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Coordinated and Intersecting: How Preservice Secondary Science Teachers Understand Science and Engineering Practices and Instructional Principles for Diverse Students

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ABSTRACT

Teacher education programs need to prepare their preservice teachers to both implement current science education reforms and teach in culturally and linguistically diverse classrooms. In this qualitative study, we used a framework of four instructional principles to investigate 31 preservice secondary science teachers' understanding of instruction aligned with current reforms and responsive to culturally and linguistically diverse students. We analyzed interview data to examine preservice teachers' evolving understanding of the principle of engaging students in disciplinary practices, specifically the eight science and engineering practices (SEPs) highlighted in current U.S. standards. We found that, over time, participants more often discussed using multiple SEPs together in coordinated ways. However, they consistently reported struggling with the SEPs of *developing and using models* and *using mathematics and computational thinking*. Further, we examined how participants discussed engaging students in disciplinary practices in intersection with the three other principles in our framework: providing students with language production opportunities, attending to and supporting disciplinary language demands, and using student funds of knowledge and other resources. We found that participants focused more often on language production and language support than on student funds of knowledge in intersection with SEPs. Further, participants most frequently discussed the SEP of *engaging in argument from evidence* in intersection with the other three principles. This study is useful for informing teacher educators on how to better support preservice secondary science teachers in developing their understanding of engaging students in disciplinary practices and other instructional principles for diverse students.

Keywords: science and engineering practices, preservice science teachers, secondary science, diverse students

Introduction

The current science education reform movement in the U.S. emphasizes the importance of providing opportunities for ambitious and equitable science learning for all students. *A Framework for K-12 Science Education* [Framework] (National Research Council [NRC], 2012) and the *Next Generation Science Standards* [NGSS] (NGSS Lead States, 2013), in particular, expect teachers to implement rigorous learning goals and instructional approaches that engage all students in science and engineering practices to make sense of and use core ideas and crosscutting concepts. These documents also expect science teachers to "acquire effective strategies to include all students regardless of racial, ethnic, cultural, linguistic, socioeconomic, and gender backgrounds" (NGSS Lead States, 2013, Appendix D, p. 38). Thus, to adequately prepare beginning science teachers to teach science in ways aligned with current reforms and standards, teacher education programs must attend both to rigorous disciplinary instruction and to the diversity of students in U.S. classrooms (National Academy of Sciences et al., 2011).

Our study responds to recent shifts in teacher education that emphasize the complementary nature of effective methods for teaching science and effective methods for teaching culturally and linguistically diverse students (Bravo et al., 2014; Brown, 2017; Lee & Buxton, 2013; Tolbert et al., 2014). These new models of science teacher education provide beginning teachers with principle-based approaches for teaching science content in ways that are responsive to students' cultural and linguistic backgrounds (Bravo et al., 2014; Lyon et al., 2016; Nava et al., 2018; Roberts et al., 2017; Rutt & Mumba, 2020). At the heart of these principle-based approaches is instruction aligned with current reforms and standards, where teachers engage students in science and engineering practices in coordinated ways to make sense of complex problems or phenomena. These principle-based approaches also call for teachers to capitalize on opportunities for students to produce and use language while engaging in these practices; to correspondingly provide necessary language supports; and to use students' diverse cultures, languages, and experiences as resources for disciplinary learning. In this study, we used a framework of four interrelated instructional principles to examine preservice teachers' understanding of science instruction that is aligned with current reforms and responsive to culturally and linguistically diverse students. The principles of our framework include (1) engaging students in disciplinary practices, (2) providing students with rich language production opportunities, (3) attending to disciplinary language demands and providing language supports, and (4) building on student funds of knowledge and other resources.

We consider the principle of engaging students in disciplinary practices as the center of our framework. This principle is rooted in sociocultural perspectives that view learning as increased participation in a community's practices along with the development and use of knowledge from participating in those practices (Lave & Wenger, 1991). It connects to current reforms and standards, which encourage teachers to engage students in eight science and engineering practices (SEPs) that are both reflective of the work of scientists and engineers and central to student learning (NGSS Lead States, 2013; NRC, 2012). Teachers need to provide all students, regardless of linguistic or cultural background, with opportunities to engage in this kind of disciplinary work (Lee et al., 2013; Windschitl & Calabrese Barton, 2016).

For this study, we focused on how 31 preservice secondary science teachers from three teacher education programs described engaging students in disciplinary practices. We also examined how their understanding of instruction in these disciplinary practices intersected with the other three principles in our framework. We asked two sets of research questions:

1. How did preservice science teachers describe engaging students in SEPs? More specifically, how did they describe using multiple SEPs in coordinated ways during instruction? What challenges with engaging students in SEPs did they identify?
2. How did preservice science teachers discuss SEPs in intersection with other principles of effective instruction for culturally and linguistically diverse learners? More specifically, what types of language production opportunities, language demands and supports, and student funds of knowledge related to SEPs did preservice teachers identify?

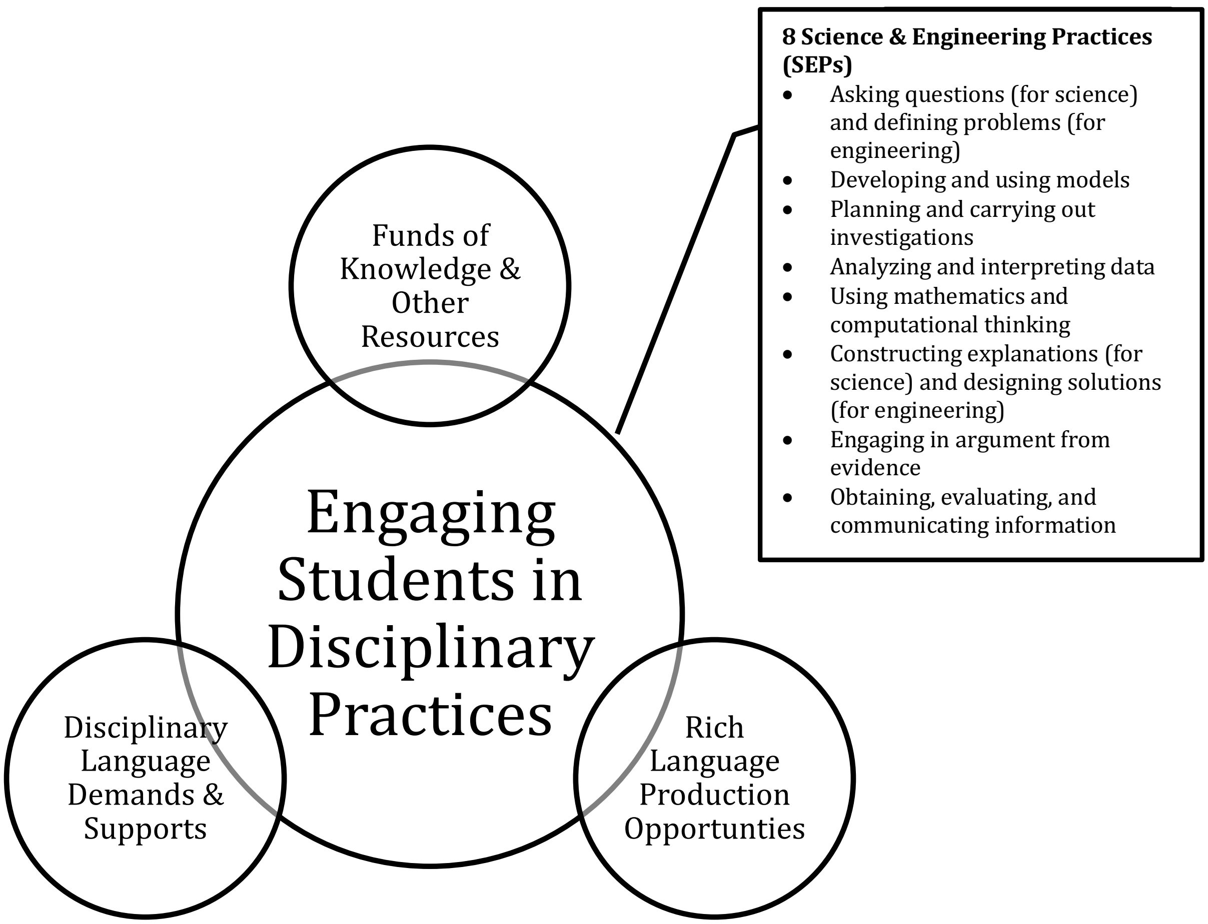
For both sets, we looked for patterns overall, over time, and across programs.

Conceptual Framework

As introduced above, our study was informed by a framework of four interrelated principles of effective science instruction for culturally and linguistically diverse students (see Figure 1). We designed this framework with colleagues (see also Moon et al., 2021; Roberts et al., 2017) based on literature on science instruction that is aligned with current reforms and responsive to culturally and linguistically diverse students. We used this framework to inform both our data collection and analysis.

Figure 1

Conceptual Framework



Disciplinary Practices

The central principle in our framework is engaging students in disciplinary practices. As students participate in the disciplinary work of science, they better understand scientific concepts as well as how scientific knowledge is developed (NRC, 2007, 2012). As described above, the Framework and NGSS specify eight science and engineering practices (SEPs) as important for K-12 science learning (see again Figure 1). The focus on these eight SEPs is rooted in sensemaking: Scientists, engineers, and students use these SEPs to build, refine, and use knowledge to make sense of the world and solve problems (Schwarz et al., 2017). As a means to sensemaking, the SEPs inherently build on and relate to each other; they are not a list of isolated steps. Thus, teachers should engage students in the SEPs in *coordinated* ways to make sense of phenomena.

Rich Language Production Opportunities

Another principle in our framework is providing students with opportunities for rich language production. Learning science involves learning the language unique to science and how to use that language to express ideas and build understanding (Lemke, 1990). The SEPs highlighted in the NGSS are language intensive; participating in these SEPs provides authentic contexts for students to produce and use language (Lee et al., 2013). As students use language to engage in these practices, they make sense of science ideas, which enhances their understanding of scientific concepts and the nature of science (Tolbert et al., 2014). Further, language production is both central to culturally relevant instruction, which positions students and teachers as social makers of knowledge (Ladson-Billings, 1995), and important for multilingual learners, as they develop both language and scientific understanding in science classes (Lyon et al., 2016).

Disciplinary Language Demands and Supports

Another principle in our framework is attending to disciplinary language demands and providing needed language supports. As teachers engage students in authentic disciplinary practices, they also need to attend to the associated language functions that drive the disciplinary practices (e.g., asking questions, constructing explanations) and understand the receptive and productive language demands required of students to engage in these practices (Lyon et al., 2016). Thus, beyond providing opportunities for students to produce language, teachers need to pay attention to those aspects of language that might prove challenging and to provide adequate scaffolding for students to interpret and produce language. Indeed, the language and literacy demands of the SEPs can be challenging for all students, including multilingual learners (Bunch, 2013). In short, as teachers engage students in the language intensive work of the SEPs, they need to attend to the corresponding language demands and provide appropriate supports as well.

Student Funds of Knowledge and Other Resources

The final principle in our framework is building on and using student funds of knowledge and other resources. Student funds of knowledge, the "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being," are powerful resources teachers can use to inform instruction (Moll et al., 1992, p. 133). In addition to home-related funds of knowledge, students bring other resources that are valuable for science learning, such as their prior content knowledge, personal interests, and concerns about socioscientific issues (Basu & Calabrese Barton, 2007; Calabrese Barton & Tan, 2009; Campbell et al., 2016). Teachers can draw on these funds and resources in moment-by-moment instruction to engage students in SEPs (Razfar & Nasir, 2019). Contextualizing content knowledge and student engagement in SEPs by building on students' ideas and everyday experiences makes the science more meaningful to all students and can improve learning and participation for culturally and linguistically diverse students, in particular (Tolbert et al., 2019).

Literature Review

There has been limited work specifically examining *preservice secondary* science teachers' understanding of the SEPs articulated in the Framework and NGSS. In one study, Brownstein and Horvath (2016) analyzed preservice secondary science teachers' written responses to the edTPA teacher performance assessment to understand their use of SEPs in their lessons. Researchers found that preservice science teachers consistently described implementing three SEPs in their edTPA lessons: *analyzing and interpreting data*; *constructing explanations and designing solutions*; and *obtaining, evaluating, and communicating information*. The preservice teachers, however, showed limited use of the remaining SEPs. In a second study, French and Burrows (2018) administered a questionnaire to preservice secondary science teachers to gauge their knowledge of and confidence with implementing the SEPs. Researchers found that teachers generally had a working knowledge of the SEPs with respect to curriculum, student understanding, and instructional strategies. However, they also noted that the preservice teachers struggled with enacting certain SEPs, including *developing and using models*, *constructing explanations and designing solutions*, and *engaging in argument from evidence*.

In addition to the few studies that have focused on preservice secondary science teachers, studies of practicing secondary teachers as well as preservice and practicing elementary teachers provide insight into teachers' successes and struggles with SEPs. Prior research with practicing secondary science teachers has examined teachers' understanding of the epistemic nature of science practices as well as how teachers' goals align or misalign with the NGSS (Kawasaki & Sandoval, 2020; Kite et al., 2020). These prior studies found that even practicing secondary science teachers lacked a sophisticated understanding of the SEPs and underestimated how different their teaching practice needed to be to engage students in the SEPs. For example, Kite et al. found that teachers had a limited understanding of the role of models and computational thinking. Prior research with elementary teachers has investigated teachers' ideas about the SEPs as well as how and which SEPs teachers implement in their instruction (Berland et al., 2020; Dalvi et al., 2020; Kang et al., 2018; Kang et al., 2019; Smith & Nadelson, 2017). In previous studies, elementary teachers were found to be successful at integrating the SEPs with each other: Teachers treated the SEPs as comprising a single sensemaking system rather than eight distinct practices (Berland et al., 2020; Kang et al., 2019). However, teachers still struggled with implementing certain SEPs, such as *engaging in argument from evidence* (Kang et al., 2019).

Overall, prior studies have found that preservice and practicing teachers alike need further support in understanding what the SEPs are and how to implement them in their instruction. Our study seeks to extend this body of scholarship by focusing explicitly on preservice secondary science teachers' descriptions of engaging students in the SEPs in ways that intersect with principles of effective instruction for culturally and linguistically diverse students. This work uniquely informs researchers and teacher educators in how to better support preservice teachers so that they deepen their understanding of the SEPs and of how to implement them in relation to each other and to the three interrelated principles discussed above.

Method

Participants and Context

A total of 31 preservice secondary science teachers from three teacher education programs participated in this qualitative study. They represented 69% of the preservice science teachers enrolled in the three programs during the 2016-2017 academic year. Participant demographics are shown in Table 1. All three teacher education programs were housed at universities from the same state university system in the western U.S. The programs were similar in that they included science methods courses that focused on reform-based instruction, additional courses that specifically addressed teaching linguistically and culturally diverse students, and intensive classroom-based field experiences. The program at University 1 was an integrated undergraduate credential program in which preservice teachers earned a bachelor's degree and teaching credential simultaneously, whereas programs at

Universities 2 and 3 were postbaccalaureate credential programs. A summary of characteristics and the number of participants for each teacher education program is shown in Table 2.

Table 1

Preservice Teacher Participant Demographics

Gender	***n***
Female	21
Male	10
Race/Ethnicity	
White/European American	20
Asian/Asian American	7
Multiracial	2
Latinx	1
Other	1
First Language	
English	25
Language(s) other than or in addition to English	6

Note. All demographic data were self-reported.

Table 2

Teacher Education Program Information

University	**Type of Program**	**Length**	**Coursework & Field Placements**	**Credential & Degrees**	***n***
1	Undergraduate	Possible to complete in four years	University-based courses with short-term practicum placements throughout the four years, plus final semester of "student teaching" with associated university seminar	Minor in STEM education, bachelor's degree (in content area), and credential	8
2	Post-baccalaureate	11 months	University-based courses concurrent with field experiences	Potential to earn MEd the following year	11
3	Post-baccalaureate	13 months	University-based courses concurrent with field experiences	Potential to earn MEd concurrently with credential	12

Data Collection

Participants were individually interviewed twice during their teacher education programs (initial and follow-up interviews) using semi-structured interview protocols (Brenner, 2006; see

Appendices A and B for the protocols). Both the initial and follow-up protocols included the same 24 questions to elicit participants' ideas about science teaching and learning. The initial protocol contained an additional five questions about participants' interests in teaching; the follow-up protocol contained an additional nine questions about participants' teacher performance assessment portfolios (i.e., edTPA portfolios); both protocols included similar questions about participants' field placements. The set of 24 common questions included questions that, to varying degrees, addressed all four principles of our conceptual framework. For example, the question, "How would you engage students in discussions?" addresses the principle of language production opportunities, and the question, "What kinds of connections would you make between school science and students' lives outside of school?" addresses the principle of funds of knowledge. The set of 24 common questions also included specific questions about SEPs, including what participants learned about the SEPs, the two SEPs they most frequently implemented in their field experiences, the one SEP they considered as most important to teach students and the one or two SEPs they needed more help to understand or implement. There were also questions about participants' ideas about effective instruction for multilingual learners. We note that we used the term English Language Learner (ELL) in the interview protocols but have since revised our language to multilingual learner. We included all questions from both protocols in our analysis.

Participants at University 1 were interviewed toward the beginning and end of their student teaching semester; participants at Universities 2 and 3 were interviewed toward the beginning and end of their yearlong programs. Initial interviews occurred after participants had started their coursework and had some experience in field placement classrooms. All 62 initial and follow-up interviews lasted approximately one hour. All were audio recorded, professionally transcribed, and checked by researchers for accuracy. Transcripts were anonymized, and all participant names used in the Findings section are pseudonyms.

Data Analysis

We analyzed transcript data using three cycles of coding (Saldaña, 2016). For all coding, the unit of analysis was a main interview question from the interview protocol, including any probes or clarifications that were under the main question. For the first cycle of coding, we analyzed each transcript and coded for instances where participants implicitly or explicitly addressed one or more of the eight SEPs. We applied subcodes for each SEP that was implicitly or explicitly discussed. For the second cycle of coding, we further examined those responses identified in the first cycle where participants addressed one or more SEPs. To do this, we applied codes to mark responses where participants discussed using multiple SEPs in a coordinated way, where participants discussed challenges with engaging students in specific SEPs, and where participants described a clear intersection between SEPs and one or more of the remaining three principles of our Conceptual Framework (i.e., providing rich language production opportunities, attending to disciplinary language demands and supports, and using student funds of knowledge). For the third cycle of coding, we explored the intersections of SEPs with these three principles in more detail. To do this, we narrowed in on the SEP of *engaging in argument from evidence*, because we found that this was the SEP with the most intersections overall. We inductively created a coding scheme to characterize how preservice teachers described the language production opportunities, disciplinary language demands and supports, and student funds of knowledge associated with the SEP of *engaging in argument from evidence*. Descriptions of codes for cycles 1 through 3 are shown in Tables 3, 4, and 5, respectively.

Table 3

Codes for the First Cycle of Analysis

Code	Subcodes	Description
SEPs		Participant talks implicitly or explicitly about engaging students in one or more of the Science and Engineering Practices (SEPs) articulated in the NGSS. Includes examples of engaging students in SEP(s) during actual instruction, hypothetical descriptions of engaging students in SEP(s), or descriptions of why SEP(s) is/are important.
	Asking questions (for science) and defining problems (for engineering)	Includes asking questions about texts, phenomena observed, and conclusions drawn from models or investigations. For engineering, questions should define the problem to be solved and elicit ideas that lead to its solution.
	Developing and using models	Includes diagrams, physical replicas, mathematical representations, analogies, and computer simulations. Although models do not correspond exactly to the real world, they bring certain features into focus and obscure others.
	Planning and carrying out investigations	Includes opportunities to plan and carry out different kinds of investigations, spanning those structured by the teacher and those that emerge from students' own questions.
	Analyzing and interpreting data	Includes use of a range of tools for tabulation, graphical representation, visualization, and statistical analysis of data.
	Using mathematics and computational thinking	Includes using algebraic thinking and analysis, a range of linear and nonlinear functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used as well.
	Constructing explanations (for science) and designing solutions (for engineering)	Includes explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
	Engaging in argument from evidence	Includes using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s).
	Obtaining, evaluating, and communicating information	Includes reading, producing, and evaluating genres of texts that are intrinsic to science and engineering.

Note. Descriptions taken from Appendix F of the *NGSS* (NGSS Lead States, 2013).

Table 4

Codes for the Second Cycle of Analysis

Code	Description
Coordinated	Participant describes coordinating or connecting multiple SEPs with one another so that SEPs are being used together or building from each other in one activity or lesson or over a series of activities/lessons.
Challenges	Participant describes challenges with engaging students in specific SEPs.
Intersection-language production opportunities	Participant describes students' production of language (talk or writing) related to specific SEPs and/or opportunities for students to produce language related to specific SEPs.
Intersection-disciplinary language demands and supports	Participant describes disciplinary language demands and/or language supports related to specific SEPs.
Intersection-funds of knowledge	Participant describes students' backgrounds, prior knowledge, experiences, everyday life, language, cultural strengths, or other resources that students bring in relation to specific SEPs.

Table 5

Codes for Third Cycle of Analysis

Category	Code	Description
Language production opportunities		
Modality	Talking	Participant refers to students engaging in argument from evidence specifically through talk (can include group work, working with a peer, debates).
	Writing	Participant refers to students engaging in argument from evidence specifically through writing.
	Both talking and writing	Participant refers to students engaging in argument from evidence specifically through talk AND writing.
	Unspecified	Participant refers to students engaging in argument from evidence, but type of language use is not explicit and could be interpreted as either writing or talking.
Context	Activity	Participant describes engaging in argument from evidence as part of or resulting from a lab, investigation, project, or larger activity.
	Assessment	Participant refers to engaging in argument from evidence as part of a formative or summative assessment.
	Classroom discussion	Participant refers to engaging in argument from evidence as part of whole-class or small-group discussions.
	Reading	Participant refers to engaging in argument from evidence as part of or related to a reading assignment (e.g., using evidence from a reading to support an argument).
Disciplinary language demands and supports	Writing assignment	Participant refers to engaging in argument from evidence as part of a writing assignment.
	Language demands	Participant discusses language demands specific to the practice of engaging in argument from evidence.
	Claim-Evidence-Reasoning framework (CER)	Participant refers to the Claim-Evidence-Reasoning (CER) framework to scaffold students engaging in argument from evidence.
	Graphic organizer	Participant refers to providing students with a graphic organizer or other visual chunking method to help students write or construct arguments (e.g., providing separate boxes for evidence, reasoning, etc.).
	Group work or peer collaboration	Participant refers to having students work in groups or with peers for engaging in argument from evidence.
	Guided or scaffolded questioning	Participant refers to using specific questions (oral or written) to guide or scaffold students' arguments or evidence; not necessarily assignment questions, but questions to scaffold students' arguments or evidence; can include asking students probing questions to explain or expand their reasoning/argument/evidence.
	Rubric or checklist	Participant refers to providing students with a rubric, checklist of required elements, specifications of requirements related to engaging in argument from evidence (e.g., include 3 pieces of evidence).
	Sentence frames or starters	Participant refers to using sentence starters or sentence frames for engaging in argument from evidence.
Funds of knowledge and other resources	Everyday science experiences	Participant refers to using science topics or examples because they are related to students' everyday life experiences in the context of engaging in argument from evidence.
	Linguistic resources	Participant refers to using students' home language(s) or everyday language(s) in the context of engaging in argument from evidence.
	Prior content knowledge	Participant refers to using students' prior content knowledge or skills in the context of engaging in argument from evidence. Can include content knowledge from previous courses, earlier in the same course, or other STEM learning experiences.
	Socioscientific issues	Participant refers to using social or global issues in the context of engaging in argument from evidence.

We established inter-coder reliability for each of our three cycles of coding in a stepwise fashion following the process of MacPhail et al. (2015). First, members of the research team coded the same interview excerpts independently, and a kappa coefficient was calculated (Fleiss, 1971). The researchers then discussed and resolved areas of disagreement. The process was repeated with additional interview data until a kappa coefficient of 0.8 was achieved and maintained. The researchers then coded remaining data independently or in pairs. To ensure that inter-coder reliability remained acceptable, the researchers coded additional data at designated times throughout the independent/paired coding process and a kappa coefficient of at least 0.8 was maintained. For each cycle, approximately 20% of the transcripts were coded collectively, and 80% were coded independently or in pairs. In addition to establishing inter-coder reliability, we tracked analytic decisions using a detailed audit trail (Guest et al., 2012) to increase the trustworthiness of our analysis (Brenner, 2006).

After coding was completed, we calculated percentages of codes to look for patterns overall, over time, and across universities. We note that because this is a qualitative study, any comparisons of percentages over time and across universities are not for statistical tests of differences but rather to understand general patterns in what participants discussed.

Findings

Finding Set 1: Engaging Students in Disciplinary Practices

Disciplinary Practices as Coordinated

For our first research question, to probe preservice teacher participants' understanding of engaging students in disciplinary practices, we examined responses where participants described using SEPs in a coordinated way. In these responses, participants either discussed coordinating multiple SEPs in a particular activity, lesson, or series of activities/lessons, or they discussed how certain SEPs connect with one another more generally. Overall, we found that 43% of all responses coded for SEPs were also coded as coordinated. In other words, in 43% of responses where participants addressed SEPs, they described engaging students in two or more SEPs in coordinated ways. We also found that the proportion of responses coded as coordinated increased from the initial to follow-up interviews. In initial interviews, 32% of responses addressing SEPs were considered coordinated. In comparison, in the follow-up interviews, 50% of responses addressing SEPs were considered coordinated. This pattern of an increase in the proportion of coordinated responses over time was consistent across universities. Again, we reiterate that this comparison of percentages over time indicates the general pattern of what participants discussed; the statistical significance of this difference was not determined.

In references where participants discussed coordinating SEPs, they most frequently connected the practice of *analyzing and interpreting data* with other SEPs. Over half of all responses coded as "coordinated" included this SEP (see Table 6). For example, in her follow-up interview, Harper described several SEPs, including *analyzing and interpreting data*, as part of the lesson series for her edTPA teacher performance assessment. In this lesson series, Harper guided students in completing a simulated DNA extraction activity to investigate mutations by comparing three species of a fictional organism called "gorks". As she described:

> They [students] definitely went through the series of the science and engineering practices in that they planned and carried out their own investigations as far as what the mutations were actually doing to the gorks—they figured out what would be the best way to actually test that, and what kind of data they would need to collect. And they also got practice in analyzing that data in comparing the different kinds [of DNA sequences] that they got, and then saying how

> that would affect the gorks. And then, in that final paper, [they] had a chance to be communicating the information they got as well as arguing from evidence. Their claim ended up being which of the three mutations was harmful, which was helpful, and which was neutral, and then based on the evidence that they had collected, here's why we're saying that.

Harper coordinated the practice of *analyzing and interpreting data* with *planning and carrying out investigations*; *obtaining, evaluating, and communicating information*; and *engaging in argument from evidence* to support her students in learning about genetic mutations.

Table 6

Percentage of Coordinated Responses That Included Each SEP

SEP	%
Asking questions and defining problems	28
Developing and using models	33
Planning and carrying out investigations	43
Analyzing and interpreting data	56
Using mathematics and computational thinking	22
Constructing explanations and designing solutions	40
Engaging in argument from evidence	49
Obtaining, evaluating, and communicating information	28

Note. Percentages were calculated as the number of responses that included a specific SEP out of the total number of responses coded as coordinated. Percentages do not sum to 100% because each response included multiple SEPs.

Challenges With Implementing Disciplinary Practices

To extend our investigation of participants' understanding of disciplinary practices, we identified responses where participants discussed challenges with implementing SEPs. We found that participants most frequently discussed the two SEPs of *developing and using models* and *using mathematics and computational thinking* as being challenging to implement. *Developing and using models* accounted for 22% of codes for SEPs identified as challenging; *using mathematics and computational thinking* accounted for 21%. This pattern remained consistent across initial and follow-up interviews and was similar across campuses.

For the SEP of *developing and using models*, several participants noted that they lacked an understanding of the practice; they did not understand what a model is. Participants also discussed struggles with implementing the practice, including issues with incorporating modeling into their instruction and a lack of clarity in how to support students' engagement in the practice. For example, in her follow-up interview, Mia described:

> I want to be confident that I'm implementing modeling or models in my class correctly or appropriately, but I struggle with letting students develop their own model. It's like, "What do you think?" But, I'm less competent at helping them revise their models or provide them with the perfect, "Well, this is what it actually is." I'm not sure that needs to happen, but I do know that I can't let students who develop grossly incorrect models to just stop at that point, but

> I'm not sure of the best ways to help them revise their models without invalidating what they did.

Other participants noted their own lack of experience with this practice, either as a K-12 student learning science or as a student teacher in their field placements. As Kayleigh noted in her initial interview, "With the models, I never experienced that growing up. So, it's hard for me to understand all this NGSS stuff because it's totally new."

For the SEP of *using mathematics and computational thinking*, several participants noted challenges with implementing the practice because of students' prior experiences with mathematics or perceived lack of mathematical skills. For example, in her follow-up interview, Sue described this SEP as challenging because of students' math anxiety:

> Because a lot of my students come into my classroom really terrified of math. Whether that's because they had bad math experiences in the past, teachers that they didn't necessarily agree with or like, or that they feel like they just don't know how to do it and aren't good at it…between 75% and 90% of my students say they are not good at math. It becomes very difficult to implement and go for any math things because they tend to just shut down as soon as they see it.

Similar to the challenges discussed with *developing and using models*, participants also noted a lack of clarity about what it means to engage students in *mathematics and computational thinking* or noted challenges with incorporating it into their curricula. In particular, several noted challenges with integrating mathematics into their biology curricula. For example, in her initial interview, Luna commented, "Especially [in] 9th-grade biology, we don't touch on any math equations. I don't know how if I can integrate types of math into what I'm teaching for biology… I'm not really sure where to start for that one."

Finding Set 2: Disciplinary Practices in Intersection With Other Principles

For our second research question, we analyzed where and how preservice teachers talked about disciplinary practices in intersection with the other three principles of effective instruction for culturally and linguistically diverse students described in our Conceptual Framework: providing rich opportunities for student language production, attending to disciplinary language demands and providing language supports, and using student funds of knowledge. Overall, we found that participants addressed one or more of these three principles in approximately 55% of their responses that addressed SEPs. As shown in Table 7, participants most often discussed providing language production opportunities in intersection with SEPs, followed by disciplinary language demands and supports. They least often discussed using student funds of knowledge or other resources in intersection with SEPs. This pattern remained consistent across initial and follow-up interviews and across universities.

Table 7

Percentage of Responses with One or More Intersections that Included Each Principle

Principle	%
Rich language production opportunities	84
Disciplinary language demands and supports	64
Funds of knowledge and other resources	24

Note. Percentages were calculated as the number of responses that included each specific principle out of the total number of responses that included an intersection with one or more principles and SEPs. Percentages do not sum to 100% because one to multiple principles could be included in each response.

To elaborate, we found that participants most frequently discussed the SEP of *engaging in argument from evidence* in intersection with one or more of the other three principles; nearly half of the responses addressing an intersection of SEPs with one or more of the three principles included *engaging in argument from evidence* (see Table 8). To clarify, this differed from the SEP, most often discussed in coordination with other SEPs, *analyzing and interpreting data*. This pattern was consistent across initial and follow-up interviews and across universities. The proportions of principles intersecting with this SEP also followed the same patterns as discussed above, with the principle of language production opportunities intersecting the most and the principle of funds of knowledge intersecting the least. Thus, we focused on *engaging in argument from evidence* to further explore the types of language opportunities, disciplinary language demands and supports, and student funds of knowledge discussed by the participants in relation to this SEP. We characterized how preservice teachers described (1) the context and modality of student language production associated with this SEP, (2) the types of disciplinary language demands and/or supports for this SEP, and (3) the types of student funds of knowledge or other resources used as students engaged in this SEP.

Table 8

Percentage of Responses with One or More Intersections that Included Each SEP

SEP	%
Asking questions and defining problems	17
Developing and using models	26
Planning and carrying out investigations	31
Analyzing and interpreting data	32
Using mathematics and computational thinking	14
Constructing explanations and designing solutions	30
Engaging in argument from evidence	48
Obtaining, evaluating, and communicating information	23

Note. Percentages were calculated as the number of responses that included a specific SEP out of the total number of responses that included an intersection with one or more principles and SEPs. Percentages do not sum to 100% because one to multiple SEPs could be included in each response.

Rich Language Production Opportunities

To characterize the ways participants described student language production associated with the SEP of *engaging in argument from evidence*, we examined both the language modality (i.e., writing, talking) and the context of student participation in the SEP (e.g., as part of an investigation or larger activity, as a class discussion). We note that participants' descriptions of *engaging in argument from evidence* did not always describe participation in the complete practice: Participants often described the practice as students making and supporting claims without addressing the evaluation, critique, and reconciliation components of argumentation (Berland et al., 2017). We found that in approximately 30% of responses, participants described students engaging in argument from evidence through writing, and in another, approximately 30% of responses, participants described students engaging in argument through talking. Further, we found that in approximately 30% of responses, the language modality was unspecified—the type of language use was not explicit and could be interpreted as either writing or talking. We found few instances (less than 10% of responses) where participants described students engaging in both written and oral arguments.

For the modality of written argumentation, participants regularly described students *engaging in argument from evidence* in the contexts of writing assignments connected to investigations or larger activities. For example, in her initial interview, Lanh described how students in her placement typically completed writing assignments using the claim, evidence, and reasoning framework to "wrap up what they've learned" after an activity or lesson. She further explained that students engaged in argument from evidence "through the claim, evidence, reasoning [writing assignments] that they have to do…which are pretty big because we have an activity or lesson that goes before they can actually create a claim, evidence, and provide reasoning." Less often, participants described students engaging in written argumentation in the contexts of general writing assignments, reading assignments, or assessments.

For the modality of oral argumentation, participants most often described students engaging in argument in the context of classroom discussions. For example, when describing how she facilitated discussions, Madelyn said, "I just really like asking questions and asking students to draw out what they're saying, or expand on what they're saying, or maybe provide an argument against what someone else is saying." Less often, participants described students engaging in oral argumentation in the context of an investigation or larger activity.

When the language modality was unspecified, participants typically described students engaging in argument in the context of an investigation or larger activity. For example, while describing how she implemented the SEP of *engaging in argument from evidence*, Kathryn stated that students "were asked to use that evidence, use their data from their lab, to explain whether or not their original prediction was correct, and why they thought that." Here, we clarify, it was unclear whether students' arguments about their predictions were written or oral.

For the few instances where participants described students engaging in argument through both talking and writing, the contexts were typically both specific writing assignments and classroom discussions connected to an investigation. For example, in the follow-up interview, Eric described:

> Essentially after the labs, they [students] have to write claims, and those claims have to be backed up with evidence they collected in the lab. And so, it allows them to engage in more argument from evidence because some students, their evidence might point to different things, and then we talk about it, and argue about it in a productive way so that the concepts are more explicitly laid out for them.

Here, Eric pointed out how students engaged in both written and oral argumentation stemming from laboratory activities. We add that, in this example, as did Madelyn above, Eric did include students arguing with one another about differing claims and evidence.

Disciplinary Language Demands and Supports

Regarding the principle of attending to disciplinary language demands and providing disciplinary language supports, we found that discussions of disciplinary language demands associated with the SEP of *engaging in argument from evidence* accounted for 10% of codes for this principle. The remaining 90% of codes for this principle comprised the various types of language supports that participants discussed related to this SEP. In their discussions of disciplinary language demands, participants often spoke of the demands of students' struggles with identifying and using evidence to support arguments. For example, in the follow-up interview, when describing an assignment about evolution, Kayla said:

> I wanted them [students] to use all of the evidence we had gathered to engage in an argument, which some students just defined each category [of evidence] instead of using the category as an argumentative tool. For instance, they knew that DNA was evidence for evolution, but they didn't know how to talk about, how to argue about DNA.

Here, Kayla acknowledged the challenges her students had with using the evidence they had gathered to support their arguments.

In their discussions of language supports for *engaging in argument from evidence*, participants most frequently mentioned using a claim, evidence, reasoning (CER) framework (McNeill & Krajcik, 2012). Discussions of the CER framework accounted for 30% of the codes for the principle of disciplinary language demands and supports. For example, in her initial interview, Luna noted, "I usually do a claim, evidence, reasoning to promote the writing." When asked about SEPs implemented most often in her placement, she replied:

> Let's say engaging in an argument from evidence. Like I said, I have them doing a claim, evidence, reasoning. I usually have a driving question that I introduce three to five lessons beforehand.…Then students are then able to use those lessons and what they took from those lessons as evidence. They'll make their claim and they'll have evidence from all the activities we did. Then they'll do the reasoning part where they'll restate their claim and pull specific things from their evidence to support that claim.

Luna used the CER framework to support students engaging in argument as part of summative writing assignments following a series of lessons. The next most frequently discussed language support for *engaging in argument* was group work or peer collaboration (17% of codes for this principle). For example, in his follow-up interview, Timothy commented that argumentation "doesn't necessarily need to be a whole-class discussion. It could be in lab groups, anywhere that you can maximize opportunities for students to speak in that specific academic register where you have arguing from evidence, citing or stating your claims, reasoning your arguments, that sort of thing." Finally, participants less frequently discussed other language supports, such as rubrics or checklists, graphic organizers, and sentence frames.

Funds of Knowledge and Other Resources

Overall, we found that the principle of using student funds of knowledge and other resources was seldom discussed in intersection with the SEP of *engaging in argument from evidence*. Of the few instances, participants mainly discussed the resource of students' prior content knowledge to support argumentation. Sadie noted in her follow-up interview that students engaged in arguments about the rock cycle using conventions of molecular diagramming, which they had covered in a previous unit. As she described, "We connected it to what we had been talking about when we talked about convection and making pictures of those molecules then. They used those molecular diagrams to support their arguments." Other types of resources, including students' every day science experiences, linguistic resources, and awareness of socioscientific issues, were discussed once each. As an example of using a socioscientific issue to connect to student funds of knowledge, Kayla described an activity where students participated in a mock city council meeting and engaged in a debate about genetically modified organisms (GMOs). As she explained, "I gave them a fake case study about these GMO papayas in Hawaii. So, I had each student take on the role of a different person in the debate – so a farmer, the GMO person, someone who's an organic farmer." She used a current and familiar social issue as a context for engaging in argument.

Discussion and Implications

Our findings provide insight into the successes and struggles that preservice secondary science teachers experience with engaging students in the disciplinary practices of science and engineering and in the principles of effective instruction for diverse students. We examined how preservice teachers from three teacher education programs discussed the eight SEPs highlighted in recent U.S. reform documents. We also examined how they described rich language production opportunities, language demands and supports, and student funds of knowledge associated with these SEPs. We found that, over time, preservice teachers more often described the SEPs as coordinated. However, we also found that preservice teachers consistently identified struggles to understand and implement two SEPs: *using mathematics and computational thinking* and *developing and using models*. Further, we found that preservice teachers readily and consistently described opportunities for students to produce language with the SEPs and, to a lesser extent, language demands and supports associated with the SEPs. However, we found that preservice teachers struggled with the principle of using funds of knowledge or other resources to engage their students in the SEPs.

Strengthening Preservice Teachers' Understanding of Disciplinary Practices

Looking more closely at the findings for our first research question, we found that preservice teachers' descriptions of using the SEPs in coordinated ways increased over time: A higher percentage of their discussions included descriptions of using two or more SEPs in coordinated ways at the end of their teacher education programs compared to the beginning. This growth over time is promising and suggests that preservice teachers developed a better sense of the coordinated nature of SEPs through their teacher education experiences. This finding is consistent with other research that has found increases in teachers' use and understanding of SEPs as coordinated after learning opportunities focused on the SEPs (Berland et al., 2020; Kang et al., 2019). It contrasts with other studies, such as that by Kite et al. (2020), where relatively few practicing secondary science teachers were found to exhibit sophisticated understandings of scientific practices that extended beyond the rigid, linear scientific method. Our finding remains important because understanding the SEPs as coordinated is aligned with the larger goals of the NGSS, which emphasize that the SEPs should be conceived not simply as a list of practices to check off but rather as a coordinated way to build, use, and make sense of scientific knowledge (NGSS Lead States, 2013; Schwarz et al., 2017). However, we did not examine how the three teacher education programs in our study facilitated preservice teachers' growth in their understanding of the coordinated nature of SEPs—that was beyond of the scope of this study. This is a fruitful avenue for further research. Future studies should examine the opportunities for learning that teacher education programs provide to facilitate such growth.

We also examined which SEPs preservice teachers reported as especially challenging to implement. Identifying the SEPs that preservice teachers described as challenging is important to inform how teacher educators can better support them. We found one of the most common SEPs that preservice teachers deemed challenging was *using mathematics and computational thinking*. They reported struggling to accommodate students' varying mathematical backgrounds and skills, a lack of clarity on what the SEP entails, and uncertainty on how to incorporate it into their instruction, particularly biology instruction. Other studies have similarly identified *using mathematics and computational thinking* as a challenging SEP for teachers to understand and implement (Brownstein & Horvath, 2016; Kite et al., 2020). We also found preservice teachers reported the SEP of *developing and using models* as challenging. This resonates with other, more specific studies on modeling, which have found that teachers struggle with understanding and using models as tools for scientific inquiry, having students construct and evaluate models, and seeing models as more than illustrations of phenomena or patterns (Khan, 2011; Schwarz & Gwekwerere, 2007; Windschitl & Thompson, 2006). With such clear struggles surrounding these two SEPs, teacher education programs need to better support preservice teachers in understanding and implementing them.

We recommend that teacher educators leverage the SEPs that preservice teachers feel more comfortable with as a focal point for exploring the SEPs that are more challenging. Given the coordinated and overlapping nature of the SEPs, teacher educators can point out explicit connections and overlaps between SEPs that preservice teachers find challenging and SEPs they readily use and understand. As one example, in our study, *analyzing and interpreting data* was the SEP preservice teachers most often described as coordinated with other SEPs—perhaps indicating a high level of familiarity with and understanding of this SEP. Interestingly, although preservice teachers seemed to have facility with implementing *analyzing and interpreting data*, they still encountered difficulties with implementing *mathematics and computational thinking*—an SEP with clear connections to analyzing and interpreting data. Indeed, mathematics and computation are tools for analyzing and interpreting data that facilitate the analytic process along with making sense of and reasoning with data (Rivet & Ingber, 2017). Thus, highlighting the coordination between these two SEPs could support preservice teachers in better recognizing and understanding the use of mathematics and computational thinking in their curricula. As a second example, other researchers have suggested *developing and using models* as an anchor for engaging students in other SEPs (Passmore et al., 2013; Passmore et al., 2009). However, we found that *developing and using models* was a challenging SEP for preservice teachers to understand and implement. Our study provides evidence that the SEP of *analyzing and interpreting data* could serve as an alternative anchor practice, as a strong entry point to develop their understanding of the other SEPs, because preservice teachers are comfortable with it.

Strengthening Preservice Teachers' Understanding of Intersecting Principles

For our second research question, we examined how preservice teachers discussed SEPs in intersection with the instructional principles of providing language production opportunities, attending to disciplinary language demands and supports, and using student funds of knowledge and other resources. We found that in their discussions of SEPs, preservice teachers most often touched on the principle of providing language production opportunities, followed by the principle of attending to disciplinary language demands and supports. The SEPs are noted as being language intensive (Lee et al., 2013), and current reforms emphasize the need for students to engage in the language of science (NRC, 2007). Thus, it is promising that preservice teachers in our study recognized opportunities to use language through SEPs and provided support for this language use.

We also found that preservice teachers tended to focus on the language aspects of certain SEPs over others: They most often discussed the language principles in intersection with the SEP of *engaging in argument from evidence*. A closer examination of the types of language opportunities, demands, and supports related to *engaging in argument from evidence* showed that preservice teachers used supports like the claim, evidence, reasoning (CER) framework (McNeill & Krajcik, 2012) and peer collaboration to facilitate students engaging in argument through writing assignments connected to larger activities and through classroom discussions. The CER framework was a frequent support mentioned by preservice teachers from each of the three universities. Since the preservice teachers had a clear tool to support the disciplinary language demands of *engaging in argument from evidence*, perhaps they were better able to describe the language opportunities of this SEP.

Teacher educators could do more to help teachers recognize the language opportunities and demands associated with each of the SEPs. A focus on tools, like the CER framework, that support students' language use with each SEP could help teachers recognize and implement opportunities for language production through student engagement with all the SEPs. For example, Windschitl et al. (2018) developed a suite of tools to support student language production with *planning and carrying out investigations*, *constructing explanations*, and *engaging in argument from evidence*.

Although preservice teachers recognized opportunities and supports for student language production through SEPs, they struggled to recognize how student funds of knowledge or other resources could be used to engage students in SEPs. This finding resonates with prior studies that have documented similar struggles among beginning teachers to contextualize classroom science activity in students' lives outside of school (Bravo et al., 2014; Tolbert et al., 2019). In our examination of *engaging in argument from evidence*, we found few instances of preservice teachers acknowledging student funds of knowledge and resources in relation to this SEP; most consisted of discussing students' prior content knowledge. As Razfar and Nasir (2019) pointed out, student funds of knowledge about scientific practices can come from in-school, out-of-school, and in-between experiences, and teachers can draw on these various funds of knowledge in dynamic ways by considering how student funds come into play beyond curricular topics—for example, by connecting to students' values, beliefs, and contested ideologies as students engage in argument from evidence.

Building on the example given by Kayla, we recommend that teachers connect to their student funds of knowledge while *engaging in argument from evidence* by contextualizing the SEP in socioscientific issues (SSIs). SSIs are controversial social issues that have conceptual or procedural links to science and readily connect to student funds of knowledge (Sadler, 2004; Zeidler et al., 2009; Zeidler & Sadler, 2011). Further, grounding argumentation in SSIs can help teachers facilitate deeper argumentation beyond claims, evidence, and reasoning—which we also found as a struggle for preservice teachers. Indeed, argumentation is a central focus of SSI instructional frameworks (Aikenhead, 1985; Driver et al., 2000), where the SSIs examined and argued have personal meaning to students. As a result, students can construct more substantive arguments because of their interest in and connection with an SSI. In sum, including SSI frameworks in teacher education programs can help teachers connect their lessons to students' lives (Johnson et al., 2020) and improve students' ability to effectively argue in their classrooms.

Limitations

We recognize that our study has several limitations. First, although our interview questions asked preservice teachers about their practice, we did not examine their actual classroom instruction. As such, we were unable to determine how closely their reports resonated with their actual instruction. Second, our interviews asked a range of questions that addressed each of the four principles of our

Conceptual Framework. However, we did not ask questions that directly addressed the coordination of SEPs with one another or the intersection of SEPs with these principles. Had participants been asked about such intersections directly, they may have elaborated on their understandings. Finally, we did not specifically examine the opportunities for learning about SEPs and instruction for diverse students provided by the three teacher education programs in our study. A deeper examination of programmatic factors would generate additional recommendations for preparing preservice teachers for instruction that incorporates SEPs and instructional principles for diverse students.

Conclusion

Although a deeper examination of programmatic factors is needed, the inclusion of multiple programs in our study does contribute to a broader understanding of preparing preservice science teachers because studies of teacher education are often small in scale and consist of case studies of individual interventions (Sleeter, 2014). Indeed, our findings were generally consistent across the three teacher education programs included in our study, pointing to common successes and struggles that preservice teachers experienced. Said another way, this study offers insight into how to better support preservice teachers beyond improvements to single programs.

To conclude, we found that preservice teachers grew in their understanding of the coordinated nature of SEPs, and while they reported challenges with certain SEPs, they seemed successful with others. Thus, we recommend that teacher educators leverage these strengths to help preservice teachers better understand challenging SEPs. Further, we found that preservice teachers more readily recognized the intersections of SEPs with language opportunities and supports than with student funds of knowledge. More specifically, preservice teachers described oral and written language production opportunities for the SEP of *engaging in argument from evidence* along with specific supports, like the CER framework. Thus, we suggest that teacher educators consider other tools and instructional supports that can help preservice teachers draw on the language opportunities and student funds of knowledge related to all SEPs – to fully engage culturally and linguistically diverse students in reform-based science education.

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Appendix A
Initial Interview Protocol

Thank you for agreeing to be interviewed today. The purpose of this interview is to learn about some of the successes and challenges you are experiencing as a teacher candidate. We are studying science and mathematics teacher education to better support beginning teacher learning. We ask that you try to be as candid and specific as possible.

The information from this interview will not affect your course grades, your teaching placements, or your standing in the Teacher Education Program. If there is a question you do not wish to answer, you can ask that it be skipped. If you later wish to revise an answer or to ask that an answer be deleted, you are free to do so as well.

The interview should last about 60 minutes. It is divided into several parts. Do I have your permission to begin recording the interview?

[Turn on recorder]

Background Information (Initial interview only)
First, I'd like to ask you a few questions about your interest in teaching.

1) What are some reasons why you decided to become a teacher and to teach ________ *[specific credential subject area (known from survey), e.g., biology, chemistry]* in particular?

2) Why did you decide to enroll in the _______ teacher education program?

3) *[if involved in undergrad recruitment program]* How did [undergrad recruitment program] help prepare you for teaching?

4) Where do you hope to teach after completing the program? In what kind of school, or what kinds of students, would you like to teach? Any particular grade levels and/or courses you would like to teach?

Conceptions of Science Teaching
These next few questions are about your ideas about effective science teaching.

5) Thinking back to middle school and high school, please describe a typical science lesson that you experienced as a student.

6) What do you think are the characteristics of an excellent science teacher?

7) What have you learned about effective science instruction from your teacher education program so far?

8) What more would you like to learn or feel you need to learn about effective science instruction?

For the next few questions, imagine that you are teaching a secondary science course, for example, in your student teaching placement.

9) If an observer walked into your classroom, what do you hope the observer would notice about what you are doing as a teacher?

10) What do you hope the observer would notice about the disciplinary core ideas, cross-cutting concepts, and/or science and engineering practices you are teaching?

11) What do you hope the observer would notice about what the students are doing?

12) How would you engage students in discussions?

13) How would you engage students in reading and writing?

14) What kinds of connections would you make between school science and students' lives outside of school?

Science Practices
These next few questions are about the *Next Generation Science Standards* science and engineering practices.

15) In general, what have you learned about the eight science and engineering practices from the *Next Generation Science Standards* in your teacher education program or from your prior experiences?

This is a list with the eight science and engineering practices from the *NGSS* [*at end of document*].

16) Which **two** have you implemented, or seen implemented, most often in your current student teaching placement? What are some examples of how these two practices have been implemented in your placement?

17) Out of all eight, which **one** do you think is most important to teach students? Why?

18) Which **one or two** practices do you think you need more help to understand or implement?

Conceptions of Learners
These next few questions are about students and student learning.

19) How do you think students learn science?

20) Why do you think some students succeed and other students struggle in school science courses?

21) Do you think students should be tracked according to ability in secondary science? What are the advantages and disadvantages of tracking?

Conceptions of Effective Practices for English Language Learners
These next few questions are about science instruction for diverse learners.

22) Classrooms are becoming increasingly culturally and linguistically diverse. How prepared do you feel to teach in a culturally and linguistically diverse classroom?

23) How do you define an English language learner (ELL)?

24) How do you think ELL students differ from one another?

25) What do you think ELL students bring as resources to increase the richness in class?

26) What knowledge and skills do you think it takes to be an effective secondary science teacher of English Language Learners?

For the next few questions, imagine that you are teaching a secondary science class with English language learners as well as native English speakers, for example, in your student teaching placement.

27) What supports for ELLs would you consider as you planned your instruction?

28) What factors would you consider when developing or selecting science texts for ELLs?

29) What would you consider when designing and using science assessment materials for ELLs?

Practicum Experience

These final questions are about your current practicum placement.

30) In what secondary school are you currently placed?

31) In what science class or classes are you currently placed?

32) What are the student demographics of the class or classes, in terms of gender, ethnicity, and ELLs?

33) What kinds of instructional responsibilities have you had so far?

34) How much autonomy do you have with your teaching, for example, in selecting topics and deciding what strategies to implement?

Science and Engineering Practices from NGSS

Asking questions (for science) and defining problems (for engineering)

Developing and using models

Planning and carrying out investigations

Analyzing and interpreting data

Using mathematics and computational thinking

Constructing explanations (for science) and designing solutions (for engineering)

Engaging in argument from evidence

Obtaining, evaluating, and communicating information

Appendix B
Follow-Up Interview Protocol

Thank you for agreeing to be interviewed today. This interview will be similar to the one you did previously.

The interview should last about an hour. It is divided into a few parts. Do I have your permission to audio record the interview?

[Turn on recorder]

Conceptions of Science Teaching
The first few questions are about your ideas about effective science teaching.

1) What do you think are the characteristics of an excellent science teacher?

2) What have you learned about effective science instruction from your teacher education program?

3) What more would you like to learn or feel you need to learn about effective science instruction?

For the next few questions, imagine that you are teaching a secondary science course, for example, in your student teaching placement or when you have your own classroom.

4) If an observer walked into your classroom, what do you hope the observer would notice about what you are doing as a teacher?

5) What do you hope the observer would notice about the disciplinary core ideas, cross-cutting concepts, and/or science and engineering practices you are teaching?

6) What do you hope the observer would notice about what the students are doing?

7) How would you engage students in discussions?

8) How would you engage students in reading and writing?

9) What kinds of connections would you make between school science and students' lives outside of school?

Science Practices
These next few questions are about the *Next Generation Science Standards* science and engineering practices.

10) In general, what have you learned about the eight science and engineering practices?

This is a list with the eight science and engineering practices from the *NGSS* [*at end of document*].

11) Which **two** have you implemented most often in your current student teaching placement? What are some examples of how these two practices have been implemented in your placement?

12) Out of all eight, which **one** do you think is most important to teach students? Why?

13) Which **one or two** practices do you think you need more help to understand or implement?

Conceptions of Learners
These next few questions are about students and student learning.

14) How do you think students learn science?

15) Why do you think some students succeed and other students struggle in school science courses?

16) Do you think students should be tracked according to ability in secondary science? What are the advantages and disadvantages of tracking?

Conceptions of Effective Practices for English Language Learners
These next few questions are about science instruction for diverse learners.

17) Classrooms are becoming increasingly culturally and linguistically diverse. How prepared do you feel to teach in a culturally and linguistically diverse classroom?

18) How do you define an English language learner (ELL)?

19) How do you think ELL students differ from one another?

20) What do you think ELL students bring as resources to increase the richness in class?

21) What knowledge and skills do you think it takes to be an effective secondary science teacher of English Language Learners?

For the next few questions, imagine that you are teaching a secondary science class with English language learners as well as native English speakers, for example, in your student teaching placement.

22) What supports for ELLs would you consider as you planned your instruction?

23) What factors would you consider when developing or selecting science texts for ELLs?

24) What would you consider when designing and using science assessment materials for ELLs?

Practicum/Student Teaching Experience
These questions are about your current practicum or student teaching placement.

25) In what secondary school are you currently placed?

26) In what science class or classes are you currently placed?

27) What are the student demographics of that class, in terms of gender, ethnicity, and ELLs?

28) In your placement, how aligned do you feel your teaching is to the *Next Generation Science Standards*?

29) How much support do you feel you get to teach in ways that are aligned with the *NGSS*?

EdTPA
This final set of questions is about your edTPA teaching event.

30) For your edTPA, what was the central focus of your lesson sequence?

31) How did you address the *NGSS*?

32) How did you support ELLs?

In your edTPA lesson sequence, in what ways did you…
33) Engage students in scientific sense-making?

34) Engage students in scientific discourse?

35) Support students' English language and literacy development?

36) Make connections between lesson activities and students' lives outside of school?

37) What kinds of support did you receive in completing your edTPA?

38) What additional support would you have liked?

Thank you!

Science and Engineering Practices from NGSS

Asking questions (for science) and defining problems (for engineering)

Developing and using models

Planning and carrying out investigations

Analyzing and interpreting data

Using mathematics and computational thinking

Constructing explanations (for science) and designing solutions (for engineering)

Engaging in argument from evidence

Obtaining, evaluating, and communicating information