

Using an Integrated STEM Methods Course to Prepare Pre-service Teachers for Ambitious STEM Instruction

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Introduction

Over the past decade, like other teacher preparation programs across the U.S., we have redesigned our teacher education curriculum to include a practice-based approach that engages pre-service teachers (PSTs) in learning about and rehearsing ambitious instruction. A critical component of our redesign includes an Integrated STEM Methods course. Built upon research from mathematics and science teacher educators (Ball & Forzani, 2009; Windschitl et al., 2012), the course prepares PSTs for ambitious instruction (Lampert, 2013) using pedagogies of practice to provide PSTs multiple opportunities to examine, decompose, and approximate (Grossman et al., 2009) four practices: (1) teaching to the “Big Ideas” and CCSSM or NGSS standards (NGSS, 2013; CCSSM, 2010; Windschitl et al., 2018); (2) analyzing, selecting, and sequencing worthwhile tasks (Smith & Stein, 2018; Tekkumru-Kisa, Stein, & Schunn, 2015); (3) using the launch of a lesson (Jackson et al., 2012) to elicit and build on student thinking; and, (4) orchestrating whole-class discussion using teacher talk moves (Windschitl, et al., 2018). The goal of engaging PSTs in these four practices is to support them in becoming “well-prepared beginning teachers of mathematics [who] use a core set of pedagogical practices that are effective for developing students’ meaningful learning of mathematics” (AMTE, 2017, p. 15). In this paper, we use examples from Emily (pseudonym), a career changing engineer seeking grades 6-12 mathematics licensure, to provide a descriptive account of the pedagogies of practice we use in our course.

Integrated STEM Methods and Ambitious Instruction

Integrated STEM Methods is a 6-credit component of our 14-month Robert Noyce Teacher Scholarship program (NSF #1660541) which provides funding for career changing professionals with undergraduate STEM degrees to obtain a master’s degree and grades 6-12 teaching license. PSTs enrolled in our 30-credit program work in small cohorts and complete three methods courses, including Integrated STEM Methods, which is the only course to address ambitious instruction. Over the past four years, 18 PSTs have completed our program.

The class meets 2 days a week for 2 hours each session over a 16-week semester while PSTs are concurrently immersed in an 80-hour field experience in a middle or high school STEM classroom. As mathematics and science teacher educators, we co-teach the class, using unit planning as a context for our PSTs to learn about the practices involved in ambitious instruction. Like other teacher educators (Lampert et al., 2013; Windschitl, et al., 2012), we conceptualize ambitious instruction to mean the kind of rigorous yet equitable teaching that supports *all* students in engaging deeply with subject matter while learning how to use the practices involved in the disciplines to approach and solve real-world problems (CCSSM, 2010; NGSS, 2013). Well-designed

instructional activities, termed pedagogies of practice (Grossman et al., 2009), sequenced throughout the course, support PSTs in their learning. Accordingly, when completing the course, PSTs examine practices by participating in lessons we model, decompose practices using frameworks to isolate discrete skills, and approximate practices through video-recorded teaching rehearsals followed by analysis, feedback, and reflection.

Teaching to the Big Ideas and CCSSM or NGSS Standards

We adapted Windschitl and colleagues' (2018) "whiteboard activity" (pp. 21-24) to help PSTs learn about the practice of teaching to the "Big Ideas" and CCSSM (2010) or NGSS (2013) standards associated with a mathematics or science unit. The activity asks PSTs to use sticky notes to record the concepts found in a curricular unit and then match unit concepts to standards. PSTs display their concepts and standards sticky notes on the whiteboard, arranging and rearranging the sticky notes to find different ways to think about the relationships between the concepts and standards involved in their unit. PSTs finish the whiteboard activity by using their concepts and standards sticky notes to write "Big Ideas" for their unit, focusing on how to use the "Big Ideas" to explain a range of ideas and express a variety of relationships. Figure 1 recreates the whiteboard Emily generated for her 7th grade unit on data analysis and statistics.

Figure 1

Emily's Whiteboard Activity

Unit Concepts	Standards	"Big Ideas"
<ul style="list-style-type: none"> • Sample population • Random sampling • Measures of center and spread • Graphing to represent data • Inferences and interpretation 	<p>7.SP.1. Understand that statistics can be used to gain information about a population by examining a sample of the population; Understand that random sampling tends to produce representative samples and support valid inferences.</p> <p>7.SP.2. Use data from a random sample to draw inferences about a population with an unknown characteristic of interest.</p> <p>7.SP3. Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability.</p>	<ol style="list-style-type: none"> 1. We can answer some questions by collecting and analyzing data. 2. The questions we want to answer determines what data to collect and how to collect it. 3. We can use graphs to represent data and the type of data collected helps to determine the best graph to use. 4. We can use numerical measures to describe a data set.

7.SP.4. Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations.

Analyzing and Selecting Worthwhile Tasks

Once PSTs have identified “Big Ideas” and standards for their unit, they learn about the practice of selecting worthwhile tasks. To do so, PSTs read about mathematics and science task analysis frameworks (Smith & Stein, 2018; Tekkumru-Kisa, Stein, & Schunn, 2015) and use these frameworks to classify a collection of tasks as lower-level (i.e., memorization, procedures without connections) and higher-level (i.e., procedures with connections, doing mathematics or science). To introduce our novice PSTs to the existing collection of high-quality curricular materials (i.e., Illustrative Mathematics, Mathematics Assessment Resource Services) we ask them to use the frameworks to find a high-level task to include in their unit rather than modify or create a task. Emily, for example, included [Eruptions: Old Faithful Geyser](#) (Shaughnessy et al., 2009) as a high-level task for her unit on data analysis and statistics. Once PSTs understand how to select a worthwhile task, they plan lessons for their unit, using a launch-explore-discuss model for planning (Appendix A) to help them make connections between a worthwhile task, the teacher’s role in enacting the task, and the students’ role in engaging in the task.

Using the Launch of a Lesson to Elicit and Build on Student Thinking

PSTs read Jackson et al.’s (2012) “Launching Complex Tasks” to learn about the four aspects involved in launching a worthwhile task: (1) discuss key contextual features of the task, (2) discuss the key concepts involved in the task, (3) develop common language to describe the key features of the task, and (4) maintain the cognitive demand of the task. To isolate (i.e., decompose) each aspect, PSTs view videorecording of teachers launching a lesson, noting instances in which they observe teachers enacting each aspect during instruction. PSTs then approximate this practice by rehearsing (and videorecording) the launch of a lesson with their peers in the integrated methods course. Using Jackson et al.’s (2012) aspects of a lesson launch as a framework for analysis, PSTs code instances in which they find each aspect on their videorecorded rehearsal. Figure 2 presents Emily’s analysis of the launch of her lesson: Eruptions: Old Faithful Geyser.

Figure 2

Emily’s Lesson Launch Analysis

Launch Feature	Coding Example
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1. Discuss key contextual features of the task.	"Okay, so not all of you have visited Yellowstone to see Old Faithful so I'd like you to watch a video of eruption." Old Faithful
2. Discuss the key concepts involved in the task.	"So how could you figure out how long to expect to have to wait for Old Faithful to erupt?"
3. Develop common language to describe key features of the task.	"As you look at the two sample days of Old Faithful wait times, what trends do you notice and what might you do to explain those trends?"
4. Maintain the cognitive demand of the task.	"Well, what are the different graphs we've learned about so far? What kinds of graphs do you know how to make?"

Using Teacher Talk Moves to Orchestrate Whole Class Discussion

PSTs approximate the practice of orchestrating whole-class discussion via a videorecorded rehearsal with peers in the integrated methods course. Again, PSTs use a launch-explore-discussion model for planning (Appendix A) in conjunction with Bloom's Taxonomy (Anderson & Krathwohl, 2001) to write different types of questions for whole-class discussion: knowledge, comprehension, application, analysis, synthesis, evaluation. Using the taxonomy to write discussion questions supports PSTs in thinking about the cognitive demand of their questions, how questions progress from simple to complex and concrete to abstract. PSTs also detail in their lesson plan how they will enact Smith and Stein's (2018) practices for orchestrating whole-class discussion: (1) anticipating student approaches to a task, (2) monitoring student work on a task, (3) selecting students work for presentation during whole-class discussion, (4) sequencing the order of student work to present and, (5) connecting ideas found in student work during whole-class discussion. Finally, PSTs rehearse (and videorecord) a whole-class discussion in the integrated methods class and then analyze their practice using Windschitl et al.'s (2018) teacher talk moves (Figure 3). The teacher talk moves provide a helpful framework for PSTs to isolate the skills involved in responding to students during whole-class discussion. Figure 3 provides examples from Emily's analysis.

Figure 3

Emily's Coding Teacher Talk Moves

Teacher Talk Move	Definition	Coding Example
Probing	Asking student to share ideas	"What did you think each of the different graphs highlight?"
Pressing	Asking for examples	"How would it look if you had a lot of data points that were right next to each other, what would the box look like?"
Follow-ups	Asking for clarification	"What does it mean when you say the stem of your graph is rather long?"
Opening up cross-talk	Asking students to talk to one another	"What do you easily see in your graph that you do not see in other graphs, why?"
Wait time	Quiet pause	

Revoicing	Rephrase a student's idea	"So you're saying the variability in the data calls that into question a little bit."
Focusing	Asking about one part of the solution	"What does it mean if the box on your graph is really compressed? Or if the box on your graph is really wide?"

Conclusion

The purpose of sharing this descriptive account of our Integrated STEM Methods is to highlight the benefits and constraints of our approach to teacher preparation. Our integrated course creates the opportunity to provide a more coherent preparation program by utilizing the researched-based practices of mathematics and science teacher educators (AMTE, 2017; Ball & Forzani, 2009; Windschitl, et al., 2012). As our PSTs learn about ambitious STEM instruction, they develop common language for this kind of teaching, thus fostering their capacity to conceptualize a vision for their practice that aligns with K-12 mathematics (CCSSM, 2010) and science (NGSS, 2013) reform initiatives. The integrated course also creates a context in which PSTs learn about the interdisciplinary connections between mathematics and science content as they engage in class discussions, share lesson plans, and participate in videorecorded rehearsals.

At the same time, we notice constraints. For example, our PSTs are novices who are moving along a trajectory of professional development in relationship to ambitious instruction. Thus, we frequently observe inconsistencies in PST development. We also notice that while some PSTs embrace and enact ambitious practices during videorecorded rehearsals, they use a traditional-didactic approach in their field experience. This phenomenon may reflect the influence the cooperating teacher has on PST practice. Despite our best efforts, we continue to struggle to find cooperating teachers who embrace the vision of practice we share with PSTs in our integrated methods course. We contend, however, that PSTs can progress in their development when they have opportunities to observe and enact ambitious instruction in field experience with the support of a cooperating teacher. We are hopeful that as pre-service and in-service teachers learn about ambitious instruction in preparation programs and professional development opportunities, more K-12 STEM classrooms will reflect the vision of teaching and learning outlined in reform documents (CCSSM, 2010; NGSS, 2013).

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Appendix A Integrated STEM Methods Lesson Plan Template

Title of Lesson:

Grade Level:

Lesson Plan Preparation:

1. If you are using a curricular textbook, read through all materials before planning or teaching. Complete any of the activities students will be asked to do. As you read through the curricular materials, begin to think about the teaching practices supporting student learning.

Description of Learners: (10 pts.)

1. Contextual information of middle school students - family, culture, community, student interest, student motivation, etc.
2. What “Big Ideas” are addressed in this lesson? (Windschitl et al., 2018)
3. What prior knowledge, skills, and understanding must students have to successfully engage in this lesson?
4. What conceptions and misconceptions might students have about the concepts in this lesson?
5. Why might students have difficulties understanding particular concepts?

Learner Objectives and National/State/District Standards: (5 pts.)

1. Which CCSSM/NGSS content standards align with your lesson?
2. Which CCSSM/NGSS practices align with your lesson?

Learner Assessment: (5 pts.)

1. How will you know if the students have learned?
2. Include a simple rubric/checklist to assess student learning of concepts.

Instructional Procedure: (65 pts.)

Launch (Jackson et al., 2012)

1. Describe the key contextual features of the lesson task.
2. Describe the key mathematical concepts included in the task.
3. Describe the common language students will need to use for the task.
4. Describe how you will maintain the cognitive demand of the task.

Explore

5. What worthwhile task will the students use for inquiry? (Smith & Stein, 2018)
6. How will the worthwhile task assist the students in building new content knowledge?

Whole-Class Discussion (Smith & Stein, 2018; Windschitl, et al., 2018)

7. What questions will you pose for students during whole-class discussion (Anderson & Krathwohl, 2001)
8. How will you elicit samples of student thinking orally and in writing?
9. What major concepts will you address during discussion? (“**Instructional Language**”)
10. Reflection – How will you assist students in reflecting on what they learned?

Materials/Resources/Technology: (5 pts.)

1. What materials/resources/technology will you need to implement this lesson?

Addressing Diverse Learners: (10 pts.)

1. Content – How will you change/modify the content to meet the needs of all students?
2. Process – What teaching and learning strategies will you use to meet the needs of all students?

3. Product – How will you change/modify the assignment to address the needs of all students?
4. Environment – How will you change/modify the classroom to address the needs of all students?