science Teacher Retention Rate

A measure of a TPP's success is arguably the persistence of its teachers in terms of classroom retention. The 2012-2013 National School and Staffing survey found that 13.3% of science and math teachers left the teaching profession (Carver-Thomas & Darling-Hammond, 2017) and that longer placements and a more robust TPP support greater teacher retention of new teachers. As reported in our introduction, this retention rate was exacerbated during the COVID-19 pandemic.

For over 10 years, we tracked our alumni and investigated how our pre-pandemic teacher alumni averages had been affected by it. Pre-pandemic, of alumni who graduated from 2012-2018, we found that the seven cohorts of MA-level teacher graduates ($n = 67$) had a higher six-year average retention rate (91% versus 80%) than the comparable seven cohorts of UG-certified science teachers ($n = 71$); about half

of those teachers were employed in high-needs schools (i.e., 40+% Free or Reduced Lunch). During the pandemic, more alumni teachers from both MA- and UG-level programs left teaching, which reduced the 10-year retention rate averages to 75% (MA) versus 70% (UG) (Table 7). While there is a reduction in retention, these rates are more robust than national rates.

Table 7
Science TPP Average Retention Rates

Retention Rates of Science Teachers Hired within 2 years of Graduation	MA Cohorts 1-7 2012-2018 Average (%)	UG graduating classes 2012-2018 Average (%)
2018-2019 (Pre-pandemic)	91	79
2022-2023 (Post-pandemic)	72	69

Conclusion: Lessons Learned and Other Resources for Designing Innovative Science Teacher Preparation Programs

In summary, in an effort to improve the mentoring of future science teachers, we used our clinical activities and observations to aid us in developing the two matrices provided in this article (Table 2 and Handout #1). They each align with the mentoring cycle and one of the two national documents we selected as being most critical to TPP design. There is some overlap between the 2020 NSTA teacher preparation standards and the ACESSE framework in terms of equitable teaching. Thus, it is likely easier to use one matrix first and then the other. Connecting program design with these national science education visions and mentorship activities can empower others to self-assess and potentially realign specific aspects of their programs.

Lessons Learned

Throughout our combined experiences as teacher educators, cooperating teachers, and university supervisors, we have found these mentoring strategies to be beneficial. Over the years, we have adjusted courses in the teacher preparation program to teach more strategies for supporting diverse students. In parallel, we strategically focused our students' placements in more diverse schools than in the past and only used public schools. Meticulous record keeping has enabled us to improve preservice teachers' placements and increase placements with teachers who are teaching in-field with strong content knowledge. However, this is not always possible due to the demographics and availability of teachers in local schools.

Mentoring student teachers involves a variety of factors, including some that are science subject-focused, some pedagogy-focused, and others that are equity-focused. Through compassionate coaching and mentoring, cooperating teachers can work with their student teachers on a variety of topics, from centering racial justice and disrupting ableism to using culturally relevant practices and inquiry-based instruction.

Preservice teachers should gain more and more responsibility throughout their placement, which leads to an evolution of mentoring strategies that are used, some of which are iterative throughout the course of the placement. These strategies include providing feedback, co-teaching, and co-planning. Through supervision and mentorship, we have learned that PSTs respond well to focusing on a few strategies at a time and gradually incorporating others into their repertoire. With knowledgeable CTs' mentorship and as student teachers increase their placement responsibilities, we see them gain confidence. Mentoring student teachers is a complex endeavor that is a crucial part of the teacher preparation program for preservice teachers. We hope that busy mentor science teachers find these suggestions practical and straightforward to implement and that student teachers experience an accelerated pathway to ambitious and inclusive science teaching.

Supplemental Files

[Lewis-Supplementary.png](#)

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