

# Scaffolding Preservice Science Teacher Learning of Effective English Learner Instruction: A Principle-Based Lesson Cycle

---

by [Sarah A. Roberts](#), University of California, Santa Barbara; & Julie A. Bianchini, University of California, Santa Barbara

## Abstract

---

This paper examines a lesson development, implementation, revision, and reflection cycle used to support preservice secondary science teachers in learning to teach English learners (ELs) effectively. We begin with a discussion of our framework for teaching reform-based science to ELs – four principles of effective EL instruction and three levels of language – that shaped both our science methods course, more generally, and the lesson cycle, in particular. We then present a model lesson implemented in the methods course that highlighted these principles and levels for our preservice teachers. Next, we describe how preservice teachers used their participation in and analysis of this model lesson as a starting point to develop their own lessons, engaging in a process of development, implementation, revision, and reflection around our EL principles and language levels. We close with a description of our course innovation, viewed through the lens of the preservice teachers. We attempt to provide practical insight into how other science teacher educators can better support their preservice teachers in effectively teaching ELs.

## Introduction

---

Learning to teach English learners (ELs) in content areas should be a priority for both beginning teachers and teacher educators, as the number of ELs in U.S. schools has increased 152% in the past 20 years (National Clearinghouse for English Language Acquisition, 2009). Indeed, across the U.S., over 11% of all students in K-12 settings are identified as ELs (Lee & Buxton, 2013). To teach ELs effectively, beginning teachers must be able to recognize and use the diverse cultures, languages, and experiences of ELs as resources for instruction in their discipline. Offering methods courses that attend specifically to ELs, including EL-focused methods courses for preservice secondary science teachers, is one way teacher education programs can attend to this pressing need.

The purpose of this paper is to share our approach to embedding best instructional practices for ELs in a secondary science methods course. We begin from the conviction that attending to the resources and needs of ELs is more complex than most of our preservice science teachers (PSTs) envision (Buck, Mast, Ehlers, & Franklin, 2005). We see our approach as innovative in that it reflects calls to move beyond lists of uncoordinated EL scaffolds (Bravo, Mosqueda, Solís, & Stoddart, 2014; Johnson, Bolshakova, & Waldron, 2016) focused on the

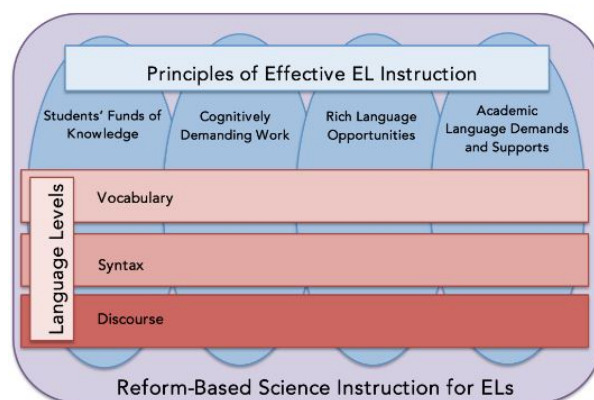
teaching of vocabulary (Richardson Bruna, Vann, & Escudero, 2007) to promote implementation of coherent, principle-based instruction centered at the discourse level of language. Below, we present the framework we have developed for teaching reform-based science to ELs – four key principles of effective EL instruction and three levels of language – that informed both the larger course and the specific assignment presented here. We then describe how we integrated these key principles and language levels into a model lesson implemented during the second week of the course that served to anchor subsequent lessons our PSTs developed, implemented, revised, and reflected upon. We conclude with PSTs’ reflections on our principle-based framework and suggest steps for other such methods courses.

## Theoretical Perspectives and Instructional Framework

---

Four key principles of effective EL instruction and three levels of language guided our work. This principle-based instructional framework grounded the planning of our methods course; the conversations that we, as instructors, had with PSTs about the teaching and learning of science to ELs; and the structure of our major assignment, the lesson development, implementation, revision, and reflection cycle. Figure 1 presents the framework we developed and used for teaching reform-based science to ELs in visual form. We next describe each element in detail.

*Figure 1 (Click on image to enlarge).* Framework authors developed and used for teaching reform-based science to ELs. See text for specific citations for each of the four principles and for the construct of language levels.



### Four Principles of Effective Instruction for ELs

---

As the first part of our instructional framework, we identified four key principles of effective EL instruction. These principles are understood as re-enforcing and overlapping with one another. They are:

1. Building on and using ELs’ funds of knowledge and resources,
2. Providing ELs with cognitively demanding work,
3. Providing ELs opportunities for rich language and literacy exposure and practice, and

#### 4. Identifying academic language (AL) demands and supports for ELs.

The first principle, *building on and using ELs' funds of knowledge and resources* (Lee, Deaktor, Enders, & Lambert, 2008; Moll, Amanti, Neff, & Gonzalez, 1992; Moschkovich, 2002), asks PSTs to identify, celebrate, and use the knowledge and skills students, their families, and their communities bring to the classroom. PSTs were encouraged to engage in such practices as recognizing and utilizing their ELs' primary languages as resources for learning in addition to encouraging ELs to speak in multiple languages, to use different dialects or registers, and/or to work across varying levels of literacies in their production and display of ideas. PSTs were also expected to incorporate students' home, cultural, and community resources into their instruction to make content relevant and meaningful.

The second principle, *providing ELs with cognitively demanding work* (Tekkumru-Kisa, Stein, & Schunn, 2015; Tobin & Kahle, 1990; Understanding Language, 2013; Windschitl, Thompson, & Braaten, 2018), demands that ELs have the opportunity to engage in the same kinds of activities and assignments often reserved only for non-EL students (Iddings, 2005; Planas & Gorgorió, 2004). This principle focuses on student sense-making and reasoning (Windschitl et al., 2018). PSTs were expected to provide analytical tasks that require students to move beyond "detailed facts or loosely defined inquiry" (Lee, Quinn, & Valdés, 2013, p. 223) to focus on the science and engineering practices, crosscutting concepts, and disciplinary core ideas outlined in the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013). Indeed, because the eight science and engineering practices emphasize students' active sense-making and language learning (Quinn, Lee, & Valdés, 2012), PSTs were expected to foreground one or more of these practices in each lesson they designed and implemented.

The third principle, *providing ELs opportunities for rich language and literacy exposure and practice* (Bleicher, Tobin, & McRobbie, 2003; Khisty & Chval, 2002; Lee et al., 2013; Moschkovich, 2007), attends to the importance of engaging ELs in the language of science. PSTs were encouraged to address this principle by creating opportunities for students to receive comprehensible input through listening and reading and to produce comprehensible output through speaking and writing. In attending to this principle, PSTs were to facilitate their EL students' participation in constructing and negotiating meaning to advance both their English language development and science learning.

The fourth principle is *identifying academic language demands and supports for ELs* (Aguirre & Bunch, 2012; Lyon, Tolbert, Stoddart, Solis, & Bunch, 2016; Rosebery & Warren, 2008). This principle asks PSTs to attend to the language demands in the tasks they provide ELs and to implement appropriate supports so that all students can read disciplinary texts, share their ideas and reasoning in whole class and small group discussions, and communicate science information in writing. PSTs could have supported students in learning the language of science by beginning with an anchoring phenomenon and/or driving question to provide context for key vocabulary, concepts, and practices; using gestures, graphic organizers,

demonstrations, and other visuals; modeling target language (e.g., what engaging in argument looks like); including sentence starters and/or frames to use in discussions or writing tasks; fostering peer collaboration through think-pair-shares or groupwork; and encouraging use of students' home language(s). (See Roberts, Bianchini, Lee, Hough, & Carpenter, 2017, for additional discussion of the first three of these principles.)

### Three Levels of Language

---

As the second part of our instructional framework, to deepen PSTs' understanding of effective EL instruction, we drew from and used Zwiers, O'Hara, and Pritchard's (2014) three levels of academic language: *vocabulary*, or word/phrase; *syntax*, or sentence/structure; and *discourse*, or message. At the vocabulary level, doing and talking science requires understanding and using general academic and science-specific terms as well as common words that have technical meanings (Fang, 2005). At the syntax level, it entails navigating the lengthy noun phrases and complex sentence structures typical of formal writing (Fang, 2005); being able to control the vocabulary and grammatical resources necessary to perform academic language functions, such as predicting, explaining, justifying, and arguing (Dutro & Moran, 2003); and creating and deciphering graphs, tables, and diagrams (Quinn et al., 2012). At the level of discourse, it involves distinctive ways of structuring information; signaling logical relationships and creating textual cohesion; and setting up an objective, authoritative relationship among the presenters or writers, their subject matter, and their audience (Schleppegrell, 2004). (See Table 1 below.)

We emphasized to PSTs the importance of attending to these three levels of language across the four EL principles – the idea that the principles and language levels overlap and should be used in concert with one another. To use students' funds of knowledge as resources, for example, PSTs could engage their EL students at each language level: They could ask ELs to define science vocabulary, construct sentences about a class topic, or communicate an argument in either or both their home language and English. We also emphasized the importance of including supports at all three language levels so that EL students could share their ideas and participate in sense-making discussions. We noted that most types of AL support, for example, a teacher's modeling of target language, could be used to scaffold ELs' learning at the vocabulary, syntax, or discourse level depending on its implementation. In short, we attempted to underscore for PSTs that while vocabulary is the easiest language level to assess, and syntax is key for building ideas, discourse is necessary for engaging in reasoning and communicating complex explanations and arguments.

Further, to demonstrate the overlapping nature of the principles and language levels, we implemented a model lesson on infiltration near the beginning of our methods course; we discuss this lesson in greater detail below. In this lesson, for example, to address the principle of cognitively demanding tasks, we asked PSTs to engage in a number of the NGSS science and engineering practices, including analyzing and interpreting data, developing and using models, and engaging in argument from evidence. We supported

PSTs' participation in these science and engineering practices at each level of language: We included visuals, realia, a word wall, and a word bank as supports at the vocabulary level; sentence frames and starters, a conversation support card, and a graphic organizer as supports at the syntax level; and an anchoring phenomenon, a driving question, groupwork, teacher modeling of target language, and home language use as supports at the discourse level. (See again Table 1.)

Table 1

*Definitions and Examples of Levels of Language (Adapted From Zwiers et al., 2014)*

| Level of Language                    | Vocabulary                                                                                                                                                                                                                                                                     | Syntax                                                                                                                                                                                                      | Discourse                                                                                                                                                                  |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Definition of Level                  | Determine the meaning of new words. Use appropriate words and phrases to communicate.                                                                                                                                                                                          | Combine ideas, phrases, and clauses into sentences. Use a variety of sentence types.                                                                                                                        | Create a logical flow of and connections between ideas, matching language with the purpose of the message.                                                                 |
| Example of Support from Model Lesson | Use terms from the word bank to communicate your thinking about permeability during your group and jigsaw discussions: milliliters, infiltrometer, surface, absorbed, infiltrated, rate, ranked, difference/no difference, permeable, semipermeable, impermeable, and pathway. | Craft two sentences to summarize findings (with or without the following sentence frames): "When we tested _____ (first surface), we found _____." "When we tested _____ (second surface), we found _____." | Participate in a jigsaw to discuss findings and engage in argument, providing claims, evidence, and reasoning for rankings of which surfaces were more and less permeable. |

## Methods Course Context

As stated above, this principle-based instructional framework structured our secondary science methods course. This course is part of a small, 13-month, post-baccalaureate teacher education program at a research university in Central California. It is the third in a series of science methods courses completed by PSTs, offered in their final semester of the program; there are typically 6 to 12 PSTs enrolled. PSTs complete their student teaching in a grade 7-12 science classroom while in this course. During the first half of the academic year, PSTs observe and help teach in classrooms as well.

## Infiltration Model Lesson: Highlighting the Four Key Principles and Three Language Levels

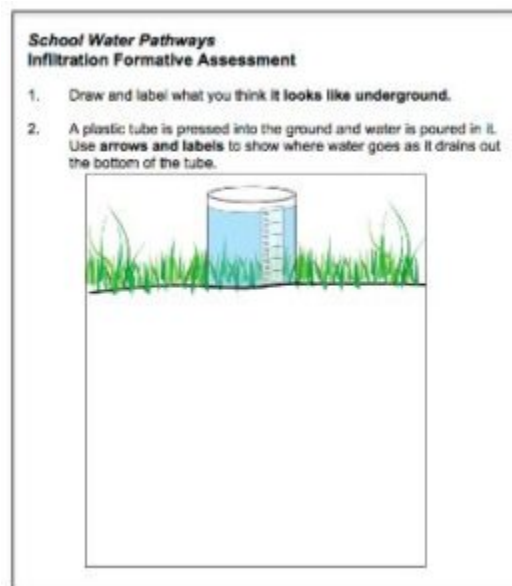
To situate our course and major assignment (i.e., the lesson development, implementation, revision, and reflection cycle), we implemented an environmental science lesson on infiltration. This model lesson highlighted both our four key principles of effective EL instruction and three levels of language. (The lesson was adapted from Exploration 4 of the *School Water Pathways* curricular unit, part of a learning progression-based environmental science curriculum. See Warnock et al., 2012.) It was implemented during the second week of the methods course, taking the entire three-hour session. Our PSTs first completed this lesson in their role as students and then discussed its strengths and limitations in their role as beginning teachers.

## Overview of the Infiltration Lesson

We began this lesson by introducing the PSTs to the larger *School Water Pathways* unit. The unit's purpose is to understand the complexities of the water cycle by exploring relationships among multiple processes, pathways, driving forces, and constraining factors on a school campus. PSTs watched a brief video clip of an anchoring event – rain falling and then pools of water “disappearing” from a school playground – and then were introduced to the driving question – Where does the water that falls on our school campus go? We also asked them to engage in the science and engineering practice of developing and using models by constructing an initial model of the water cycle in small groups.

PSTs next moved to the infiltration lesson, the fourth lesson in the *School Water Pathways* unit. To situate their infiltration investigation, they first completed a formative assessment, drawing and labeling where water moves after it is poured into a tube, or infiltrometer, that has been pressed into the ground (see Figure 2). After sharing their drawings with their elbow partner and then with the whole class, PSTs viewed both PowerPoint slides and physical samples of five surface types present on their campus (i.e., grass, asphalt, gravel, sand, and concrete) as well as made predictions about which surface they thought would be most permeable. They also viewed PowerPoint slides of scientists using infiltrometers; were reminded to consult a word wall of key vocabulary terms and their definitions related to the water cycle and a poster of groupwork norms; and were given a learning log with clear instructions, visuals, a conversation support card (i.e., question starters and response starters), and sentence frames to use for their investigation.

*Figure 2 (Click on image to enlarge).* Infiltration formative assessment task. Adapted from Warnock et al. (2012).



PSTs were next put into small groups, assigned group roles (e.g., facilitator, reporter, recorder, etc.), and were asked to select two surfaces found at their campus to investigate. They gathered their equipment (e.g., a bucket of water, an infiltrometer, a graduated cylinder, and a mallet), and moved outside to test the rate of infiltration of these surfaces, recording their data in their learning logs (see Figure 3). After the small groups had collected their data and returned to the classroom, they determined which surfaces were more or less permeable, calculating average rates of infiltration and providing evidence and reasoning for their rankings. PSTs then engaged in a jigsaw, sharing their findings and reasoning with members of other groups. We provided PSTs with a word bank and additional sentence starters and sentence frames to help with these discussions, supporting their work at the vocabulary, syntax, and potentially discourse levels.

*Figure 3 (Click on image to enlarge).* Preservice teachers collecting data on the rate of infiltration for grass.



As a summative assessment of understanding, PSTs completed a modified Frayer Model (i.e., a graphic organizer) of permeability that included four sections: definition, examples/representations, connections to the water cycle, and connections to the driving question of the unit. Given the contextualization of vocabulary during the investigation, in addition to a word wall and word bank, we expected PSTs to complete this Frayer Model using scientific terms. The lesson ended with a return to the science and engineering practice of developing and using models. PSTs reexamined their initial models of the water cycle and the driving question: How does this investigation help us understand water processes and pathways on our school campus? If we had additional time, at this juncture, we would press teacher candidates to ensure they bridged their initial ideas about infiltration from the formative assessment with the work they had completed during the investigation – to ensure they understood the concepts of water movement, evaporation, transpiration, infiltration, soil structure, gravity, permeability, and porosity.

### **Integrating the Four EL Principles and Three Language Levels in the Infiltration Lesson**

---

Below, we briefly discuss how we used this model lesson on infiltration to highlight for PSTs the four principles and three language levels in our framework for teaching reform-based science to ELs.

**EL principle funds of knowledge and resources.** This lesson demonstrated how PSTs could build from their students' funds of knowledge and resources in several ways. First, the larger unit was organized around a phenomenon, the science and engineering practice of developing and using models, and a question that connected to students' daily experiences as members of a school community: the movement of water on their campus. Second, the lesson we implemented began with a formative assessment (see again Figure 2): PSTs were asked to describe what they thought it looked like underground and to use arrows and labels to show where they thought water would move as it drained out of the bottom of an infiltrometer. The purpose of the formative assessment was to learn what students already knew about water, soil structure, gravity, permeability, porosity, evaporation, transpiration, and infiltration from their everyday lives and previous science classes. Because the larger curricular unit was informed by a learning progression framework (National Research Council [NRC], 2007) on water processes and pathways, the instructors were able to align PSTs' formative assessment responses with learning progression levels as well. Third, PSTs drew on their prior campus and community experiences to make predictions about the permeability of different surfaces before beginning their investigation. Fourth and finally, we encouraged PSTs to use any and all language(s) they knew – from their home language, to informal, everyday registers, to academic English – to complete the series of activities. For example, we reminded students as they worked in groups to record their observations and to compose their arguments using whatever words and/or phrases came to mind, encouraging them through instructor questioning and modeling as well as use of the word wall and word bank to gradually move from everyday language to more scientific terms.

**EL principle cognitively demanding work.** The infiltrometer lesson met the requirements of cognitively demanding work. PSTs engaged in sense-making and reasoning (Windschitl et al., 2018) while completing an authentic, analytic task that allowed students both to actively and meaningfully participate in the work of science and to develop language at the same time (Lee et al., 2013): They explored an NGSS core idea related to the water cycle and engaged in multiple science and engineering practices (NGSS Lead States, 2013). More specifically, in this lesson, PSTs explored performance expectation HS-ESS2-5 (plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes) and disciplinary core idea ESS2.C (the roles of water in Earth's surface properties). They learned about content related to water, soil structure, gravity, permeability, porosity, evaporation, transpiration, and infiltration. As part of the science and engineering practice of planning and carrying out investigations, PSTs made predictions, identified two different locations on campus to investigate, measured infiltration rates by recording time and amounts of water, and plotted their findings on a graph. As part of the practice of engaging in argument from evidence, they provided evidence and reasoning for their rankings of



surfaces. They also used mathematics to calculate infiltration rates and engaged in developing and using models to inform the driving question of water processes and pathways in the context of a school campus.

**EL principle language rich opportunities.** Throughout the lesson, the instructors created multiple, purposeful opportunities for PSTs to produce appropriate comprehensible output – to engage in talking and writing science. They also provided opportunities for PSTs to receive comprehensible input through listening and speaking. As one example, PSTs worked in small groups to collect and analyze data as well as to share their tentative arguments, grounded in evidence, about the relative permeability of surfaces tested. Groupwork norms and roles were used to productively structure these small group interactions (Cohen & Lotan, 2014). As a second example, in completing both formative and summative assessments, PSTs conveyed their understanding of water processes and pathways using a diagram (formative assessment) and a graphic organizer (summative assessment); in the former instance, they were encouraged to use everyday language, and in the latter, academic language or the language of display (Bunch, 2014).

**EL principle academic language demands and supports.** The instructors identified the language demands of the tasks that they provided PSTs and created a range of supports appropriate for ELs to help move the PSTs toward participation in a science community of practice. Supports were organized into five categories: creating a meaningful context, making input comprehensible, helping students produce oral and written discourse, validating existing language and linguistic practices, and other (see Quinn et al., 2012, for a similar organization of supports). As one example, the instructors included realia (e.g., an infiltrometer and glass jars of different surface types) and visuals of the tasks that students would complete so that terms like *infiltration* and *permeability* would not serve as a barrier to participation. As a second example, the instructors modeled the use of science discourse, included sentence starters on a conversation support card and additional sentence frames in the learning logs (Zwiers et al., 2014), and implemented groupwork to facilitate productive classroom discussions – to help PSTs move beyond a focus on science terminology to encourage investigating, using mathematics, arguing from evidence, and developing and using models. Finally, as noted already under funds of knowledge, PSTs were encouraged to use multiple languages and registers across representations of and discussions about rich science content so as to advance their understanding of the science concepts.

**Three levels of language.** Across the infiltration lesson, as introduced under our discussion of academic language demands and supports above, we included systematic supports not only to facilitate PSTs' practice of vocabulary terms, but their production of sentences and discourse as well. We explicitly reminded PSTs of the importance of attending to and including supports not only at the vocabulary level of language, but at the syntax and discourse levels as well. In the section Three Levels of Language and Table 1, presented above, we provide specific examples of supports present in our infiltration lesson at each of these three levels of language (see again Zwiers et al., 2014).

## PSTs' Lesson Development, Implementation, and Reflection Cycle

In the weeks after participating in this model lesson, PSTs followed a seven-step process to develop, implement, revise, and reflect on their own lesson, using our four EL principles and three language levels as guides. As we explained above, the infiltration lesson implemented in Week 2 served as the backdrop for the PSTs' own lesson development.

### Step 1: Develop Initial Lesson Using the Four EL Principles and Three Language Levels

PSTs worked in partners to develop a science lesson that incorporated all four EL principles as well as at least one support for each of the three levels of language. Zwiers et al. (2014) emphasized the importance of moving beyond vocabulary and grammar rules to teaching students complex ideas through discourse. As such, we pushed our PSTs to support ELs' development of *discourse* as well as *vocabulary* and *syntax* in their lesson. We note that we scaffolded PSTs in developing and implementing their lessons using supports they could use with their own ELs: We both modeled a lesson (discussed above) and provided them a lesson checklist (see Figure 4), organized by principles and including sentence starters (see also Calabrese Barton & Tan, 2018).

*Figure 4 (Click on image to enlarge).* EL lesson plan checklist developed by authors to facilitate PSTs' use of the four principles and three language levels in their design and implementation of a lesson.

| Principles                                                                                                                                    | Yes                                                                   | Sort of | No |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|---------|----|
| <b>EL Principle 1: I will elicit and build from students' funds of knowledge by attending to their...</b>                                     |                                                                       |         |    |
| Home life                                                                                                                                     |                                                                       |         |    |
| Cultural background                                                                                                                           |                                                                       |         |    |
| Home language(s)                                                                                                                              |                                                                       |         |    |
| Community resources                                                                                                                           |                                                                       |         |    |
| <b>Local geographical and ecological resources/place</b>                                                                                      |                                                                       |         |    |
| <b>EL Principle 2: I will engage my students in cognitively demanding tasks that address the following science and engineering practices:</b> |                                                                       |         |    |
| SAE.1 Asking questions and defining problems                                                                                                  |                                                                       |         |    |
| SAE.2 Developing and using models                                                                                                             |                                                                       |         |    |
| SAE.3 Planning and carrying out investigations                                                                                                |                                                                       |         |    |
| SAE.4 Analyzing and interpreting data                                                                                                         |                                                                       |         |    |
| SAE.5 Using mathematics and computational thinking                                                                                            |                                                                       |         |    |
| SAE.6 Constructing explanations and designing solutions                                                                                       |                                                                       |         |    |
| SAE.7 Engaging in argument from evidence                                                                                                      |                                                                       |         |    |
| SAE.8 Obtaining, evaluating, and communicating information                                                                                    |                                                                       |         |    |
| <b>EL Principle 3: I will provide my students opportunities for rich language and literacy ....</b>                                           |                                                                       |         |    |
| Exposure by listening                                                                                                                         |                                                                       |         |    |
| Exposure by reading                                                                                                                           |                                                                       |         |    |
| Practice through speaking                                                                                                                     |                                                                       |         |    |
| Practice through writing                                                                                                                      |                                                                       |         |    |
| <b>EL Principle 4 Part 1: I will provide my students adequate scaffolds and supports for ....</b>                                             |                                                                       |         |    |
| Oral academic language                                                                                                                        |                                                                       |         |    |
| Written academic language                                                                                                                     |                                                                       |         |    |
| <b>EL Principle 4 Part 2: I will provide my students adequate scaffolds and supports for academic language at the level(s) of...</b>          |                                                                       |         |    |
| Vocabulary                                                                                                                                    |                                                                       |         |    |
| Syntax                                                                                                                                        |                                                                       |         |    |
| Discourse                                                                                                                                     |                                                                       |         |    |
| <b>EL Principle 4 Part 3: I will provide my students adequate scaffolds and supports for academic language by....</b>                         |                                                                       |         |    |
| Creating a meaningful context                                                                                                                 | Connecting to everyday life                                           |         |    |
|                                                                                                                                               | Connecting to a socioscientific issue                                 |         |    |
|                                                                                                                                               | Starting with a phenomenon                                            |         |    |
|                                                                                                                                               | Implementing a hands-on activity                                      |         |    |
| Making input comprehensible                                                                                                                   | Defining vocabulary terms                                             |         |    |
|                                                                                                                                               | Chunking the task                                                     |         |    |
|                                                                                                                                               | Providing a low floor, high ceiling, and wide walls                   |         |    |
|                                                                                                                                               | Speaking slowly and providing clear directions                        |         |    |
|                                                                                                                                               | Structuring reading                                                   |         |    |
|                                                                                                                                               | Using visuals, gestures, graphic organizers, demonstrations, or media |         |    |
|                                                                                                                                               | Including word learning strategies (e.g., etymology, context clues)   |         |    |
| Helping students produce spoken and/or written discourse                                                                                      | Facilitating small group discussion                                   |         |    |
|                                                                                                                                               | Facilitating whole class discussion                                   |         |    |
|                                                                                                                                               | Including a word wall and/or word bank                                |         |    |
|                                                                                                                                               | Modeling target language                                              |         |    |
|                                                                                                                                               | Providing opportunities for students to practice academic language    |         |    |
|                                                                                                                                               | Implementing peer collaboration                                       |         |    |
|                                                                                                                                               | Including a rubric or checklist                                       |         |    |
|                                                                                                                                               | Including sentence starters and/or frames                             |         |    |
|                                                                                                                                               | Using student work exemplars                                          |         |    |
| Validating existing languages and linguistic practices                                                                                        | Encouraging home language(s)                                          |         |    |
|                                                                                                                                               | Code-switching/translating between everyday and scientific languages  |         |    |
|                                                                                                                                               | Starting with everyday language                                       |         |    |
| Other                                                                                                                                         | Differentiating                                                       |         |    |
|                                                                                                                                               | Providing individual or extra instruction                             |         |    |

### Step 2: Interview an EL to Test Out Part of the Lesson

To begin the revision phase of this lesson cycle assignment, PSTs tried out part of their lesson in an interview with an EL in their student teaching placement. As with each pair's lesson plan, each pair's EL interview protocol was unique. We asked PSTs to select a part of their lesson for the interview that they thought was challenging, in order to give them a chance to see how a real student would respond before "going live" with a full class. We

viewed the interview as an opportunity for PSTs to work one-on-one with an EL not only to get to know this student better but also to get to know more about what this student understood about the content. PSTs then shared what they had learned from this interview with the other PSTs in the class and wrote a one-to-two-page reflection. Through this process, the PSTs were able to see how well their content and language supports worked with an EL and to have the space for reflection and modifications needed before presenting their lesson to the whole methods class.

### **Step 3: Meet With and Receive Feedback From Instructors**

---

Each pair of PSTs next met with the course instructors to discuss their revised lesson; this meeting occurred the week before the lesson was to be presented to the methods class. The PSTs walked the instructors through the content goals, the lesson activities and assignments, and how they intended to attend to the four EL principles and the three levels of language. Additionally, because the PSTs had already tried out a part of their lesson in the context of an interview, they shared what they had learned from their ELs and what subsequent revisions they had made. The PSTs then used the instructors' feedback to revise their lesson yet again.

### **Step 4: Try Out Lesson in Methods Course**

---

PST pairs presented their lesson to the full methods class; they were given approximately 40 minutes to do so. In the five minutes following the lesson, the PSTs and their peers filled out a self- or peer-assessment that focused on how well the PSTs attended to the four key principles and three levels of language as well as two plusses (things they liked) and two deltas (things they would change) more generally; they referred to the lesson plan checklist to do so. In the next five minutes, the PSTs who presented the lesson highlighted what they thought they did well and wanted to improve, again related to their implementation of the four EL principles and the three levels of language. This provided the foundation for the additional feedback and discussion that followed. At the end of this debriefing session, the PSTs' peers and instructors provided their written feedback to the PSTs. The PSTs took this oral and written feedback to continue to improve their lesson for enactment in their student teaching placement. They were also encouraged to ask their cooperating teachers for insight and feedback prior to their implementation of the lesson, based on the individual needs of their students.

### **Step 5: Enact Lesson in Placement**

---

On the agreed upon day, PSTs taught their lesson in their student teaching placement. The PSTs were expected to take notes about how the lesson went and what they might have done to further adjust the lesson. Additionally, the PSTs collected student work during their enactment to analyze during the following methods course.

### **Step 6: Reflect on Lesson Using Student Work**

---

Using the below prompts (see Figure 5), which we modified from the National School Reform Faculty (2014) to specifically address our principles and language levels, PSTs individually reflected on three samples of student work, at least one of which was from an EL. Using a structured student work reflection protocol such as this allows PSTs to focus on a specific aspect of instruction: to direct their attention towards students, including EL students, and how they responded to their instruction. Without such a tool, in their final reflections on their lesson, PSTs might instead focus on surface level aspects of their instruction, such as how often they used “um” or their ability to pass out papers with fluidity.

*Figure 5 (Click on image to enlarge).* Student work reflection prompts completed by PSTs. Adapted from the National School Reform Faculty (2014).

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>1. Describe the work. What do you see and notice with regards to the EL supports you provided using the four EL principles and the three language levels for discourse, syntax, and vocabulary? Avoid inference, interpretation, or judgment.</p> <p><i>I see... I notice... There are many... There are few...</i></p> <p>2. Interpret the work. What does the student seem to be trying to do, especially with regards to the supports you provided? Now is when you infer, interpret, and judge.</p> <p><i>The student seems to think... The student has learned... The student understands...</i></p> <p>3. Discuss implications for classroom practice. What would be the best next steps for the teacher to take, especially using the four EL principles and three language levels? What does the student seem ready to learn?</p> <p><i>As a next step, a teacher could... The student needs additional help with...</i></p> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Step 7: Final Share Out of Process

---

Our final step was to bring all pairs of PSTs together in the methods class to reflect on the lesson cycle collectively. PSTs wrote a second one-to-two-page reflection and shared with each other what they had learned through this process, highlighting the four EL principles and the three levels of language, how they used each to support ELs, and what they learned from analyzing their students’ work. This collective reflection closed the lesson process by allowing PSTs to once again learn from each other.

## Preservice Teachers’ Reflections

To summarize, we see our four key principles and three levels of language as useful both for teacher educators in designing and implementing a science methods course to support ELs and for PSTs themselves as they work with ELs in their science classrooms. In our methods course, we used the infiltration lesson to provide PSTs with an opportunity to see the four key principles and three levels of language in situ. The lesson also offered PSTs a shared context to begin discussions with colleagues about how these principles and levels of language could play out and interact with each other when teaching disciplinary content. Further, the principles and levels – as outlined in the lesson plan checklist – served to structure PSTs’ own attempts to craft science lessons responsive to ELs.

We have evidence from PSTs’ written reflections that they found the lesson cycle, framed by the principles and language levels, useful in thinking more deeply about how to teach ELs reform-based science. During our Spring 2018 methods course, we collected two written

reflections from each of our PSTs related to the lesson cycle: one after interviewing an EL student about their draft lesson (interview reflections) and another at the close of the cycle (lesson cycle reflections). In analyzing the PSTs' interview and lesson cycle reflections, we found that each used the four EL principles and at least two of the three language levels to gain insight into the strengths and limitations of their lessons.

As one example, Vince and Savannah partnered to develop a middle school life science lesson about a wetland ecosystem (see performance expectation MS-LS2-3, where students are asked to develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem). Working in groups, students were to create a food web organized by trophic levels and use it to predict the effects of species loss. In his reflections, Vince discussed the strengths and limitations of this lesson in terms of cognitive demand, academic language demands and supports, language opportunities, and attending to students' funds of knowledge. In particular, he viewed the cognitive demand of the lesson – targeted at the discourse level – as a strength:

Students were answering the question, “What is a food web?”, by developing their own model of a food web through peer discourse. . . . In the formation of their model, students analyzed and interpreted data on what each species in their food web ate. This information was used to decide which species belonged in which trophic level and also to model the flow of energy through the food web and ecosystem. . . . Students also used mathematical thinking to calculate the flow of energy from one trophic level to the next by using the 10 percent rule. . . . Lastly, students evaluated their information and engaged in argument using the evidence from their model to form a prediction as to what would happen to their food web if all the fish species were to go extinct.

Vince also noted ways he could further strengthen attention to this principle in future iterations of this lesson:

I would include more of an individual component [in addition to a group poster] to ensure all students are adequately being exposed to the concepts and are thinking critically about them. I also think that it could be interesting to add in a component of designing solutions to species loss or invasive species.

Vince identified strengths and limitations in his efforts to address academic language demands and supports at each level of language. At the vocabulary level, although he had provided students with a list of new vocabulary terms, he “felt that students could have benefited from a more explicit vocabulary acquisition activity” as they “either did not look at the list or immediately lost it.” He thought that “syntax was [adequately] support[ed] by sentence starters on the free response questions.” Further, while the lesson included visuals, peer support, chunking of the task, and student work samples to support students' oral and written discourse, Vince thought he could have better supported “small and whole group

discussions through differentiation of food web questions and providing students with some sort of discussion scaffolds.” He connected this last point to the language production opportunities he provided students:

To improve this lesson in the future, I would build in more discourse and differentiation of questions for the prediction aspect of the lesson and have the students present to the class their arguments [in addition to creating a group poster]. This would allow students to communicate their predictions using academic language.

Finally, Vince thought that attention to students’ funds of knowledge was the weakest aspect of Savannah’s and his wetlands ecosystem lesson. Although Vince drew from students’ previous understanding of food chains when introducing this lesson, he thought he could have done more. He elaborated, “[T]his lesson was very accessible to all students in the class but was most lacking in this principle. The food web was based on a wetland ecosystem but did not specifically connect with local resources or students’ home backgrounds.” Next time, Vince continued, he would attempt to use a local wetland as the context for the lesson.

As a second example, Madison and Drew designed a high school chemistry lesson on equilibrium and Le Chatelier’s Principle. Students first participated in a paper-ball-throwing activity to develop an initial model of equilibrium then attempted to make sense of color changes in the reaction  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$  (pink) +  $4\text{Cl}^{-}(\text{aq}) \rightleftharpoons [\text{CoCl}_4]^{2-}(\text{aq})$  (blue) +  $6\text{H}_2\text{O}(\text{l})$ , and finally worked to revise their initial model of equilibrium.... Like Vince, Madison thought Drew’s and her lesson “was cognitively demanding for students”:

This lesson sequence focused on creating and using models as well as being aligned to the DCI [of chemical reactions]. . . . The assessment is aligned to the performance expectation, HS-PS1-6, which reads: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

She noted that while she and Drew had connected the lesson to a performance expectation, disciplinary core idea, and science and engineering practice, they “missed an opportunity to include stability and change,” one of the NGSS crosscutting concepts as well.

Madison discussed the multiple intersections in their lesson between language opportunities and academic language supports at the vocabulary, syntax, and discourse levels. At the vocabulary level, during the assessment, students were provided with “vocabulary terms and definitions . . . so that there is no pressure on memorizing terms, but rather a focus on using them properly in a [written] argument.” At the sentence level, “sentence frames for both writing and speaking are addressing the syntax of this topic.” At the discourse level, students were encouraged to “code-switch” in their small group and whole class discussions, using everyday language to explain when initially engaging in the science and engineering practice

of modeling but using academic language to argue why a particular variable (e.g., adding  $\text{Cl}^-$  via  $\text{KCl}$ , adding heat) caused a color change in the reaction. She added that, next time, she would include “teacher modeling of conversation . . . especially if we are asking students to argue their ideas” as an additional academic language support.

Also, as did Vince, Madison acknowledged that she and Drew struggled to effectively connect this activity to students’ funds of knowledge. For the assessment piece, she positioned students as engineers tasked with producing methanol ( $\text{CH}_3\text{OH}$ ), because they “are all very eager to begin driving.” She elaborated, “I attempted to connect the assessment to their everyday lives . . . , however, I did not support this with context”: the information that methanol is a cleaner alternative to petroleum. “Moving forward,” Madison continued, “I would either provide more context for the methanol reaction or use the fertilizer reaction instead,” a reaction recommended by a preservice teacher colleague as a way to more directly connect to students’ lives.

Overall, Vince, Savannah, Madison, and Drew developed lessons enacting principles of effective EL science instruction and three levels of language. They thought they had provided their students with adequate opportunities to engage in the principle of cognitively demanding work. Additionally, they immersed their students in language opportunities and language demands at multiple language levels. The PSTs found funds of knowledge the most challenging of the four principles to incorporate and execute in their lessons. They also noted that going forward, they would use modeling as an additional academic language support at the syntax and discourse levels.

## **Innovations and Next Steps**

---

We think our course and this assignment, in particular, are innovative for three reasons. First, we maintained a focus on ELs throughout our course; there are few science methods courses (or content methods courses, more generally) currently using such an approach. While many methods courses might attend to ELs on a single day, in a single lesson, or with a single reading, our course used a principle-based framework to organize instruction and types of support for ELs. Second, we used a model lesson built on a learning progression (NRC, 2007) to introduce our EL principles and levels of language to our PSTs. Using such a lesson is linked to one of our four key principles, funds of knowledge, which we have found is difficult for PSTs to attend to in their instruction (Roberts et al., 2017). Third, to further strengthen their instructional practice, we encouraged PSTs’ use not only of traditional supports for ELs, but of other research-based practices as well, including groupwork (Cohen & Lotan, 2014) and productive academic interactions (Zwiers et al., 2014), to elicit and build on students’ language.

As the population of ELs continues to grow across the U.S. (Goldenberg, 2008), there is a clear need for all beginning science teachers to be able to support ELs. In other words, as demographics continue to change, ELs are a student population that all teachers need to be

prepared to attend to and engage in their instruction. To help PSTs learn to teach ELs effectively requires creating content methods courses that are systematically organized around principles and that focus specifically on how to meet ELs' needs. In this paper, we attempted to provide insight into what is needed for science teacher educators going forward to better support beginning science teachers of ELs, as well as examples of what this work might look like when implemented in methods courses. Additional research is needed to understand how teacher education programs overall should be structured to support PSTs in working with ELs – so that all ELs have access to effective science curriculum and instruction, and to the larger science communities of practice.

## Author Note

---

Sarah A. Roberts, and Julie A. Bianchini, Department of Education, University of California, Santa Barbara.

This researcher was supported by a grant from the National Science Foundation (DUE-1439923).

Correspondence concerning this paper should be addressed to Sarah A. Roberts, University of California, Gevirtz Graduation School of Education, Santa Barbara, CA 93106-9490. Contact: [sroberts@education.ucsb.edu](mailto:sroberts@education.ucsb.edu)

ORCID ID: [0000-0002-7191-9175](https://orcid.org/0000-0002-7191-9175)

## References

---

- Aguirre, J. M. & Bunch, G. C. (2012). What's language got to do with it?: Identifying language demands in mathematics instruction for English language learners. In S. Celedón-Pattichis & N. Ramirez (Eds.), *Beyond good teaching: Advancing mathematics education for ELLs*. (pp. 183-194). Reston, VA: National Council of Teachers of Mathematics.
- Bleicher, R. E., Tobin, K. G., & McRobbie, C. J. (2003). Opportunities to talk science in a high school chemistry classroom. *Research in Science Education*, 33, 319-339. doi:10.1023/A:1025480311414
- Bravo, M. A., Mosqueda, E., Solís, J. L., & Stoddart, T. (2014). Possibilities and limits of integrating science and diversity education in preservice elementary teacher preparation. *Journal of Science Teacher Education*, 25, 601-619. doi:10.1007/s10972-013-9374-8
- Buck, G., Mast, C., Ehlers, N., & Franklin, E. (2005). Preparing teachers to create a mainstream science classroom conducive to the needs of English-language learners: A feminist action research project. *Journal of Research in Science Teaching*, 42, 1013–1031. doi:10.1002/tea.20085



- Bunch, G. C. (2014). The language of ideas and the language of display: Reconceptualizing academic language in linguistically diverse classrooms. *International Multilingual Research Journal*, 8(1), 70-86. <https://doi.org/10.1080/19313152.2014.852431>
- Calabrese Barton, A., & Tan, E. (2018). Teacher learning and practices toward equitably consequential science education. In H. Kang (Chair), *Pre-service science teacher education symposium: Re-framing problems of practice in preparing new science teachers for equity in the NGSS era*. Symposium conducted at the meeting of the National Association for Research in Science Teaching, Atlanta, GA.
- Cohen, E. G., & Lotan, R. (2014). *Designing groupwork: Strategies for the heterogeneous classroom* (3<sup>rd</sup> ed.). New York, NY: Teachers College.
- Dutro, S., & Moran, C. (2003). Rethinking English language instruction: An architectural approach. In G. Garcia (Ed.), *English learners: Reaching the highest level of English literacy* (pp. 227-258). Newark, DE: International Reading Association.
- Fang, Z. (2005). Scientific literacy: A systemic functional linguistics perspective. *Science Education*, 89, 335–347. doi:10.1002/sce.20050
- Goldenberg, C. (2008). Teaching English language learners: What the research does – and does not – say. *American Educator*, 32, 8-23, 42-44.
- Iddings, A. C. D. (2005). Linguistic access and participation: English language learners in an English-dominant community of practice. *Bilingual Research Journal*, 29, 165-183. <http://dx.doi.org/10.1080/15235882.2005.10162829>
- Johnson, C. C., Bolshakova, V. L. J., & Waldron, T. (2016). When good intentions and reality meet: Large-scale reform of science teaching in urban schools with predominantly Latino ELL students. *Urban Education*, 51, 476-513. doi:10.1177/0042085914543114
- Khisty, L. L., & Chval, K. B. (2002). Pedagogic discourse and equity in mathematics: When teachers' talk matters. *Mathematics Education Research Journal*, 14, 154-168. doi:10.1007/BF03217360
- Lee, O., & Buxton, C. A. (2013). Teacher professional development to improve science and literacy achievement of English language learners. *Theory Into Practice*, 52, 110-117. <http://dx.doi.org/10.1080/00405841.2013.770328>
- Lee, O., Deaktor, R., Enders, C., & Lambert, J. (2008). Impact of a multiyear professional development intervention on science achievement of culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching*, 45, 726-747. doi:10.1002/tea.20231

- Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to Next Generation Science Standards and with implications for Common Core State Standards for English Language Arts and Mathematics. *Educational Researcher*, 42, 223-233. doi:10.3102/0013189X13480524
- Lyon, E. G., Tolbert, S., Stoddart, P., Solis, J., & Bunch, G. C. (2016). *Secondary science teaching for English learners: Developing supportive and responsive learning contexts for sense-making and language development*. New York, NY: Rowman & Littlefield.
- Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and schools. *Theory into Practice*, 31, 132-141. <http://dx.doi.org/10.1080/00405849209543534>
- Moschkovich, J. (2002). A situated and sociocultural perspective on bilingual mathematics learners. *Mathematical Thinking and Learning*, 4, 189-212. [http://dx.doi.org/10.1207/S15327833MTL04023\\_5](http://dx.doi.org/10.1207/S15327833MTL04023_5)
- Moschkovich, J. (2007). Using two languages when learning mathematics. *Educational Studies in Mathematics*, 64, 121-144. doi:10.1007/s10649-005-9005-1
- National Clearinghouse for English Language Acquisition. (2009). *How has the limited English proficient student population changed in recent years?* Washington, DC: NCELA. Retrieved from [http://www.ncele.us/files/rcd/BE021773/How\\_Has\\_The\\_Limited\\_English.pdf](http://www.ncele.us/files/rcd/BE021773/How_Has_The_Limited_English.pdf)
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Retrieved from <http://www.nextgenscience.org/next-generation-science-standards>
- National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, D.C.: National Academies Press.
- National School Reform Faculty. (2014). *ATLAS: Learning from student work*. Retrieved from [https://www.nsrharmony.org/system/files/protocols/atlas\\_lfsw\\_0.pdf](https://www.nsrharmony.org/system/files/protocols/atlas_lfsw_0.pdf)
- Planas, N., & Gorgorió, N. (2004). Are different students expected to learn norms differently in the mathematics classroom? *Mathematics Education Research Journal*, 16, 19-40. doi:10.1007/BF03217389
- Quinn, H., Lee, O., & Valdés, G. (2012). *Language demands and opportunities in relation to next generation science standards for English language learners: What teachers need to know*. Retrieved from <http://ell.stanford.edu/publication/language-demands-and-opportunities-relation-next-generation-science-standards-ells>
- Richardson Bruna, K., Vann, R., & Escudero, M. P. (2007). What's language got to do with it?: A case study of academic language instruction in a high school "English learner science" class. *Journal of English for Academic Purposes*, 6(1), 36-54.

Roberts, S. A., Bianchini, J. A., Lee, J. S., Hough, S., & Carpenter, S. (2017). Developing an adaptive disposition for supporting English language learners in science: A capstone science methods course. In A. Oliveira & M. Weinburgh (Eds.), *Science Teacher Preparation in Content-Based Second Language Acquisition* (pp. 79-96). Columbus, OH: Association of Science Teacher Educators.

Rosebery, A. S., & Warren, B. (Eds.). (2008). *Teaching science to English language learners: Building on students' strengths*. Arlington, VA: NSTA Press.

Schleppegrell, M. J. (2004). *The language of schooling: A functional linguistics perspective*. Mahwah, NJ: Lawrence Erlbaum Associates.

Tekkumru-Kisa, M., Stein, M. K., & Schunn, C. (2015). A framework for analyzing cognitive demand and content-practices integration: Task analysis guide in science. *Journal of Research in Science Teaching*, 52, 659-685. doi:10.1002/tea.21208

Tobin, K. G., & Kahle, J. B. (1990). *Windows into science classrooms: Problems associated with higher-level cognitive learning*. Bristol, PA: The Falmer Press, Taylor & Francis Group.

Understanding Language. (2013). *Six key principles for ELL instruction*. Retrieved from Stanford University, Graduate School of Education, Understanding Language website <http://ell.stanford.edu/content/six-key-principles-ell-instruction>

Warnock, A., Berkowitz, A., Blank, B., Cano, A., Caplan, B., Covitt, B., . . . Whitmer, A. (2012). *School water pathways*. Retrieved from [http://www.pathwaysproject.kbs.msu.edu/?page\\_id=49](http://www.pathwaysproject.kbs.msu.edu/?page_id=49)

Windschitl, M., Thompson, J., & Braaten, M. (2018). *Ambitious science teaching*. Cambridge, MA: Harvard University.

Zwiers, J., O'Hara, S., & Pritchard, R. (2014). *Essential practices for developing academic language and disciplinary literacy*. Portland, ME: Stenhouse Publishers.