

SECONDARY SCIENCE TEACHERS' LANGUAGE AND LITERACY INSTRUCTION
WITH AN EMPHASIS ON ENGLISH LEARNERS

by

SHIM LEW

(Under the Direction of Linda Harklau)

ABSTRACT

This study examines the language and literacy instruction of science educators who participated in an English to Speakers of Other Languages (ESOL) professional development program. Using in-depth longitudinal case study methods, the study explores the various ways in which science educators interpret and incorporate language and literacy components into their classrooms. With a rapidly increasing immigrant population and persistent achievement inequity between English learners (ELs) and non-ELs, it is crucial for all K-12 teachers to be prepared to work with ELs. This is especially true for science teachers due to the demonstrated underachievement of ELs on standardized science tests. In addition, with the introduction of the highly language intensive Next Generation Science Standards, science teachers need ESOL professional learning to work with all students in linguistically responsive ways. The first article of this dissertation reveals that the participating science teachers adopted a new hybrid professional identity as science and language teachers as a result of the participation in an ESOL professional development program; however, their extended identity was not enacted in actual classroom practices. The second article indicates that there is a considerable gap between current policy and standards discussions and classroom realities, especially in reading instruction for

ELs. The third chapter shows that science teachers offered very little explicit writing instruction despite their efforts to meet advanced writing demands and the presence of a variety of supports for ELs to engage successfully in writing tasks. In all, regardless of the teachers' self-evaluation of their preparedness, they displayed starkly different enactments of their learning in the program depending on their instructional histories, personal backgrounds, previous learning and teaching experience, and current instructional circumstances including mandatory standardized tests and students' literacy levels. The study thus emphasizes how each science educator's uptake of the ESOL endorsement program is distinctive, complex, and multi-layered, resulting in widely varying instantiations of actual ESOL instruction in their science classrooms. This study contributes to the development of more focused and systematic ESOL education for science educators and, eventually, will help to attract more educators to ESOL professional development.

INDEX WORDS: English learners, ESOL professional development, Hybrid professional identity, Secondary science teachers, Science language and literacy

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DEDICATION

This dissertation is dedicated to all teachers who battle with countless obstacles, but still make changes every day.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

English learners (ELs) are among the lowest-achieving groups in American schools. 9.2% of students in U.S. public schools, which represents an estimated 4.4 million students, were identified as ELs in the school year 2012–13. However, the National Assessment of Educational Progress (NAEP) shows that achievement inequities between ELs and non-ELs have persisted over a couple of decades (Kena et al., 2015). Accordingly, many educators and scholars have called for increased English to Speakers of Other Languages (ESOL) education for all teachers, including content-area educators. In particular, with the introduction of the highly language-intensive Next Generation Science Standards (NGSS), science teachers need ESOL professional learning to work with all students, including ELs, in more linguistically responsive ways.

Historically, instructional interventions for ELs reduced the rigor of course work, such as simplifying the curriculum or slowing the pace, which exacerbated the low achievement of ELs, who were already behind (Greenleaf, Litman, Hanson, Rosen, Boscardin, Herman, & Schneider, 2011). The recent educational reform in science education through the NGSS focuses on high academic achievement for all students, including ELs. Another intervention used by mainstream teachers to make academic content more accessible to culturally and linguistically diverse (CLD) students¹, culturally responsive instruction, has been extensively investigated. Moreover there

¹ Due to “both the homogeneity and heterogeneity within and among, linguistically and culturally diverse populations,” one set of descriptions or prescriptions will not be sufficient; however, members of these populations share some features including their bilingual/bicultural character and certain aspects of their instructional circumstances (Garcia, 1991, p.2).

has been a great amount of work in literacy research regarding disciplinary literacy instruction and in applied linguistics to integrate content and language.

Research regarding science teachers' integration of science instruction and language development has been growing over the past decade; however, the research foci have generally been restricted to elementary teachers. While a few studies have included middle school science teachers, information on high school science teachers is lacking. Moreover, most research on ESOL professional learning for in-service science teachers has looked only at short-term professional development² programs. Virtually no research has been done on teachers' experiences in relatively long-term programs. Also, there has been a lack of details about individual or groups of teachers' adoption of or resistance to what they learn in these programs. There is no longitudinal case study investigating the experience of the individual science teachers in ESOL programs. Moreover, very little work has carefully documented the baseline conditions of actual literacy practices and instruction in science classrooms with ELs. Even less research has looked at the implications of teacher beliefs and practices regarding reading and writing in science for ELs' language development and content learning.

In all, there is a noticeable lack of research in secondary science teachers' instruction for ELs. In order to address these educational problems and gaps in the literature, this study provides an in-depth description of what science teachers experience in the process of one ESOL professional development program and what actually happens in science classroom regarding language and literacy instruction by using a longitudinal multiple case study method. The study asks how science teachers' beliefs regarding their professional identity, good science teaching, and good ESOL teaching evolve as a result of the ESOL professional learning and how they

² Professional development (PD) refers to "formal in-service training to upgrade the content knowledge and pedagogical skills of teachers" (Quint, 2011).

provide reading and writing instruction in their classrooms to meet the advanced language demands of the new science standards. Accordingly, the guiding questions for each chapter are:

1. How do science teachers develop their hybrid professional identity as science and language/ESOL teachers through a boundary crossing experience of participating in ESOL professional development?
2. How do reading practices in actual science classrooms coincide with and diverge from the ideal NGSS notions of scientific literacy?
3. How do writing practices and instruction in the science teachers' classrooms converge toward and diverge from the principles of writing practices recommended by the Common Core State Standards (CCSS) and the NGSS?

Literature Review

In a 2002 national survey, 41% of teachers had ELs in their classrooms (Gruber, Wiley, Broughman, Strizek, & Burian-Fitzgerald, 2002). In 2007-2008, 11.3% of all K-12 students were ELs, and 55% of all schools had at least one EL (Keigher, 2009). However, the percentage of teachers who participated in professional development focused on teaching limited-English proficient students or ELs was only 24.3% overall in 2011-2012 (Goldring, Gray, & Bitterman, 2013).

In response to this urgency in teacher preparation, a number of frameworks have been proposed to describe the knowledge, skills, and dispositions of mainstream teachers who are effective with ELs. Regarding knowledge and skills, de Jong and her colleagues (de Jong & Harper, 2005; de Jong, Harper, & Coady, 2013) assert that effective EL teachers need additional linguistic and cultural knowledge and skills in addition to “just good teaching” practices and must apply that special knowledge and those skills to curriculum planning, instruction, and

assessment for ELs (de Jong & Harper, 2005, p.102). Linguistic knowledge that they identify includes second language learners' oral language development, second language literacy development, and specialized language in content areas. Cultural knowledge that they believe teachers of ELs need includes understanding that learning opportunities for ELs might be limited because of culturally different expectations regarding classroom routines or literacy backgrounds. Regarding implementation skills, they suggest the inclusion of linguistic and cultural diversity as explicit goals of curriculum and instruction. The knowledge and skills that de Jong and her colleagues identify inform teacher educators of what to add in regular teacher education programs to prepare pre-service and in-service teachers to work with ELs.

Lucas and her colleagues are concerned that language issues tend to be ignored within a culturally responsive teaching framework, such as a diversity course, and differentiate language issues from cultural diversity in EL teacher education (Lucas & Grinberg, 2008; Lucas, Villegas, & Freedson-Gonzalez, 2008). They emphasize the linguistic domain even further and propose linguistically responsive pedagogical practices (Lucas et al., 2008). For example, to scaffold learning for ELs, it is suggested that teachers expand the linguistic and extra-linguistic context of a learning task by using extra-linguistic supports, supplementing and modifying written text/oral language, facilitating and encouraging the use of students' native languages, and so forth (Lucas et al., 2008; Walqui, 2008).

In the literature on science education, the framework of instructional congruence emphasizes building congruence between academic disciplines and students' cultural and linguistic experiences (Lee & Fradd, 1998). In this framework, teachers are required to look into the relationship between science and students' linguistic and cultural knowledge and to develop various ways to connect them to make science meaningful and accessible to all students (Lee,

2004). To construct an instructional congruence of science instruction for ELs, Lee argues that teachers need to integrate knowledge of “science disciplines, students’ linguistic and cultural experiences, and English language and literacy” (p. 67).

The following review briefly traces the general principles or ideas identified as important in linguistically responsive science education for ELs and the gaps that remain in the research on the literature.

Important Principles and Ideas in the Field

The overriding principle promoted by science education scholars to support science teachers to become linguistically responsive is the integration of teaching science content and teaching English language and literacy. One can identify five major themes in these scholars’ work that are the basis of the three articles in this dissertation: 1) inquiry-based science, 2) the vital role of language in science class and explicit teaching of discipline-specific language, 3) synergistic effects for inquiry science and English language development, 4) effective strategies to integrate science instruction and English language development for ELs, and 5) effective teacher professional development and challenges.

Inquiry-based science. Inquiry is the cornerstone of the science curriculum that the National Research Council (NRC) envisioned (NRC, 1996, 2000). An inquiry-based curriculum views science as “a process for producing knowledge that depends on careful observations and grounded interpretation” (Fang & Wei, 2010, p. 263). Inquiry-based science promotes students’ construction of meaning through exploration of scientific phenomena, observations, experiments, and hands-on activities with emphasis on “student ownership, student-student interactions, teachers’ role, assessment through questions and discussion, [and] sense of wonder” (Bergman, 2010, p. 117; NRC, 1996). Lee and Buxton (2013a) assert that as main inquiry practices in

science classes, students “generate questions, formulate hypotheses, design investigations, collect and interpret data, draw conclusions, and communicate results” (p. 38).

Science education scholars believe that these features of inquiry-based science also provide an authentic context for purposeful language use, therefore asserting that inquiry-based science is a particularly powerful instructional context for the integration of academic content and language development for ELs (Lee & Buxton, 2013a). By participating in inquiry practices, ELs can not only engage in authentic communicative interactions but also communicate their understanding in a variety of formats, whether by writing, presenting orally, drawing, or creating tables and graphs (Lee & Buxton, 2013a).

The vital role of language in science class and explicit teaching of discipline-specific language. Another major principle of linguistically responsive science teaching is the emphasis on academic literacy and advocacy for explicit teaching. Since students’ academic achievement requires both content area knowledge and literacy skills, reading and writing proficiency serves as “a gatekeeper to their further learning” (Greenleaf et al., 2011, p. 653). Yore, Hand, Goldman, Hildebrand, Osborne, Treagust, and Wallace (2004) view one of the challenges in science education as a shift in the view of language activity from marginal to vital. They see language as both a means of doing science and, also, an end because of its use “to communicate about inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed actions” (p. 348).

According to these scholars, academic literacy involves discipline-specific thinking (Greenleaf et al., 2011). They therefore contend that teachers need to make explicit specific reasoning processes, strategies, discourses, and practices (e.g., Greenleaf et al. 2011; Moje, 2008; Shanahan & Shanahan, 2008). In order to meet inquiry foundation and rigorous science learning

and achievement standards set by the NRC (1996, 2000) and the NGSS, Lee and Buxton (2013b) believe that it is important and necessary to develop the use of precise language to express scientific ideas. Likewise, Wellington and Osborne (2001) stated that "... we must give prominence to the means and modes of representing scientific ideas, and explicitly to the teaching of *how to read, how to write and how to talk science*" (p. 138). Fang (2004) even argues that science teachers should be language teachers. This supports Halliday view of literacy as always a semiotic process.

Synergistic effects for inquiry science and English language development. Due to increasing numbers of ELs in mainstream classes, science teachers as well as other content area teachers have extra responsibilities and pressure. Contrary to many science educators' concerns about additional time and attention for ELs to meet instructional standards, a contrastive analysis of English Language Proficiency standards and National Science Education Standards demonstrates that "they do not compete for time and attention, but rather compliment and corroborate with one another" (Bergman, 2010, p. 128), which means that effective language instruction for ELs in science class can promote science learning, and a well-designed science lesson can improve language learning for ELs.

The English Language Proficiency (ELP) Standards created by the World-Class Instructional Design and Assessment Consortium (WIDA) tie language learning to state academic content standards and deal with educators' needs in pedagogy, assessment, and educational policy (WIDA, 2007). The National Science Education Standards (NSES) were developed to improve scientific literacy for all students (NRC, 1996; Bergman, 2010). Through a contrastive analysis of ELP standards and NSES, Bergman (2010) found that both standards promote instructional strategies such as using "meaningful and memorable materials," "learning

by doing,” giving suitable time instead of requiring rapid speed, pursuing student-centered design, giving “opportunities for application,” “connecting content to students’ experience,” “teachers’ critical role,” and “student groups and interactions” (p. 128). Accordingly, Bergman (2010) concludes that these two standards are interdependent and complementary for the successful science instruction of ELs; furthermore, he argues that a “well-designed and well-delivered lesson for ELs” will lead to successful learning by nearly every student (p. 120). His argument is in line with the finding in a study of Stoddart, Pinal, Latzke, and Canaday (2002) that engaging in science inquiry develops academic English and a science register as well as higher-order thinking skills, while developing advanced language use is crucial to understanding science concepts.

Effective strategies to integrate science instruction and English language development for ELs. Teachers expect to learn effective instructional strategies from professional development programs. Lee and Buxton (2013a) identified five effective strategies that they believe are necessary to integrate science and English language for ELs in science classes. The first is general literacy strategies for all students, such as providing opportunities to write in the different genres of scientific writing and encouraging the use of a variety of academic language functions related to science inquiry. The second is language support strategies for ELs through hands-on, inquiry-based activities. The third is discourse strategies for ELs, such as modifying the level and mode of communication according to the ELs’ proficiency levels. However, the key is balancing the reduction of the language load while maintaining academic rigor. The fourth is home language support, such as allowing ELs to write in their home language and introducing cognates or Latin roots. Exposure to science vocabulary in multiple languages is beneficial to English speaking students as well. The fifth is home culture

connections. This strategy is “more abstract and subtle” than the connection between home language and science concepts (p. 40). Teachers can use students’ funds of knowledge or cultural artifacts related to science topics and use culturally-based communication and interaction patterns. However, teachers should “balance consideration of culturally-based communication and interaction patterns with the dangers of stereotypes or overgeneralization based on students’ cultural background” (p. 41). This study investigates the strategies science teachers consider important and practical and use in their classrooms.

Effective teacher professional development and challenges. Lee and Buxton (2013b) described the features that they believe lead to the most effective professional development for science instruction with ELs based on core features of effective professional development identified by Garet, Porter, Desimone, Birman, and Yoon (2001): 1) balancing science content focus with explicit attention to the language; 2) active learning, in which teachers engage in inquiry-driven science learning and teaching – by taking both the student’s role and the teacher’s role – and use ESOL and science discourse strategies; 3) coherence between NGSS and Common Core State Standards for English/language arts and mathematics, coherence between professional development programs and the curriculums that the participating teachers are required to use, and consistency in opportunities for the teachers to adopt and practice what the professional development provides; 4) sufficient duration for teachers to implement what they learn; however, high mobility of teachers and students in urban settings makes it difficult to ensure a sufficient amount of time; and 5) collective participation by a broad range of educators and stakeholders including science teachers, ESOL/bilingual education teachers, paraprofessionals, and other discipline teachers for the highest support for integration of science and language learning.

However, there are some challenges to successful professional development to be considered. Lee, Luykx, Buxton, and Shaver (2007) identified in the literature six challenges to the improvement of teachers' professional development to support culturally and linguistically diverse students: 1) teachers' beliefs about student diversity (Bryan & Atwater 2002); 2) intensive engagement; 3) difficulties in developing culturally relevant curriculum materials; 4) difficulties in expanding professional development to less willing teachers; 5) standards-based instruction and accountability policies that expect minority students to "assimilate to the dominant language and culture" (Lee & Luykx 2005, p. 431); and 6) English-only policies that devalue students' home languages and disregard their role in their academic achievement (Garcia & Rodriguez, 2000; Wiley & Wright, 2004).

These key ideas that science education scholars have discussed regarding linguistically responsive science teaching give a general picture of what they believe a science classroom for ELs should look like and what many science teacher professional learning programs for ELs aim for. It is necessary to be informed of these ideas in order to understand how in-service science teachers think of science language and literacy instruction and its effects on students' science learning.

Gaps in the Literature

Research on ESOL professional learning for science teachers has been growing over the past decade; however, the research foci are disproportionately distributed, and there are some gaps that need to be addressed. First, in contrast to the plethora of studies on elementary science teachers, there are very few studies on secondary school science teachers. While many elementary teachers feel less comfortable teaching science than language and literacy (Lee, 2004), secondary teachers consider themselves discipline professionals and tend to be less

confident in teaching literacy (Stoddart et al., 2002). Since secondary school students need highly advanced academic language to prepare for high-stakes tests, developing more professional development programs to target secondary school teachers and to support them in being linguistically responsive seems urgent. Moreover, in order to recruit more high school science teachers in professional development programs or research projects, it is necessary to investigate the barriers that discourage their participation and ways to motivate them to participate in EL-related professional learning dealing with language and literacy. In particular, in order to recruit more science teachers teaching advanced level classes, it is important to make them aware that incorporating language and literacy components has been shown to be advantageous for both ELs and English proficient students. Increasing advanced-level science teachers' interest in EL-related issues and accompanying language issues has the potential to increase the number of ELs in advanced science classes.

A majority of research on in-service science teacher professional development deals with short-term, targeted programs. There are few, if any, studies on long-term and less strong intervention programs, such as ESOL endorsement or certificate programs for content area teachers, which require two years or more. The majority of studies document teachers' initial and final status in terms of knowledge, beliefs, and practices (e.g., Lee & Maerten-Rivera, 2012; Stoddart et al., 2002), while there are few studies investigating the mechanisms by which teachers' implementations of their learning vary as a result of dynamic interactions with other factors. Therefore, it is necessary to document teachers' experiences in these programs in a comprehensive manner and examine individuals' or a group of teachers' uptake of what they learn in the programs and the curricular, personal, and contextual factors that facilitate or hinder their adoption and implementation of their learning.

Moreover, even though a large body of research from multiple disciplinary perspectives has discussed literacy instruction for ELs in science and content areas, a majority of studies have tended to presuppose ideal classroom practices and recommend prescriptive instructional strategies and curriculum materials for linguistically responsive science classes. Very few studies have examined what science teachers think about literacy-intensive science lessons and what they actually do in classrooms to develop science literacy and ELs' language learning. Descriptions of the existing conditions of real classrooms and what actually happens in classrooms are missing across a range of educational research.

In sum, this chapter reviewed the major principles that science teacher educators have found to be important in working with ELs and gaps in the literature that need to be addressed. These findings form the foundations of this research and provide the theoretical orientation for the study.

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CHAPTER 2

SCIENCE TEACHERS' ESOL PROFESSIONAL LEARNING AND NEW HYBRID
IDENTITY DEVELOPMENT³

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Abstract

This multiple case study investigates four science teachers' experiences of boundary crossing through participation in an ESOL (English to Speakers of Other Languages) professional development program and the extension of their identity as ESOL/language teachers. The study examines how science teachers transform into science and language teachers by exploring teachers' disciplinary identity, their adoption of a new extended professional identity, and the mismatch between their new identity and its enactment in science classrooms. Through classroom observations, interviews, and document analysis, this study finds that the secondary science educators had a flexible disciplinary identity, and thus, adopted a new professional identity as ESOL/language teacher without strong resistance. However, their extended identity was not enacted in their classrooms. For successful transformation of science teachers into science and ESOL teachers, contextual adjustment and a continuous support system is required. The paper concludes with implications for further research on teacher education for content area educators teaching English learners.

Key words: science teachers, ESOL, boundary crossing, professional identity, transformation

Introduction

Educators across the content areas are increasingly called upon to differentiate instruction to reach all students (Ballantyne, Sanderman, & Levy, 2008; Janzen, 2008; National Comprehensive Center for Teacher Quality, 2012), and current research suggests that many English learners (ELs) benefit from inclusive content area instruction (Gándara, 2011; Gándara & Orfield, 2012). However, teaching ELs requires science educators to increase their training and professional identities to include English to Speakers of Other Languages (ESOL) instruction. In most U.S. states, this means earning an ESOL certification or endorsement. Nevertheless, most research to date on ESOL education for science teachers has focused on short-term professional development efforts (August, Branum-Martin, Hagan, & Francis, 2009; Greenleaf et al., 2011), and little is known about how science teachers take on extended training and a professional identity as an ESOL educator. This multiple case study provides an in-depth portrait of the experiences of science teachers in one ESOL endorsement program as a boundary crossing experience and shows its effects on their professional identities and classroom practices.

The study addresses a number of gaps in the existing research. First, while the majority of research and professional development projects have targeted elementary school teachers (Avraamidou, 2014a; Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2016) or, to a lesser extent, middle school teachers (Arce, Bodner, & Hutchinson, 2014; Lakin & Wallace, 2015), this study looks at high school science teachers, who might have the strongest disciplinary allegiance and identity. Second, while most research on ESOL training for in-service science teachers has examined only short-term professional development (PD) programs (August et al., 2009; Greenleaf et al., 2011), this study takes on the virtually unexamined impact of more sustained ESOL certification or endorsement programs. Third, while much science teacher education

focuses on the quality of PD content and effective delivery models (Buxton & Lee, 2010; Johnson, 2010), fewer studies describe the identity that in-service secondary science teachers take on in the process of becoming ESOL/language teachers. This study provides new theoretical insights into science teacher preparation for working with ELs and has implications for how we support science teachers in becoming emergent language teachers.

The particular approach adopted in this study is the application of the concept of “boundary crossing” (Akkermna & Bakker, 2011; Dillon, 2008; Hobbs; 2013), an approach that offers a new perspective to understand diversity and mobility in content area teachers’ ESOL instruction. In all, this study explores how, through the boundary crossing experience of participating in an ESOL professional development program, science teachers transform their disciplinary identity as science teachers into a new hybrid identity as science and language/ESOL teachers and how their new identity is enacted in their classroom practices.

Literature Review

Teacher Professional Identity Development

Identity has been defined by a number of scholars in various ways. The emphasis on identity development broadens the field of teacher education by including psychological and physical constructs in addition to cognitive constructs. Luehmann (2007) summarized four common characteristics of identity within a situated and social constructivist frame: 1) “socially constituted,” 2) “constantly being formed and reformed,” 3) “considered by most to be multifarious,” and 4) “constituted in interpretations and narrations of experiences” (p. 827). Beauchamp and Thomas (2009) also summarized the topics frequently studied regarding the current interpretations of teacher identity: 1) the complex relationships between the self and identity including the role of emotion in shaping and expressing identity, the importance of

narratives and discourse in understanding identity, the role of reflection in developing teacher identity, and the inextricable link between identity and agency; 2) the contextual factors influencing identity construction; and 3) the role of teacher education programs to develop new teacher identities.

A particular perspective of identity is a positional identity. A teacher's identification is found to be directly related to and essentially determined by various social factors such as ethnicity, race, age, religion, and gender (Moore, 2008; Rivera Maulucci, 2013), which can be explained by the notion of positional identities (Holland, Lachicotte, Skinner, & Cain, 1998; Moore, 2008; Rivera Maulucci, 2013). Positional identities have to do with "the day-to-day and on-the-ground relations of power, deference and entitlement, social affiliation and distance with the social-interactional, social-relational structures of the lived world" (Holland et al., 1998, p. 127). This view of identity highlights the claim that a person's position relative to others shapes the person's identity and that this identity results from the operation of language and emotion (Avraamidou, 2014b). The enactment of positional identity is described by positioning theory (Harré & Moghaddam, 2003). This theory asserts that positioning the self or others affects the "action or act repertoires" that they can access (p. 4). For example, positioning a teacher as unqualified excludes him/her from certain duties at school. Due to the relational nature of positions, positioning someone in a certain way, in turn, positions someone else with relation to that person, and the person who benefits from the position may design the situation far more than is justified in research. Therefore, teachers' positional identity affects and designs their classroom practices and interactions with their students and also positions their students in a certain way (Yoon, 2008).

With respect to teacher learning and development, professional identity has been widely studied (Beijaard, Meijer, & Verloop, 2004; Beijaard, Verloop, & Vermunt, 2000; Flores & Day, 2006; Samuel & Stephens, 2000). Researchers have been interested in how a teacher's professional identity is related to his/her knowledge and appreciation of the subject and influences his/her instructional practices, beliefs, and commitments. From a sociocultural perspective, professional identity is viewed as a continuous process of becoming (Beijjard et al., 2004) in a specific context, so the development of a content area teacher occurs along with his/her on-going process of identity construction, which arises as a result of the interaction with and reflection on his/her professional and personal experiences within a specific context (Kelchtermans, 2009). Hobbs (2013) borrowed Gee's notion of D/discourse and claimed that a teacher becomes a content area teacher by participating in subject teacher discourse⁴. Hobbs (2013) expanded this notion further in her study on out-of-field teaching, which is teaching a subject for which a teacher is not qualified. Hobbs (2013) argued that by not limiting the development of professional identity to only participation in subject teacher discourse, teachers need to have an awareness of their participation in the discourse and interact with the subject in the sociohistoric dimension in order to fully develop their professional identity and obtain competence and confidence in teaching the subject.

In the field of science teacher preparation, identity theory is used to explain the process of becoming a reform-minded science teacher. Luehmann (2007) suggested five processes to facilitate novice science teachers' implementation of the vision stated in science education professional standards: 1) "reconciling prior beliefs with reformed teaching", 2) "locating identity within a community of practice", 3) "managing emotional aspects of identity formation",

⁴ Gee defines Discourse as "the ways of combining and integrating language, actions, interactions, ways of thinking, believing, valuing, and using various symbols, tools, and objects to enact a particular socially recognizable identity" (Gee, 2005, p. 21).

4) “integrating experiences and theory”, and 5) “developing a sense of self-confidence” (p. 823-824). These five processes can be applied to experienced teachers’ uptake of professional learning and have implications for teacher training program developers and school administrators regarding how to make professional development more successful.

Current theories in the field of teacher identity cover a broad range of topics; however, there has not been research that has addressed how new hybrid identities are added onto teachers’ original disciplinary professional identity. Since add-on certifications have become common in U.S. K-12 schools, there is a need for research on how the professional learning required to earn add-on certification affects the identity of teachers.

Boundary Crossing

Boundary crossing involves “encountering difference, entering onto territory in which we are unfamiliar and, to some significant extent therefore, unqualified” (Suchman, 1994, p. 25). Emerging out of cultural historical activity theory on expansive learning (Engeström, 1987) and becoming a part of situated learning theory on communities of practice (Wenger, 1998), this concept has been employed to explore challenges, problem-solving, and learning potential at a boundary between two different domains, in particular, in education and work (e.g. Engeström, Engeström, & Kärkkäinen, 1995; Hinds & Kiesler, 1995; Hobbs, 2013). Scholars note that transporting expertise and collaborating with others between two unrelated domains is a challenging task. Different types of cognitive inertia and compartmentalization hamper boundary crossing (Engeström et al. 1995). Two major mechanisms contribute to this problem. One is groupthink (Janis, 1983), which results in “an overestimation of the in-group, closed-mindedness and stereotypes of out-groups” (Engeström et al. 1995, p. 321). Another mechanism that impedes boundary crossing is “the fragmentation of viewpoints” and “lack of shared mental

models” which inhibit experts in different communities from being able to communicate and share ideas with one another (Engeström et al. 1995, p. 321). In order to overcome the difficulties in working in the new territory, boundary crossing requires “the formation of new mediating concepts” and “cognitive retooling”, which can be directed and facilitated by boundary objects (Engeström et al., 1995, p.321-322).

In 1989, the concept of boundary object was introduced as a method of solving a wide array of problems (Star, 1989). Boundary objects exist in the spaces between actors with differing viewpoints and are “both plastic enough to adapt to local needs” and “robust enough to maintain a common identity across sites” (Star, 1989, p. 46). From that time, this concept has been refined and evolves as “the potentially shared or jointly constructed object” between two activity systems (Engeström, 2001, p.136). A recent view of boundary objects is of “organic arrangements that allow different groups to work together” (Akkerman & Bakker, 2011, p.141).

In their review on boundary crossing and boundary objects, Akkerman & Bakker (2011) summarized potential learning mechanisms at boundaries. They defined boundaries as “sociocultural differences leading to discontinuities in action and interaction” (p. 139). They highlighted that discontinuities can be resolved through a process of “reestablishing action or interaction” (p. 136) and lead to learning, which in turn leads to identity development/expansion and a re-conceptualization of practice (Akkerman & Bakker, 2011). The four dialogical mechanisms at boundaries are identification, coordination, reflection, and transformation. Identification focuses on a “renewed sense of practices and a reconstruction of current identity or identities” (p.146). Coordination highlights overcoming the boundary in order to establish continuity and facilitate smooth movement in the future between different domains. Reflection leads to an expanded set of perspectives and a new construction of identity that informs future

practice. Transformation results in “profound changes in practices, potentially even the creation of a new, in-between practice, sometimes called a boundary practice” (p. 146). Transformation includes a series of processes: confrontation; recognizing of shared problem space; hybridization; crystallization; “maintaining uniqueness of the intersecting practices”; and “continuous joint work at the boundary” (p.149). Akkerman and Bakker (2011) made it clear that boundary crossing should not be seen as a process of replacing heterogeneity with homogeneity or moving from diversity to unity but rather as “a process of establishing continuity in a situation of sociocultural difference” (p.152). Therefore, in the transformation mechanism, a new core practice emerges by exchanging the current practices because of their differences and thus, diversity remains.

Hobbs (2013) applied the concept of boundary crossing to out-of-field teaching. She conceptualized boundary crossing as “the process of extending and negotiating working boundaries beyond the in-field space to an out-of-field space” (p. 274). She used the Boundary Between Fields (BBF) Model to describe three groups of factors influencing the negotiation of teachers at the boundary between subjects and its impact on their professional identity. First is contextual factors, including rurality and conditions of teacher allotment. Second is support mechanisms, including provision of support materials or supportive people, professional development or collegial support, and personal research or experience. Third is personal resources, including adaptive expertise, teacher knowledge, and dispositions. This model is used to understand the participating science teachers’ boundary crossing in this study.

While the concept of boundary crossing has been employed in the area of education, it has not been used to understand the experience of content area teachers’ teaching ELs and participating in ESOL training. This concept potentially contributes to the field of teacher

education by providing a new insight on how to make sense of teachers' experiences earning an add-on certification in a different field, developing an accompanying and new professional identity, and practicing their new identity in their instruction.

Theoretical Framework

Within a broad sociocultural framework, this study views identity as: 1) an ongoing process of becoming in relation with the personal world and sociocultural context (Beijjard et al., 2004; Holland et al., 1998); 2) constructed through participation in social practice and shaped by and shaping the knowledge and skills people acquire (Battey & Franke, 2008; Lave, 1996; Lave & Wenger, 1991); 3) continuously reshaped and reformed by acquiring new knowledge and skills through participation in a community of practice (Franke & Kazemi, 2001; Wenger, 1998); and 4) a mediating tool to make sense of contexts and make decisions about what knowledge and skills to use (Enyedy, Goldber, & Welsh, 2005). In this sense, this study assumes that teachers exhibit and enact their professional identities in relation with teaching, the content they are teaching, their students, and their classroom and broader community. Teachers' participation in professional development is a way of "acquiring new knowledge, re-crafting identities, and challenging exiting cultural and social practices" (Battey & Franke, 2008, p. 128). Teachers' professional identities mediate their decision making of what newly learned knowledge and skills are implemented in their classrooms (Enyedy et al., 2005). This study explores the science teachers' disciplinary identity and add-on identity in relation with their personal background, their instructional context, participation in professional development, and the new knowledge and skills they acquired from the training.

In addition, this study theorizes science teachers' entering the ESOL field through their participation in an ESOL endorsement program as a boundary-crossing event and applies the

processes of transformation to the science teachers' professional learning, professional identity development, and the enactment of their identity (Akkerman & Bakker, 2011). Moreover, using the BBF Model (Hobbs, 2013), this study describes the contextual factors, support mechanisms, and personal resources that the teachers brought for successful boundary crossing. In this light, this study explores how they transform their professional identity and develop their boundary practices in profound ways by negotiating contextual factors and creating and using support systems and personal resources.

The following research questions guided this work:

How do science teachers develop their hybrid professional identity as science and language/ESOL teachers through a boundary crossing experience by participating in ESOL professional development?

1. How do the science teachers' disciplinary predispositions affect their disciplinary identities?
2. What affects their acquisition and development of add-on language/ESOL teacher identity?
3. What do their hybrid identities look like and how do they affect their classroom practices?

Methods

Setting and Participants

Data for this study were drawn from diverse secondary schools and participants in one Southeastern U.S. new immigrant community. Four schools were included in the study: 1) one school from a rural district with a relatively small English learner (EL) population (8.1%) and students from home language backgrounds other than English (31.1%), 2) two schools from a

small urban area district that has an extremely high percentage of ELs (27%) and students from home language backgrounds other than English (80.6%) (New America Foundation, n.d.), and 3) a private secondary school with a high proportion (25%) of international students representing high levels of native language literacy, education, and socioeconomic status.

Participants were recruited from a university-based federally-funded ESOL endorsement program designed for in-service educators. Teachers took three graduate ESOL endorsement courses mandated for state licensure. These included “Language & Culture in the Classroom,” which covers key principles of multilingual and multicultural education; “First and Second Language Acquisition,” which explores major concepts in linguistics and first and second language acquisition; and “TESOL K-12 Methods and Materials,” which introduces research-based strategies and techniques in EL instruction. The program is offered as a unique hybrid instructional model combining online instruction by a university-based instructor, on-site school-based teacher professional learning community groups that meet to watch video-recorded lectures and complete assignments, and regular instructor visits to participant classrooms and group meetings throughout the program. The following is the description of the three major activities as presented in the syllabi for the courses. The first two components are the same for all three courses. The third component varies for each course:

Weekly Consult, Elaborate, Confirm Exercises: to dialogue and collaborate (*consult*) with peers from professional practice as to consistencies of understanding about the instructional content of the video; to critically reflect upon, debate (challenges/strengths), and differentiate (*elaborate*) what they have learned from session content vis-à-vis differentiated strategies for their own schools/classrooms; field-test key strategies and

verify (*confirm*) the impacts of theory-into-practice applications upon the cognitive and academic growth of culturally and linguistically diverse students and other students.

Reflection Wheel Journals: to write two reflection journals using a theoretically sound, pragmatic format for process thinking and critical reflection on professional practice and professional development.

Course project: for the first course, to conduct an interview project with someone who has undergone immigration and an ethnographic report of the interview and their learning; for the second course, a linguistic case study of a child with integration of the key linguistic theories, concepts, and research; for the third course, a poster presentation of the implementation of the key strategies from the curriculum.

From the teachers in the program, four secondary science teachers were selected for in-depth case study analysis. I invited all eight science teachers among 39 teachers in the program. Six science teachers agreed to participate in this study; however, I did not include two teachers' data for this study because one teacher had no ELs in her class, and the other taught a support class for underperforming students in science and reading, which was different from other science classes. The four remaining science teachers included one female and three males. One male teacher and the female teacher taught at the middle school level, and two male teachers taught high school biology. Teachers ranged in experience from two to thirteen years in K-12 schools. One teacher was certified only in science from 6th to 12th grade, while other teachers were certified in multiple subjects including social studies, language arts, and reading. Three of the teachers had held jobs and careers in the private industry. Table 1 shows the variety of personal background of the teachers. The diversity of settings and participants provided

opportunities to explore a broad range of individual and school responses to ESOL endorsement training.

Table 1

Background Information of the Science Teachers

	Public		Private	School level		Gender		Ethnicity	Year	Qualification	Work experience other than teaching
	District			Middle (Grade)	High (Grade)	male	female	White			
	A	B									
James			*	* 8th		*		*	13	B.S.: Agricultural Science M.Ed.: Social Science Education	Corporation
Scott	*				* 10th	*		*	2	B.A.: Sociology M.A.T.: Teaching Secondary Social Science	Technician
Brad		*			* 9th	*		*	3	B.S.: Biology & Ecology M.A.T.: Science Education	
Maggie		*		* 7th			*	*	3	B.A.: Middle Grades Education	Business

Data Collection

The teachers were followed for one and a half years as they participated in the ESOL program. This study includes three main sources of data. Ten to 20 class observations, each of which is 35 to 90 minutes long, were conducted with each teacher over the course of two semesters. Sixty to 180 minute-long interviews with each teacher were conducted at the end of the second and the third semester. Data also included the teachers' completed endorsement course assignments such as their journals and classroom artifacts such as the hand-outs and

quizzes for their own science classes. These main data sources were supplemented by three to five researcher visits to participants' professional learning community group meetings each semester, pre- and post-program surveys for each participant, pre- and post-program classroom observations of each participant using the Biography-Driven Protocol (Herrera, Pérez, Kavimandan, Holmes, & Miller, 2011; Pérez, Holmes, Miller, & Fanning, 2012), and aggregated student school record data.

Classroom observation. I conducted pre-program observations during the first semester, which helped me ascertain teachers' entering dispositions and assumptions regarding ELs and multicultural education. While the teachers took the second course, I observed each teacher's class for a week or two. While they took the third course, I observed each teacher's class for a week or two again. I intended to select the class of each teacher that contains the highest number of ELs; however, some teachers preferred that I come during a certain period, and I respected their requests. During all observations, I focused on how the teachers structured their science classes and adopted, resisted, or negotiated what they learned from the training in their instructional practices, such as including ELs' language and culture and integrating science instruction with English language development. I also looked at how contextual, curricular, and personal factors played into their uptake of the training. I sometimes engaged in informal conversations. I audio-recorded the classes and took field notes during the observations.

Interviews. I conducted two separate 60 minute to three hour interviews with the teachers. These interviews took place once at the end of the second course and once at the end of the third course. These were semi-structured interviews where I asked a series of questions about their reflections on the courses they took, their instruction, their EL students, their beliefs about science, science teaching, and ESOL teaching, and their efficacy/preparedness to work with EL

and integrate science and English language development as a result of the training. These interviews revealed their dispositions and thoughts about ELs; their motivations to join the training; their reflections on their courses, instruction, and ELs; any changes in their instruction and beliefs; and any external and internal factors that influenced their uptake of the training. I audio-recorded, transcribed, and coded the interviews.

Documents. The curriculum required the teachers to submit diverse assignments, including journals, discussion reports, a student interview project, etc., throughout the courses. The teachers submitted their assignments to the online course website, and I collected these documents to examine how teachers' perceptions of ELs and teaching of ELs evolved through the courses. I collected the document data from three semesters. These data also showed what the teachers thought of the information and activity in the curriculum by revealing how thorough they were in completing the assignments.

Others. An orientation survey, a pre-program survey, and a post-program survey were conducted. These surveys showed the teachers' initial dispositions towards and assumptions about ELs, their motivations and expectations for the training, their experiences working with ELs, and the overall impact of the courses. Pre- and post-observation rubrics showed their development in instruction for ELs. Quantitative school record data with indirect identifiers showed any changes in the academic performance of the teachers' students.

Data Analysis

The data were analyzed using qualitative multiple case study methods, in which each individual case study comprises a whole study, seeking "convergent evidence of the facts and conclusions for the case" (Yin, 2014, p. 59). Data analysis was recursive and inductive (Merriam, 2009; Pascale, 2011). All interview data were transcribed. The audio-recorded

classroom observation data were selectively transcribed. I focused on how the teachers enacted their disciplinary identity and add-on ESOL teacher identity. Thus, in the classroom audio-recordings, I looked for the instances in which the teachers structured scientific practices, such as labs or hands-on activities, for clues regarding science teachers' disciplinary identities and later ESOL teacher identities, and for the instances in which the teachers made specific accommodations for ELs during the class for the practices of ESOL teacher identity.

The transcribed data, field notes, and notes from informal conversations were inductively coded using NVivo 10 software. I mainly used an attribute coding method to log essential information and characteristics of the teachers, their beliefs, and their practices, and the contexts, while simultaneous coding was also used since multiple codes were applied with qualitative data (Saldaña, 2013). During data analysis, I wrote analytical memos to reflect upon the data and relate emerging issues to research questions. While I coded the data, main themes and patterns were identified, and these emerging themes and patterns were verified and modified as new confirming or disconfirming data were found. The concurrent data analysis with data collection guided and reformulated the subsequent data collection.

In order to ensure the validity of the study, I used several tactics suggested by Yin (2014). For construct validity, I did not only use multiple data sources of evidence such as interviews, classroom observations, documents, and other supplementary sources, but also established a chain of evidence between a hypothetical conclusion, the specific data, the interview questions, and the research questions. For internal validity, I constructed explanations with the recursive process of making a statement, comparing it with the findings, revising it, comparing the revision with other data, and revising. For external validity, I used two major theories about professional identity and boundary crossing to support my arguments.

Findings and Discussion

Data analysis yielded three main areas of themes. For one, it suggested that the science teachers displayed stronger identities as teachers in a general sense than they did disciplinary identities as science teachers. Then, I found that the teachers developed their add-on identity as ESOL/language teacher as a result of the new knowledge and skills obtained from the ESOL endorsement program; however, they were not yet transformed into science and language teacher. It became evident that they hardly enacted their hybrid identity in their classroom practices, and thus, I can argue that contextual adjustment and continuous support system is necessary for the teachers' successful transformation. Each of these areas will be further explored below.

Science Teachers' Professional Identity

The literature on teacher identity has focused on the traits of disciplinary specific identity and identity development (e.g., Luehmann, 2007); however, it has paid little attention to the traits of teachers who show the identity of a general educator rather than a subject teacher. The current study revealed new insights about science teachers' flexible professional identity in the areas of qualification, weak allegiance to a discipline, and beliefs about science and science instruction.

Qualification. In order to examine the characteristics of professional identity of the participating teachers, I first present their qualification. Table 1 above provides details on the four participant teachers identified from their applications and during the interviews. The literature on professional identity tends to assume that content area teachers have a significant degree of disciplinary socialization into the field of a specific subject (Siskin, 1994; Gutiérrez, 1998). Through pre-service teacher training of undergraduate majors and discipline-specific methods and participation in professional organizations, academic discipline is said to infuse

high school teachers' professional identity and professional development throughout their career (Grossman & Stodosky, 1995). Notably, then, the current study found that only one teacher, Brad, has a degree in science, while the rest have neither an undergraduate nor a graduate degree in science. One middle school teacher, James, has a degree in agricultural science, which may provide him with some background knowledge in biology and environmental science. The other middle school teacher, Maggie, has a degree in middle grades education, which for her required only a few science courses. One high school teacher, Scott, does not have any degree in science or science education.

However, they all passed the state assessments for the certification of educators and are qualified to teach secondary science. The state-approved educator certification assessment program was developed by the state professional standards commission and a nationally well-known testing company. This test is a computer-delivered standardized test that individuals who want to teach at public schools and gain a credential in the state must pass. The test aims to help the state professional standards commission ensure that teacher candidates are equipped with the knowledge and skills needed to function as an educator in the state's public schools. This type of test is typical in most U.S. states. The certification test offers science content assessment in four areas: biology, chemistry, physics, and middle grades science. Each assessment has two tests. The first test consists of 60 selected-response questions, which are 80% of the test score, and two constructed-response assignments, which are 20% of the test score. A group of content areas and topics are covered by the first test. The second test has the same format but covers different areas and topics. Teacher candidates must complete the examination within four hours. The minimum possible score is 100, and the maximum possible score is 300; the lowest passing score is 220.

Since the four participating teachers all passed the state-approved assessment, including those who did not have a degree in science, they all were confident that their credentials gave them adequate justification and preparation for teaching science. This confidence is demonstrated in Scott's comments on the autonomy that the teachers should be given in his school.

You should have some autonomy. I mean you already proved that you can think, and we don't need job mastery. [The former school I worked in had] probably more rules, and just tighter constraints on the teachers, and I am not for that. (Scott, Grade 10)

Confidence is one important aspect of professional identity (Hobbs, 2013); however, teachers' confidence might be attributed to a lack of sophisticated reflection and interpretation of science education discourse. Hobbs (2013) noted that professional identity develops through "the interpretation or recognition of the participation" in the subject discourse and sociohistorical interaction with the subject (p. 275). It is unclear how the teachers in this study had participated in the discourse of science and the kinds of sociohistorical interactions with science they engaged in while they prepared for a standardized test for certification.

Weak disciplinary identity. In U.S. secondary schools, subject departments create a strong collective community, and members of the department share a distinctive discourse and beliefs about good teaching in their subject (Grossman & Stodolsky, 1995; Siskin, 1994). Deep divisions between departmental territories, in addition to strong allegiance to a department, often restrict the interdisciplinary approach of school reform efforts (Grossman & Stodolsky, 1995). Such divisions may also lead one to infer that a strong disciplinary science identity may make it difficult for teachers to adopt an additional identity as a language/ESOL teacher. Contrary to this assumption, the participating science teachers accepted a language teacher identity without

strong resistance, which may have resulted from their identity as general educators rather than as science teachers who are committed to science. In response to the question of what they would say if they were asked what they do for a living, they answered:

I tell them an educator. (James, Grade 8)

I teach science. (Scott, Grade 10)

My first response is I teach. That's it. I teach. If they really wanna know then, they will know I teach biology or whatever I happen to be teaching at that time, I teach biology, I teach environmental science, I teach earth system, I teach physical science, so I guess first from the most I consider myself a teacher and then secondly, a science teacher.

(Brad, Grade 9)

I spend my days with amazing, amazing kids all day long... I am a science teacher. I can teach English and reading because I passed the test. (Maggie, Grade 7)

Except Scott, these teachers tend to present themselves as “a teacher” instead of “science teacher.” Maggie included the word “science,” but also English and reading. This demonstrates that the science teachers who voluntarily participated in ESOL professional development have a flexible identity or strong identity as an educator rather than a strong disciplinary identity as a specific subject teacher.

Identities are shaped by knowledge and skills and constructed in relation to personal history, practices and communities, and a particular context, especially through the participation in social practices (Holland et al., 1998; Wenger, 1998). The teachers have multiple certifications. Three teachers, James, Scott, and Maggie, have degrees and certificates in social studies as well. Maggie even has language arts and reading certificates. Brad, with a degree in science, had worked as a writing tutor. Regardless of number and type of certificates, all the

teachers teach the subject to which they are assigned. James was teaching science and history. Scott indicated that he was hired as a science teacher because there was very little demand for a history teacher. Brad was teaching biology that year; however, he was assigned to teach earth science the next year. Maggie taught language arts and reading in summer school. There are possibilities to teach something else than science. It has been argued that teachers' professional identity is mainly acquired from their academic subject area and the department (Helms, 1998; Little, 1993; Talbert, 1995) and that the subject teachers teach plays an important role in their thoughts about "what kind of person they are and what kind of person they want to be" and attempt to connect between discipline and other part of their lives (Helms, 1998, p. 830). Unlike this argument, the science teachers' personal and educational background, knowledge and skills from multiple certifications, participation in teaching various subjects, and contingencies of subject assignments influenced the science teachers' identities as general educators first, and then, as teachers of whatever they happened to teach, rather than being loyal to one discipline. Therefore, the participation in the ESOL professional development and earning of an add-on certification led them to re-craft their original professional identity and form a new professional identity (Battey & Franke, 2008). Given their flexible identity or strong identity as an educator without necessarily committing to one discipline, they were more likely to adopt an add-on identity along with an add-on certification.

Beliefs about science and good science teaching. In relation to the teachers' rather weak disciplinary identity, they tended not to attend very much to disciplinary precepts and standards for good science instruction. Teachers' identity includes their "relationships to [their] students, the classroom community, the discipline, and representatives of the school administration" (Enyedy et al., 2005, p.72). As discourse identity stems from the discourse or

dialogue of other people (Gee, 2000), teachers' identities are constructed and upheld through discourse and dialogue about students, content, and teaching (Battey & Franke, 2008).

Accordingly, the teachers' language practices about their profession "both hold the acceptable identities for teachers and carry the important knowledge, skills, practices, and value for teaching" (Battey & Franke, 2008, p. 129). Therefore, the teachers' identity as a general educator rather than a science teacher is closely related to what they discussed about science and good science teaching.

Both of the two high school teachers, Brad and Scott, mentioned that science is very strict and clear. They referred to this belief by using phrases such as "less grey area," "cut and dry," and "fact-based." Brad, the teacher with the strongest background in science, asserted that there is a "difference between how they [the students] are engaging with science and how a scientist does." This view is in conflict with the vision that the Next Generation Science Standards (NGSS) has articulated (National Research Council [NRC], 2011). This new standard aims at moving away from "detailed facts or loosely defined inquiry" (Lee, Quinn, & Valdes, 2013, p. 223). The Framework for K-12 Science Education, which was developed by the NRC of the National Academy of Sciences before the creation of the NGSS, strongly stated that students need to understand scientific and engineering core ideas by "engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" (NRC, 2011, p. 218). The eight essential practices are 1) "asking questions (for science) and defining problems (for engineering)," 2) "developing and using models," 3) "planning and carrying out investigations," 4) "analyzing and interpreting data," 5) "using mathematics and computational thinking," 6) "constructing explanations (for science) and designing solutions (for engineering)," 7) "engaging in argument from evidence, and 8) "obtaining, evaluating, and communicating information"

(NRC, 2013, p. 1). According to the quotes below, the two high school teachers do rarely provide opportunities for engaging in argument from evidence or obtaining, evaluating, and communicating information, and they do not think that these practices are feasible in a high school level science classroom.

In biology, you do have less grey area for value judgment or ethics, so it is more strict.

You don't have as much conversation point. It is so fact-based. (Scott, Grade 10)

Science is a competition of ideas and it's very fierce and if your opinion has no basis in evidence, then your opinion doesn't matter. And for these kids, they don't have a whole lot of information or a whole lot of prior experience with science, so what I have found is that generally their preconceived notion or their opinions don't matter much.... So it's hard for me to communicate that kind of difference between how they are engaging with science and how a scientist does, I guess. (Brad, Grade 9)

James and Maggie, the middle school teachers, have a slightly different view of science.

They pointed out the nature of hands-on activities and exploration in science:

... [Science] gives them something tangible, something they can really put their hands on ... they can do the experiments. They can actually have that hands-on experience of it.

(James, Grade 8)

I think it's most unique about science is the exploration aspect of it... in science you learn about the eco system, I can take you outside. I can pull up a rock ... you are able to incorporate everything outside. You are able to see it and explore and feel it and taste it, experience it, and I think science is different because you know if you don't know, it's for field trip. Go look. (Maggie, Grade 7)

This exploration aspect of science described by James and Maggie does not fully match with

what the NRC has envisioned through the NGSS either; however, middle school science classrooms seem to have more room for asking questions, engaging in argument from evidence and obtaining, evaluating, and communicating information compared to high school science classrooms.

The beliefs regarding high quality science teaching and being a good science teacher are related to their identity as a general educator rather than as a science teacher as well:

I think that a good science teacher is someone who's constantly pursuing better ways to teach, better understanding of materials so both pedagogy as well as the content. (James, Grade 8)

Great science teacher is someone who is able to take questions, "I don't know. Let's find out." And you explore with kids... Just not giving up and trying...high quality science teacher is ... being descriptive, being patient... offering as much support as possible. (Maggie, Grade 7)

I would say a good science teacher is first and foremost to put students at ease. Because when they enter a science or math classroom, they're more, I guess, opposed to enjoying the class. first off, putting them at ease and letting them understand that what they are gonna learn in the classes is actually pretty easy, and showing them that anyone can learn, then, they will help put them at ease, and just making it fun. (Scott, Grade 10)

I think a good science teacher probably has the same characteristics as has a good history, English, or math teachers. Someone is aware, managing the class, organized, productive, that sorts of things. (Brad, Grade 9)

Identity is formed by a discursive process in which talk about actions is translated into talk about states such as "*being* and *having*," and vice versa (Sfard & Prusak, 2005, p.16). This

narrative and discursive nature of identity implies a self-prophecy effect, meaning that teachers tend to act like who they say they are (Holland et al., 1998). In addition, as a mediating tool (Enyedy et al., 2005), identity affects teachers' decision making about what knowledge to use and what classroom practices to implement. Their descriptions of the nature of science, high quality science teaching, and good science teachers reveal their identity as general educators rather than as science teachers and as traditional science teachers rather than as reform-minded science teachers, which are likely to lead to their actual teaching in the same way.

Each teacher has a different background in science and science education; however, all have quite similar beliefs about science and high quality science instruction, which are not those mandated in the science standards. Even Brad, the teacher with the most education and research experience in science, thinks that what a scientist does and what high school students need in a science class are different, and his thoughts about science teaching are similar to those of the other teachers who do not have strong science research backgrounds. Their identity as educators rather than science teachers might be malleable enough to be extended and reshaped; however, their quite traditional view of science, which does not value the aspect of communication, does not help them to construct a new practice generated at the boundary between the domains of science and ESOL.

Add-on Language/ESOL Teacher Identity

The field of teacher identity covers a broad range of topics about the disciplinary identity of subject teachers (e.g., Helms, 1998; Little, 1993; Talbert, 1995); however, few research studies have addressed new hybrid identity added onto their original disciplinary professional identity. This study addresses this gap by exploring how the add-on certification through professional learning affects the teachers' add-on identity development.

To better understand how science teachers develop extended professional identities, I theorized content area teachers' ESOL professional learning and teaching as a boundary crossing event. I employed Hobbs' (2013) BBF Model. The model suggests three groups of factors influencing identity construction: contextual factors, support mechanisms, and personal resources.

Contextual factors. The contextual barriers the teachers addressed include extra-curricular responsibilities, time constraints, standardized tests, block scheduling, lack of resources and funding, and an excessive number of standards. By hindering successful boundary crossing, these barriers prevented the teachers from making science class more culturally and linguistically responsive. The following quotes describe each barrier:

So it is hard. Mostly the barrier is finding the time. Because we really can't do anything more than we are doing, so I gotta be more about changing what it is we were doing, I guess, more accommodate, more specifically address ELL [English language learner] students. But time is the main thing. Feel like I don't have time for anything. (Brad, Grade 9)

Our barriers are always resources, funding, a lot of like we were talking about like audio and stuff like that, art, science book. We don't have a lot of resources. Most of what we teach, most of what we give the students, we make ourselves... There's not a lot of support for activities and worksheets or whatever... Not having the technology. Having to create everything. That's barriers. (Maggie, Grade 7)

However, they also mentioned several contextual supports that ease their boundary crossing such as colleague support, flexible and supportive administrators, and instructional freedom.

I think we are very fortunate here our school. We have flexibility to incorporate language learning in as part of overall holistic approach to education... I think that's been the benefit. (James, Grade 8)

Institutional[ly], I do have a fair amount of freedom in this classroom as far as what goes on, what I want to teach, how I want to teach. I do use, have a lot of freedom here compared to other places I have seen. So I appreciate that. So when I do have students, identify their needs, I know that I will have the freedom to implement kind of what I want. So that's good. (Scott, Grade 10)

As seen in the above quotes, the contextual barriers and facilitators created limitations and possibilities for the science teachers to construct their add-on identities and enact their identities in their classrooms by influencing the availability of a range of supports and professional learning opportunities.

Support mechanisms. Hobbs (2013) found that support mechanisms are vital for safe boundary crossing. She stressed that support mechanisms should be continuous over time and targeted at the teachers' needs in order for the boundary crossing to lead to genuine professional development and identity development. She listed examples of support mechanisms such as instructional coaches and supportive materials that the school provided to the teacher who teaches out-of-field. She also found that the teachers sought opportunities for professional development, collegial help, and other external support. Findings in this study confirm the importance of support mechanisms. For example, one teacher, Maggie, found collegial help from an ESOL teacher at her school:

I got on [Miss Taylor] who also teaches ESOL, and we worked together. We are like "Yes, let's rewrite this question even if just like one word, or just shorter phrase, or more

descriptive phrase,” depending on what it was. I mean they [ELs] were more successful because of that. (Maggie, Grade 7)

In his study on teachers’ cognition, Borg (2003) argues that contextual factors determine the extent to which teachers actually practice what is congruent with their beliefs. The contextual factors and support mechanisms that the teachers found at school determined whether they pursue further professional development and the extent to which they enact what they learn from the ESOL endorsement program.

Personal resources. Hobbs (2013) pointed out personal resources as one group of factors that influence teachers’ boundary crossing. One resource is adaptive expertise such as teachers’ ability to cope with situations where they have to teach ELs. Before the teachers sought professional development and joined the program, they had already been teaching a number of ELs. Brad even had taught a sheltered biology class without any training when he started teaching. In the interviews, Brad mentioned his adaptive expertise:

I found that it was okay. I mean you learn pretty quickly what sorts of vocabulary they are not gonna know... So just paying very close attention to what you are saying, how quickly you are saying it, that kind of thing. (Brad, Grade 9)

Another personal resource to help the teachers’ boundary crossing is teacher knowledge. The ESOL endorsement program in which they participated provided a good amount of knowledge and strategies that allowed them to adapt their instructions for ELs. Except Scott, who was urged by his assistant principal, all teachers participated voluntarily in this ESOL endorsement program. Since they were already teaching ELs in a context where there is a large Latino population and have a greater chance of teaching more ELs in the future, they felt a need to get ESOL training and teach ELs better. What motivated them to participate in the program

was to learn more strategies to help ELs in order to serve lower level ELs. They all thought that generally the courses were helpful to equip them with the knowledge and skills they need. They specifically pointed out the most insightful ideas they learned:

[Basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP)] was really, I guess that was important for me to learn, something I really need to hear, because I don't think it matters that I teach science but you talk to students, hear them talk all the time, and because they seem literate but it doesn't mean they are. I think it helped me reexamine my expectations of students that seem capable of using English effectively because that might not be true. (Brad, Grade 9)

I a lot more speak slower. I repeat often. I have a lot more visual aids. I ask "do you understand" more ... I am more repetitive. I try different things. I will say the same thing eight different times because I know that they need that. I've always had multiple. I understand the kinesic learner, visual learner, and auditory, but with language learners, every single child is all of the above. (Maggie, Grade 7)

I let the [students] kind of working in their own language as long as they always know that that helps them when they come back in English. (James, Grade 8)

Confidence and commitment is also one type of personal resource that teachers can bring to their boundary crossing event. Having confidence in the knowledge and skills to teach ELs appeared to be one factor that determined the degree of successful boundary crossing.

Confidence is drawn from self-assessment that they are equipped with sufficient knowledge of content, strategies, and their learners. The science teachers were seen gaining confidence through participating in this program. As a result of the ESOL professional endorsement program, all teachers said that they are more prepared and confident to teach ELs. They assessed their

preparedness on a scale of 1 to 5:

I will go 5... I feel much better than I did before. So based on where I had been, I feel I am definitely around 4 now, because I feel much more equipped and knowledgeable about how to reach out to apply some things... (James, Grade 8)

Oh, I think I'm 5 compared to say other biology teachers. I'd say 5. (Scott, Grade 10)

I think I probably would've said 2 or maybe 3 to begin with, so I would say I feel better prepared to do it. And a lot of it, maybe some of it just validation. I was doing some of the things already. I didn't know specifically they were beneficial to ESOL students but now I know that this is what I need for them, whereas before I was just using my best judgment. So I think I do feel better prepared or at least more, I definitely feel more confident in doing it. (Brad, Grade 9)

Teacher commitment was demonstrated as "seeking better ways to engage students, devoting time to planning and showing an interest in the subject" (Hobbs, 2013, p. 290). Darby (2007) stated that teachers' commitment can appear to be a passion for students, for the subject, and for engaging students in the subject. In this study, the teachers displayed their commitment to serve ELs; however, the degree of commitment became even stronger upon the completion of the program.

Having to do with all [whose] language is not their first language and so that's always been something that has been in my heart to wanna improve and do. (James, Grade 8)

I think mostly just I feel for them. I think that helps my classroom because it gives me more patience with them. (Brad, Grade 9)

Those duties, you know, that advocacy thing again, that was a big one. And that's something I did not stress. I haven't even really thought about before this program.

(Scott, Grade 10)

I said, "I wanna be ESOL next year," and he [the principal] said, "Well, I don't know who I have in ESOL." I said, "I always want to be in this type of environment. This is where my heart is." (Maggie, Grade 7)

They started to see themselves as language/ESOL teachers and were willing to teach ESOL classes and try out what they learned from the courses. The extension of identity as language teacher is closely related to their knowledge, confidence, and commitment. As a result of the participation in the ESOL endorsement program, they all admitted that they have a new professional identity as ESOL/language teacher in them.

Learning our duties as the primary ESOL teachers. To me, that was a big deal. (Scott, Grade 10)

I do want to be an ESOL teacher. I do think of myself as an ESOL teacher. (Maggie, Grade 7)

It adds another layer to it. You know. You are now a language teacher as well. (Brad, Grade 9)

I haven't really. I feel like I am growing into that... And I guess I have been very pleased to share with others over the last 18 months and that I am learning to be a teacher of students learning the English. I think that's been an ESOL part, has been something that I am working toward, but I guess I haven't really concerned myself having achieved that yet, but I guess the courses are over so maybe I can. (James, Grade 8)

The context where the teachers were working has a large and growing EL population, and the teachers are likely to teach more ELs. This context provides them with a strong pedagogical imperative to gain adequate knowledge and skills to serve ELs. The confidence and commitment in addition to knowledge and skills facilitated their add-on identity development. Also, the contextual factors and support mechanisms that eased their boundary crossing also helped them to add another professional identity successfully.

No Transformation, Yet

Even though the teachers developed a new professional identity, this does not mean that they enacted their identity in their pedagogical practices. The theoretical concept of boundary crossing has been researched in cultural historical activity theory on expansive learning (Engeström, 1987) and situated learning theory on communities of practice (Wenger, 1998); however, it has not been used to elucidate content area teachers' experience of earning add-on certification. Since add-on certification is becoming common in the U.S. K-12 setting, there needs to be much more work in this area, which this study addressed.

Transformation, one of the four mechanisms that creates the learning potential of boundary crossing, is employed to understand the mismatch between professional identity and practices. Akkerman and Bakker (2011) noted that transformation results in significant changes in practices and potentially creates a new, in-between practice, which they call a boundary practice. Transformation involves a series of processes, starting with confrontation of problems or deficiencies that cause people at a boundary to rethink their practices (Akkerman & Bakker, 2011). While teaching ELs, the teachers felt they lacked the knowledge and skills to work with them. At the boundary between ESOL and science teaching, they reconsidered their current practices and interactions with ELs as well as the difficulties that ELs have in science classes.

I have realized that I don't know nearly enough about how to identify and address [race issues] in a classroom, and I am hoping to learn more throughout the course of this program. (Brad, Grade 9)

Academic vocabulary. I think the biggest hurdle they face is comprehending test questions because of the way that they are worded with all of the academic AND content vocabulary that is all loaded with, and just having the ability to pick a part those questions, especially like EOC [End of Course test] style questions are written without any regard to literacy of the students. What I think about them the most is their inability to comprehend the questions on a test. (Brad, Grade 9)

This confrontation with problems led to recognizing a shared problem space, which can be a form of boundary object. While the original conception of boundary object (Star, 1989) is mediating artifacts between two activity systems, Engeström (2001) later described it as “the potentially shared or jointly constructed object” (p. 136) between two activity systems. In this study, boundary objects are closer to the latter view, which is a space for culturally and linguistically responsive science teaching and making accommodations for ELs. Throughout the coursework, the teachers understood the value of multiculturalism, the characteristics of ELs, and useful strategies to make their science classes more culturally and linguistically responsive by incorporating culture and language lessons. The teachers' recognition of the space for implementing what they learned is the second stage of transformation (Akkerman & Bakker, 2011). All teachers made room to incorporate language learning opportunities by allowing students to use their native languages, using cognates, or accommodating test questions such as providing a word bank or reducing the choices for multiple choice questions. However, in terms of incorporating ELs' culture, while the high school teachers did not create space for bringing in

culture in science, the middle school teachers thought that culture could be included in all topics in science if a teacher makes the effort.

That's a huge challenge. The culture thing is a big challenge for me. I mean, there's not a lot of room for that in science standards, and I am always thinking. It's always in the back of my head when I am hearing about how I need to incorporate culture into my lessons that you know science kind of transcends culture to an extent. (Brad, Grade 9)

What makes incorporating culture hard, it's just you don't try to do it. I really believe that. We talk about genetics and heredity in science. Let's research and find out where your families are from, find out why you look like your uncle, Steve. You are gonna find biomes all over the world. You are gonna find people all over the world. They talk about melanin, which makes have, you know, different color skin, and then we talk about hair, protects skin from ultraviolet rays, and then that's where we can bring in different culture. (Maggie, Grade 7)

The third process of transformation is hybridization, in which a new hybrid form emerges at the boundary (Akkerman & Bakker, 2011). In this study, hybridization is manifested as a form of the science teachers' hybrid identity as science and language teachers in terms of new practices of ESOL science instruction and new thoughts about ELs. These quotes describe the hybridization:

I think maybe my level of empathy has increased. I don't know maybe it is not the best attitude I have, but I see students, they come to me essentially as equal and I am gonna treat them as if they were equal. But when I think about my ELs now, I think more about their history and their background and where they have been and how much more

difficulties for them to do basic things like read paragraph and answer questions about it because of their lack of background of our language. (Brad, Grade 9)

I think I became more passionate because now I understand why things are the ways are, and how to support more... I think the only way that my content will work is if I can help them with their language... I realize that what was gonna keep him [an EL], the focus, wasn't on the content... They may need to learn more about how to structure sentence, *the cat ran over to the hill* more so than *the cat is mammal* whatever, but my job is to teach how to communicate in day-to-day life. (Maggie, Grade 7)

The fourth process of transformation is the crystallization of the newly created hybrid form (Akkerman & Bakker, 2011). In other words, the hybrid form at the boundary needs to be incorporated into practice and reified as a boundary object, which is a shared or jointly constructed object. In addition, in this process, “new routines or procedures that embody what has been created or learned” are built (Akkerman & Bakker, 2011, p. 148). In this study, one form of evidence of crystallization would have been the science teachers’ enactment of professional learning as a routine. Even though crystallization is considered very important, there have rarely been many empirical findings (Akkerman & Bakker, 2011); similarly, this study did not find solid crystallization of learning at the boundary.

Mismatch between their professional identity and practice. The data revealed that the science teachers had not been transformed into science and ESOL teachers due to the absence of the crystallization process. They indicated that they recognized themselves as language teachers and advocates for ELs in their schools. In addition, they evaluated themselves as being well equipped with knowledge about the language acquisition process, characteristics of ELs, and strategies to help them. They stated that they were confident and prepared to teach ELs and

willing to have more ELs in their classrooms. However, their hybrid identity as boundary crossers was not fully evidenced in their actual classroom practices. They provided language learning opportunities such as reading and writing activities in science classes; however, they rarely gave linguistic feedback to ELs. Brad had a special education (SPED) paraprofessional who made the most individual accommodations for ELs and SPED students. Maggie had an ESOL parapro who also took the majority of the responsibility for ELs. Moreover, even though they indicated that they were now language teachers, they explicitly said that they do not comment on English but only content since they are not English teachers. Furthermore, they were reluctant to give linguistic feedback because they are “science” teachers and feel obligated to focus on content.

If I have a student, this maybe, doing well with their choice of words, and understanding content, but their syntax is all, you know, [wrong], I am not gonna stress over that. I am not making mention to it... If they understand the material that’s what I wanna see.

(Scott, Grade 10)

With spoken language, it’s harder for me because I know you are not supposed to correct them like little conventions of language that they are getting wrong. I never did that anyway because it was never really the point anyway for science. If your grammar, your spelling is wrong, I never worried about that. So I don’t really know how I would provide feedback to that because I know that the micromanaging their language is not really what you are supposed to do. (Brad, Grade 9)

Hobbs (2013) found that some of her participants easily embraced a new professional identity of “in-field” because they were satisfied with maintaining traditional approaches. On the other hand, others felt “out-of-field” because they felt a deficit of knowledge regarding how to

engage the students. The science teachers who adopted a language teacher identity in this study did not intend to perpetuate traditional teaching methods for ELs. Rather, standardized tests and time constraints on covering standards prevented them from engaging with the crystallization process. The teachers were under heavy pressure to cover all standards to prepare their students for the tests. Even though the NGSS requires rigorous literacy skills, standardized tests have not been developed to reflect the standards. The standardized tests for biology have only multiple choice questions, which discouraged them from implementing more reading and writing activities and providing substantive feedback on ELs' English development.

That's hard because their knowledge of standards is not assessed based on their literacy. It's what it is. But it's they are not writing or speaking. They are taking EOC, which is multiple choice questions. So it is hard for me sometimes justify evaluating their language. So that is difficult to do. (Brad, Grade 9)

It comes down to the quality of that feedback really deals with my time. I mean it truthfully, you know as far as the time I have to grade and to give feedback, that would definitely be the best. (Scott, Grade 10)

In addition, since they had either SPED or ESOL paraprofessionals in their classrooms, they did not see themselves as primary ESOL teachers or ESOL experts despite their completion of the program.

They [ELs and SPED students] do have the coteaching which, when I have one, the accommodations for those two groups are pretty similar. So I lump them together. (Brad, Grade 9)

The last two processes of transformation, "maintaining uniqueness of the intersecting practices," and "continuous joint work at the boundary" (Akkerman & Bakker, 2011, p. 149),

should be built on crystallization of new boundary practices. Therefore, without the crystallization process, the last two processes are unlikely to be expected to occur in the teachers' classrooms. For lasting transformation, with a basis of a new routine of ESOL practices embedded in science classrooms, the teachers may need to find a balance between the creation of a hybrid form and the maintenance of the integrity of both science and ESOL. Furthermore, even though one teacher had asked for an ESOL teacher's help and made efforts towards collaborative work, for more productive boundary crossing, the teachers may need sufficient and on-going systemic supports for genuine dialogue and collaboration with ESOL professionals.

In all, then, this study suggests the usefulness of extending Hobbs' (2013) model and Akkerman and Bakker's (2011) transformation mechanism as theoretical lenses for examining science and other content-area teachers' experience with ESOL endorsement program. This study found that the teachers developed their add-on identity as ESOL/language teachers by gaining new knowledge and skills obtained from the ESOL endorsement program and confidence and commitment to support ELs, as well as adaptive skills to deal with challenging situations. In addition, they negotiated the contextual barriers and facilitators in order to incorporate the new knowledge and skills. They also looked for and created support mechanisms to develop and modify their instruction and assessment further.

However, the teachers have neither practiced their identity in their science instruction sufficiently and routinely nor yet been transformed into both science and ESOL teachers. According to the six processes in the transformation mechanism at boundaries that Akkerman and Bakker (2011) proposed, these teachers demonstrated that they had undergone the first three processes –confrontation, recognition of a shared problem space, and hybridization – but not the fourth process, crystallization, and beyond. The incongruence between their indicated new

identity and their classroom practices calls for contextual adjustment, such as sharing responsibility for ELs with paraprofessionals and a modified assessment system that emphasizes scientific language and literacy.

Conclusion and Implication

This paper provides a platform for understanding science teachers' entry into the ESOL field as a boundary crossing event and its effects on their professional identity and classroom practices. Based on their qualifications and their beliefs about science and science education, the four science teachers had a weaker disciplinary identity as science teachers than was expected and had a stronger identity as general educators. The participation in the long-term ESOL endorsement program equipped them with the necessary knowledge, skills, and dispositions to work with ELs. With a flexible identity as educators, extensive professional learning, and confidence and commitment to EL education, they indicated their willingness to adopt an add-on professional identity as ESOL/language teachers. However, their new hybrid identity did not match with their classroom practices. They insisted on their science teacher identities and were reluctant to take a major role as ESOL teachers in their classrooms, partly because they had assistants who relieved them of their responsibility and accountability for ELs and partly because of time constraints and the absence of literacy demands in standardized tests, which limited their attempts to provide substantive language instruction.

In order to overcome a discontinuity between their self-reported professional identities and their practices, Hobbs (2013) suggested that professional development take an individualized approach and identify where the discontinuity appears when a teacher crosses a boundary and what supports need to be provided. The support needed can be knowledge, strategies, commitment, or aesthetic appreciation (Darby, 2007). Likewise, in order for the science teachers'

add-on professional identity of ESOL/language teacher to be enacted in their classrooms, professional development needs to be more targeted at and focused on individual teachers' needs and contexts. In addition, teachers need opportunities to interpret and recognize their professional learning and classroom practices instead of just participating in the training program and teaching ELs. Teachers will only continuously interpret and recognize their learning if professional development is not simply disjointed, one-time events, but builds continuous support systems. Battey and Franke (2008) suggested that professional development programs must provide ways to help teachers renegotiate new identities and practices with pre-existing structures and norms. To avoid superficial changes and lead to genuine transformation, teacher educators should help teachers to reconstruct and make a new relationship with already established content, practice, and norms. In addition to on-going support and reinforcement, the findings suggest that real transformation of science teachers into science/language teachers can take place by contextual adjustments. The teachers will be motivated to generate new practices at the boundary between ESOL and science domains and incorporate their boundary practices into their instruction only if they receive some form of incentives for their efforts and successes, such as improvement in students' outcomes on tests.

Last, one teacher mentioned that he learned how to teach ELs quickly when he taught sheltered classes prior to receiving any specialized training. In order to attract more educators to ESOL professional development, teacher educators need to develop more informative and meaningful content instead of repeating what teachers think they already know and do. Thus, it is vital to do research on how the curriculum of professional development programs is different from what highly committed and effective teachers instinctively know.

This study looked at a small group of educators in one Southeastern community. Science educators in settings with different credentialing requirements or with other supports/hindrances in place would not experience ESOL professional development in the same way. Future studies could look more broadly across science educators.

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CHAPTER 3

THE IDEAL VS. THE REAL: READING INSTRUCTION FOR ENGLISH LEARNERS IN SECONDARY SCIENCE CLASSROOMS⁵

⁵ Lew, S. To be submitted to *Journal of Literacy Research*.

Abstract

New instructional standards in the U.S. supposedly call for an embedding of many language and literacy skills and practices in content area classrooms including science classrooms. Additionally, recent attention to language and literacy in science education urges science educators and literacy scholars to include reading as an integral part of learning science, which increases challenges on teachers and students. However, in U.S. secondary schools, the percentage of students reading under grade-level is high, and English learners (ELs) are significantly represented among this group. This study examines the nature of reading practices in science classrooms in which teachers had undergone English to Speakers of Other languages (ESOL) training. Using qualitative multiple case study methods, this study found a significant mismatch between actual classrooms and the ideal prescriptions about science literacy instruction portrayed in national standards and research. Despite emerging consensus among science, literacy, and ESOL researchers about the necessity to integrate literacy skills in science classrooms, little research has closely examined the starting point of existing literacy instruction in science classrooms. Even less has focused on EL instruction in these classrooms. This study finds that teachers are battling numerous obstacles to implementing research-based prescriptions. This article suggests that researchers and teacher educators need to give more consideration to negotiating existing constraints and classroom practices when implementing best practices for literacy instruction in science classrooms.

Introduction

Recent attention to language and literacy in science education has led both science education scholars and literacy scholars to view reading as an integral part of learning science (e.g., Moje, 2008; Norris & Phillips, 2003). While reading demands for complex texts increase in secondary schools, reading instruction has traditionally placed low on the list of priorities of science teachers (Fang & Schleppegrell, 2008). Yet, the percentage of students who can read at or above grade level proficiency remains low (National Center for Education Statistics [NCES], 2016). Eighth graders and twelfth graders who demonstrate reading levels sufficient for school success comprise only a third of their respective populations (NCES, 2016).

The literacy needs of English learners (ELs) and immigrant youth whose first language is not English are particularly acute. Students who speak a language other than English constitute 21% of the total enrollment in public elementary and secondary schools (NCES, 2011). In 2013-2014, ELs constituted 9.3 %, an estimated 4.5 million students (NECS, 2016). There is a massive achievement gap between ELs and non-ELs. At the eighth grade level, only 4% of ELs achieved at or above proficient level on the 2015 National Assessment of Educational Progress (NAEP) reading assessment, while 36 % of non-ELs did so (NCES, n.d.). This trend is also shown in other content areas including science. In 2009, ELs' NAEP scores at all grade levels were considerably lower than non-ELs' (August, Artzi, Mazrum, & Center for Applied Linguistics, 2010; NCES, n.d.). On the 2011 NAEP science assessment, 3% of ELs at eighth grade level achieved at or above proficient in science, in comparison to 34% of non-ELs (NCES, n.d.). In rural districts where the current study was conducted, ELs did not meet either the State or subgroup performance targets in virtually all subjects including both reading and science (State Department of Education, 2015).

In response to this urgent issue, a number of reading interventions for secondary students including ELs have been proposed and studied in science classrooms. Surprisingly, however, very little work has carefully documented the baseline conditions of actual literacy practices and reading instruction in science classrooms with ELs. Even less research has looked at the implications of teacher beliefs and practices regarding reading in science for ELs' language development and content learning. This study addressed these gaps by investigating actual reading practices of one group of science teachers who completed ESOL professional development and were newly endorsed, and their influence on ELs' science learning and English language development. This is an under-researched area in both science education and applied linguistics. The study found a significant mismatch between aspirational research-based practices touted in prescriptive pedagogical literature versus practices in actual classrooms. The paper considers implications for teacher educators, science educators, and EL education across disciplines.

Literature Review

Over the past 20 years, educational scholars have developed a consensus that understanding the nature of science language and discourse enhances science learning (e.g., Fang, 2004; Wellington & Osborne, 2001). This development can be traced to a convergence of thought in science education, literacy education, and ESOL education.

Science Education: Science Teachers as Language and Literacy Teachers

Scholars in science education have discussed the critical role of literacy in science learning and teaching for a decade (Wellington & Osborne, 2001; Yore, 2004). They have portrayed reading as an interactive and iterative process including “comprehending, interpreting, analyzing, and critiquing texts” beyond a linear process of decoding words, accumulating

meaning, and locating information (Norris & Phillip, 2003, p. 229). They have advocated reading practices that promote inquiry and conceptual understanding and develop students' scientific habits of mind (e.g., Yore, 2004). They have gone so far as to say that language is not only “a means of doing science and to constructing science understandings” but also “an end in that it is used to communicate inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed actions” (Hand et al., 2003, p. 608). Thus, “without text and without reading, the social practices that make science possible could not be engaged” (p. 612). Accordingly, in science classrooms, they advocate student engagement in active reading which involves a purpose (specific targets, instructions, and goals), a coach (support, scaffolding guidance, direction from a coach), and collaboration (as a shared activity, in groups of two or three) (Wellington & Osborne, 2001). Furthermore, the notion of science literacy has been broadened by a recent emphasis on the multimodality of semiotic tools used in science including symbols, formulas, and animated simulations (Lemke, 2004). Science teachers are also encouraged to teach explicitly how to read non-verbal modes of texts (Oliveira, 2015).

The contention that science language and discourse are key to science education is signified by the introduction of language intensive new science standards, the Next Generation Science Standards (NGSS). The NGSS demand significant changes overall in science education curricula, instructional practices, and assessments (Buxton & Lee, 2014; National Research Council [NRC], 2011). An accompanying framework (NRC, 2011) designed to guide 26 states in developing the NGSS includes eight essential practices. These eight essential practices incorporate high language demands such as asking questions (for science) and defining problems (for engineering); engaging in argument from evidence; and obtaining evaluating, and communicating information (NRC, 2011).

Science educators note that while the Framework is linguistically demanding for all students, it is particularly demanding for ELs “to engage with the full range of oral and written communication skills” to express scientific ideas and practices (Buxton & Lee, 2014, p. 206). Nevertheless, Buxton and Lee believe that the discourse-rich science and engineering practices provide both language learning and science learning environments for ELs as well as non-ELs.

Science educators researching EL pedagogy have advocated an “instructional congruence” framework, which emphasizes building ties between academic disciplines and students’ cultural and linguistic experiences (Lee & Fradd, 1998). In this framework, teachers are urged to integrate knowledge of science disciplines, students’ linguistic and cultural heritage, and English language and literacy (Lee, 2004, p. 67) and also encouraged to acknowledge the contributions of ELs and expect the same participation as non-ELs (Lee, Quinn, & Valdés, 2013).

Literacy Education: Disciplinary Literacy and Every Teacher a Reading Teacher

While science educators emphasize teaching reading as a tool to understand, practice, and communicate scientific knowledge, literacy scholars focus on teaching disciplinary-specific language and epistemology. A principal argument among disciplinary literacy scholars has been that in order to learn and practice science, one should acquire the linguistic structures and epistemological footing that are called for in science (Alvermann, Gillis, & Phelps, 2013; Gee, 2004). This idea is related to the reconceptualization of disciplinary learning as “a matter of learning the different knowledge and ways of knowing, doing, believing, and communicating that are privileged to those areas” (Moje, 2008, p. 99). It is argued that disciplinary learning is accomplished through constructing disciplinary knowledge, developing and enacting disciplinary

identities, and learning disciplinary discourses and literacy practices situated in intellectual inquiries (Moje, 2008).

This argument is grounded in the discourse of *every teacher a teacher of reading*. This discourse was taken up and bolstered by ACT (2010) and the Common Core State Standards Initiative (2010, 2012) calling for subject area teachers' responsibility to foster students' literacy skills. In order to engage with disciplinary texts in science, literacy scholars have suggested incorporating multiple text types such as a variety of genres, symbol systems, illustrations, and other semiotic tools as well as multiple sources and representations such as texts, experiments, simulations, qualitative data, and multimedia (Moje, 2008; Shanahan, 2012). Accordingly, literacy educators often invoke social semiotic theories of multimodality (see Kress & van Leeuwen, 1996; Unrau & Alvermann, 2013) to discuss science language and literacy and to examine multimodal representations of science practices such as inferences, argumentation, experimentation, intertextuality, and genre writing (see Alvermann & Mallozzi, 2009). Moreover, literacy educators also underscore power issues related to science literacy and the need to develop critical and independent thinking and to sensibly judge high-stakes problems such as human lives and future life on Earth (Alvermann & Mallozzi, 2009).

Literacy scholars have also identified multiple challenges in reading science texts, including comprehension of scientific terminology, fluent reading across multiple forms of representation, and writing precisely to represent understanding, prediction, and argumentation (Shanahan, 2012). Therefore, scholars urge science teachers to incorporate differentiated and focused reading strategies for science instead of generic reading strategies in their classrooms.

Despite a plethora of research on disciplinary literacy, it is remarked that the discourse of *every teacher a teacher of reading* has “exist[ed] for nearly a century, yet without widespread

implementation in American secondary schools” (Alvermann & Moje, 2013, p. 1072). Literacy researchers suggest that teaching adolescent literacy is a highly complex task and thus, policymakers and researchers should neither expect that all teachers accomplish this task in a generic way nor demand this task without providing sufficient planning and teaching time and substantial discipline-specific professional learning opportunities.

Literacy research studies targeting second language learners’ literacy development have occasionally been criticized for discourses viewing monolingualism as a norm, implying deficit-oriented views on language minority students, or neglecting potential biliteracy development (see August & Shanahan, 2010; Escamilla, 2009). In response, EL educators have proposed frameworks for inclusive content area instruction for ELs and called upon teachers to differentiate instruction to reach all students (e.g., Gándara & Orfield, 2012).

Applied Linguistics/ESOL: CBI/CLIL and All Teachers as Language Teachers

The learning of science language has generally been addressed in applied linguistics and ESOL education under the framework of Content-based instruction (CBI)/ Content and Language Integrated Learning (CLIL). While science educators and literacy researchers situate the learning of science literacy and language as part of learning science, CBI/CLIL emphasizes the learning of target language in tandem with the learning of science. CBI, “the integration of particular content with language-teaching aims,” refers to the simultaneous teaching of academic subject matter and second language (L2) skills (Brinton, Snow, & Wesche, 2003, p.2). The origin of CBI is usually traced to Canadian immersion programs, the most well-known form of CBI (Cenoz, 2015). In this approach, while students are learning content through their L2, they are developing their academic language skills and can eventually transfer these skills to other subject areas taught in their L2. Met (1998) described a continuum of CBI from the most content-driven,

which is total immersion, to the most language-driven, which is a language class having content- and theme-based courses. The primary goal of CBI in content classrooms is the learning of content, with the learning of English a secondary goal (DelliCarpini & Alonso, 2014); however, teachers are required to set language objectives in conjunction with content objectives.

CLIL, launched by David March and European experts in 1994, is defined as “a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language” (Coyle, Hood, & Marsh, 2010, p.1). Like Met’s (1998) content- and language-driven continuum, Massler, Stotz, and Queisser (2014) differentiate “Type A” CLIL in subject lessons and “Type B” CLIL in language lessons.

Learning science language in applied linguistics is also discussed by functional linguists. Unlike science and literacy education research, functional linguists rely on extensive analysis of science language and discourse. These scholars suggest that content area teachers be taught to recognize and teach disciplinary-specific linguistic and discourse features. For example, in order to facilitate students’ reading science texts, they encourage science teachers to show how to analyze words of Greek or Latin origin and the meanings of their parts, how nominalization works in scientific thinking and reasoning; how to deconstruct lengthy noun phrases with high information loads; and how to analyze zig-zagging Theme-Rheme structure (Fang & Scheleppegrell, 2008). They also suggest that integrating science inquiry with language and literacy instruction will facilitate students’ attainment of the depth and breadth of scientific knowledge (e.g., Tong, Irby, Lara-Alecio, & Koch, 2014).

ESOL researchers looking at the integration of content and language have also advocated linguistically responsive teaching. Lucas and colleagues, concerned that language issues tend to be ignored within a culturally responsive teaching framework, advocate that language issues be

differentiated from cultural diversity in EL teacher education and propose linguistically responsive pedagogical practices (Lucas, Villegas, & Freedson-Gonzalez, 2008). To scaffold learning for ELs, they suggest that teachers do not simplify but rather amplify language by expanding the linguistic and extra-linguistic context of a learning task. For example, teachers are encouraged to use extra-linguistic supports, supplement and modify written text/oral language, and encourage the use of students' native languages (Lucas et al., 2008; Walqui, 2008).

In sum, even though a large body of research from multiple disciplinary perspectives has been brought to bear on reading instruction for ELs in science and content areas, few studies have empirically connected secondary science classrooms, reading instruction/ practices, and EL pedagogy. Moreover, regardless of the school of thought researchers come from, the emphasis has tended to be on ideal classroom practices and the development of prescriptive instructional strategies and curriculum materials for linguistically responsive science classes. While many studies have focused on what *should* happen in classrooms, few studies have examined what *actually* happens in science classrooms in terms of reading and EL-related instruction. Describing the status-quo of classrooms, what is going on in classrooms, is absolutely missing across a range of educational research. Yet, it is just as vital to naturalistically document on actual lived classroom life and examining all the real-life affordances and constraints that science educators operate under if we are ever to successfully implement new science and literacy curricula and pedagogical practices. This study examines the reading instruction in secondary science classrooms. In particular, it looks at science teachers who have trained in ESOL professional development programs. This study explores teachers' own perspectives and experiences with incorporating reading instruction to make science classes language-rich classrooms and accessible to ELs.

The following questions guided this work:

How do reading practices in actual science classrooms coincide with and diverge from the ideal research notions of scientific literacy?

1. How is individual teachers' vocabulary instruction similar and different from applied linguistics research?
 - 1a. What are implications for ELs?
2. How are individual teachers' reading practices and reading instruction similar and different from CCSS and NGSS standard rhetoric?
 - 2a. What are implications for ELs?

Methods

Setting and Participants

Data for this multiple case study comes from diverse secondary schools and participants in one rapidly growing immigrant community in the southeastern US. Schools included 1) a rural district that has a comparatively small proportion of ELs (8.1%) and students from non-English language backgrounds (31.1%), 2) a small urban area district with a significant population of EL (27%) and students from non-English language backgrounds (80.6%) (New America Foundation, n.d.), and 3) a private secondary school with a high percentage (25%) of well-educated international students with high levels of L1 literacy and high socioeconomic status.

For in-depth case study analysis, four participants were recruited from teachers completing a university-based ESOL endorsement program that is designed for in-service educators—two middle school science teachers and two high school biology teachers. The teachers' experience varied from two to thirteen years in K-12 schools. The teachers were certified in multiple subjects including social studies, language arts, and reading except one

teacher, who was certified only in science from 6th to 12th grade. The diversity of settings and participants allowed the exploration of the extensive range of individual and school responses to science literacy teaching demanded by the new standards and suggested by researchers from a variety of fields.

Data Collection

The teachers were observed for three semesters. Data for this study come from three main sources: 1) ten to 20 class observations with each teacher, each 35 to 90 minutes in length; 2) interviews with each teacher 60 to 180 minutes in length conducted at the end of the second and third semesters; and 3) teachers' submitted endorsement course assignments such as journals and classroom artifacts such as the hand-outs and quizzes used in their own science classes. Supplementary data include field notes from three to five researcher visits to teachers' professional learning community group meetings in the ESOL endorsement program each semester, pre- and post-ESOL endorsement program surveys for each participant, pre- and post-program classroom observations of each participant using the Biography-Driven Protocol (Herrera, Pérez, Kavimandan, Holmes, & Miller, 2011), and aggregated EL student school record data.

Data Analysis

In qualitative multiple case study methods, each individual case study makes up a whole study and is used to look for "convergent evidence of the facts and conclusions for the case" (Yin, 2014, p.59). As this study investigated science teachers' reading instruction and practices, I began the analytic process by reviewing common literacy activities suggested by science, literacy, and ESOL educators (e.g., Davies & Greene, 1984; Frost, 2010; Wellington & Osborne, 2001). I sought to understand how activities directed at reading might promote learning science

content and English language and how these activities can be successfully implemented in classrooms. This analysis was guided by the research questions and recommendations for case study by Yin (2014).

I constructed detailed transcripts of all teacher interviews and relevant excerpts of audio-recorded classroom observations. Relevancy was determined based on three criteria: 1) instances in which teachers structured reading practices in science activities; 2) clues regarding specific instruction for science language and literacy; and 3) occasions in which the teachers made specific accommodations for ELs' language development during the class. The analysis consisted of three stages. First, I examined each teacher's data: transcripts, field notes from classroom observations and from teachers' group meetings, notes from informal conversations, teachers' assignments for endorsement courses, and teachers' teaching materials. I then coded the data inductively using the NVivo 10 software program. I mainly used an attribute coding method to log essential information and characteristics of the teacher's beliefs on literacy teaching in science classrooms, reading practices, vocabulary and reading instruction, reading materials, and the contextual challenges. I also used simultaneous coding since multiple codes were applied with qualitative data (Saldaña, 2013). Next, I compared each teacher's interview data and observation data to see if they were congruent with each other. Last, I examined the sets of data in each code, looking for similarities and differences in the four teachers and seeking converging themes/patterns and conclusions for the entire case.

Data analysis yielded several main dimensions of findings, which I elaborate below. I further argue that these findings have significant implications for the organization and delivery of ESOL and other language and literacy-related professional development for science educators.

Findings

The participating teachers created reading/literacy instruction environments mainly by providing vocabulary lessons, requiring reading textbooks or other reading materials, and assigning a variety of activities involving reading and short writing. These environments generated both challenges and potentials for developing ELs' language and literacy skills in the context of content learning.

Vocabulary Instruction in Secondary Science Classrooms

All the participant teachers had a high awareness of the technicality of science vocabulary.

I guess because science itself is completely different language... Science is language and you've got to help them understand that language.... There are certain words that we say don't translate exactly in regular language, so imagine academic language. (Amy)

In order to help students learn the complex language of science, teachers showed students how to analyze words of Greek or Latin origin and the meanings of their parts. This approach was employed by Ethan and Matthew. For example, Ethan explained *bio* means "life". By breaking down words in terms of prefix, root, and suffix, Matthew pointed out *-ase* in *polymerase* and *-ose* in *lactose* indicate an enzyme, which breaks things down. They also reworded technical words into everyday vocabulary that was more familiar to students. Ethan used the phrase "doesn't affect you" to explain *resistance* and associated *multitude* with "many" and *permafrost* with "permanently frozen." He also noted foreign borrow-words such as *Taiga*, the Russian word for forest. Matthew connected *locus* with "location". He first asked students their prior knowledge about the words. One student thought of the meaning of *locus* as a flower. He explained that the students thought that way because of *lotus*. This type of instruction is in

line with approaches suggested by systemic functional linguists. While they focus on whole texts and the patterns of language within as opposed to focus on discrete vocabulary, they also note that the difficult and alienating nature of science texts is partly due to technical terminology (Fang & Schleppegrell, 2008). They find that in order to establish non-intuitive interpretations of the physical world, science uses Latin- and Greek-origin technical vocabulary which can be broken down into prefixes, roots, and suffixes (Fang & Schleppegrell, 2008).

In contrast, Amy, as a middle school teacher, used more hands-on activities for vocabulary lessons. For example, she frequently used a TIP activity, asking students to write down three columns named “T (Term),” “I (Information/Definition),” and “P (Picture)”. Students then looked through their textbook and their notes selecting key terms and finding definitions and information about them. They labeled the terms in their pictures as well. Moreover, for in-depth comprehension of key vocabulary, she spent almost 20 minutes discussing the words with students and provided visuals and activities to support vocabulary acquisition.

Steve had students write the definitions of key words as a part of their notes. Rather than having them copy down the entire sentence in which the key word appeared in the textbook, he instructed them to place the key word to the left in their notebooks and paraphrase the remaining sentence in a grammatically correct manner.

All teachers frequently used visuals and illustrations. When they presented new vocabulary, they labeled the vocabulary on the respective illustrations and had students label on their worksheets. Some teachers had students draw the pictures as well and label the vocabulary. This type of vocabulary instruction is in line with the emphasis on the use of multi semiotic approach and its importance for science literacy in science education and literacy research (see Oliveira, 2015; Unrau & Alvermann, 2013).

In all, this study found a high awareness among science teachers of the technical nature of science vocabulary and the necessity to teach it explicitly. Teachers used a variety of instructional strategies for vocabulary lessons. Their instruction is in line with research recommendations by science educators to allot time for “overt, set-aside teaching time – in short, vocabulary work” for “discussing and explaining the meaning of the words themselves” (Wellington & Osborne, 2001, p. 17) and exploring the roots and origin of words, the structure of words, metaphoric aspects, and different meanings in different contexts.

Implications for ELs. The teachers perceived academic vocabulary to be the most daunting challenge for ELs. Some also noted that the vocabulary in standardized tests aggravated the hardship. Amy and Ethan specifically mentioned that even though standards and standardized tests might help students develop higher order thinking skills such as investigating, recognizing, or analyzing, ELs were not able to show their actual knowledge due to the verbiage of test questions.

I think the biggest hurdle they face is comprehending test questions because of the way that they are worded with all of the academic and content vocabulary that all loaded with.
(Ethan)

They[My students] know what *mitochondria* is, but if they have question that says, *look at this diagram, try to recognize... distinguish this, analyze this*, they are not gonna know what the question is. (Amy)

Since all participating teachers except Steve had classrooms that included students reading below grade level, they already differentiated instruction and applied the same differentiation to ELs. Their practices in this regard were consonant with vocabulary intervention research showing that effective strategies for ELs were effective for non-ELs and even students

with reading disabilities (Helman, Calhoun, & Kern, 2015; Tong et al., 2015). Ethan, for example, said several times, “I did that [language accommodations] for all, not just ELs.”

Whether it's scientific vocabulary or not, the words they [scientists] will use to describe the concept: That is not accessible to any EL student, or even college-prep 9th grade students. So I will give them the words that scientists would use in a parenthesis, ‘this is what that word means,’ but I do that for everybody, because I think everybody needs that.

The teachers’ perception that ELs’ main struggle lies in academic vocabulary led them to reduce text-heavy materials and assignments and to focus on vocabulary lessons including morphemic analysis of (non-) technical vocabulary and the use of graphic organizer and multimodal representations. These practices were in line with research and standards recommendations (e.g., Tong et al., 2014; Wellington & Osborne, 2001).

In all, these science teachers’ vocabulary instruction was the area that conformed most closely to standards rhetoric and research findings in applied linguistics, literacy research, and science education (e.g., Helman et al., 2015). The teachers were aware of the nature of science vocabulary and were using a variety of strategies to facilitate the students’ vocabulary acquisition. The teachers’ explicit instruction and use of those strategies would be beneficial to both ELs and non-ELs.

Reading Practices and Reading Instructions in Science Classrooms

Science texts are often perceived as lexically dense and thus difficult to process, dry, and uninteresting. Research shows that teachers’ tacit beliefs about reading determine their adoption of reading strategies as well as students’ reading engagement with texts (Oliveira, 2015).

Individual teachers in this study were found to vary in their beliefs about literacy and their

perceptions of the instructional environments, and thus their reading practices, instruction, and accommodations for low-performing students including ELs.

Reading aloud. Middle school teachers and high school teachers in this study conceptualized “reading” differently. When Amy and Steve were asked what kinds of reading they did in their classes, they described reading aloud, emphasizing reading fluency, which is defined as comprehending the text when vocalizing (Samuels, 2006). Reading fluency can be an indicator of other components of reading including comprehension (e.g. Başaran, 2013). Amy believed that students should be able to say the word if they need to answer her or talk to anyone in their group. Steve used reading aloud as an assessment tool to judge whether his students were strong or poor readers and their English proficiency level. Steve believed that paralinguistic aspects of reading aloud such as rhythm, speed, and pauses have meaning and was willing to provide comments on them while his students were reading aloud.

Researchers have noted that one benefit of reading science texts aloud is that students can engage in dialogic and collaborative reading while students take turns and read aloud and a teacher leads the whole-class discussions (Oliveira, 2015). Both middle school teachers appreciated this benefit; however, reading aloud did not take place in high school classrooms. When Matthew and Ethan were asked the same question about frequent classroom reading practices, they both construed “reading” to mean reading texts silently and individually.

Textbooks and Power Point slides. Historically, reading activities in science classrooms in US secondary schools relied heavily on state-approved textbooks. However, with the advent of the Common Core State Standards and digital media, this is no longer the case (see Fang & Schleppegrell, 2008). All of the participating teachers were using supplementary reading

materials in addition to textbooks. Moreover, the ways in which individual teachers used textbooks and other reading materials varied widely.

Ethan rarely used his textbook. During three-week class observations over two semesters, he never referred to the textbook while he gave lectures. However, he sporadically assigned students textbook reading to complete activities or to look for information while students were doing small group or individual work. In one genetics unit, he noted that during the entire four-week unit, his students did not touch the textbook a single time. Even in the other units, it was quite rare to use the textbook.

In fact, though, Ethan was ambivalent about his textbook. He thought that the textbook was useful and addressed standards well as long as he assigned the correct chapters. However, he found that the textbook was not accessible to his students because it was written at the presumed grade level reading ability, which many of his students had not reached. Therefore, he used the textbook only if he could not find other ways for his students to learn standards. He noted that he used the textbook when he thought it was the best way to learn the standard, which was rare.

Instead, Ethan delivered content primarily through PowerPoint slides. He used various scaffolding strategies on his PowerPoint slides. For example, he provided guided notes so that students did not have to copy every single word on the slides. He also marked the important words they had to copy in different colors. He provided sufficient wait time for them to write down the information in the slides.

Matthew also used the textbook rarely. He mainly used it when he asked students to refer to illustrations and look up the glossary for vocabulary words.

We do read certain passages and then we do use [textbook] for some exercises ... it really just has some of the best illustrations and examples in it... Other than that, we use it just for vocab look up.

He also relied extensively on PowerPoint slides to explain content. He sometimes supplied guided notes; however, he usually had his students select what to copy from the slides. However, using his considerable artistic talent, he drew many pictures to explain the key concepts. He even created a gigantic drawing connecting all the key terms and concepts of each chapter. He displayed this in his class and also handed it out as a summary for end-of-course test review.

Amy used both the textbook and PowerPoint slides. She chose the chapters to use based on how well each chapter described the standards. She believed that the textbook was a good starting resource; however, "it's not as descriptive, and then in some places, too descriptive for what we need." She had students take turns reading each paragraph in the textbook and explained concepts using PowerPoint slides. She provided guided notes as well.

Steve strictly followed his textbook. Steve believes that it was important for the students to learn how to read and extract important information and materials from the texts. He explained the key concepts and had them take notes from the textbook while they were reading. He had students take turns reading each paragraph in the textbook. Among four participating teachers, he was the only teacher who did not use PowerPoint slides. Without providing an itemized list of facts through PowerPoint slides, he helped students to select information to remember from the textbook. It is noteworthy he worked at a private school where flexibility and less pressure for accountability may make it possible to include more reading instead of delivering facts. He also mentioned that he liked the glossary in the back of his textbook. He used his textbook along with many supplementary materials such as worksheets from an old workbook and activities book. He

did not have as much technology support as public school teachers had, such as smart boards, computer stations in the classroom, or iPads; however, he had only ten students who were highly motivated, well-educated, and able to read the textbook, so his class was full of discussion and individual support.

In all, then, researchers have envisioned text reading as an essential part of disciplinary practices since “text is a primary medium through which disciplinary knowledge is produced, stored, communicated, and critiqued” (Fang & Schleppegrell, 2008, p. 9). In order to engage in disciplinary social practices, literacy researchers have argued that students need to develop the ability to read the disciplinary texts, which includes understanding the language and linguistic structures that disciplinary experts use to create new knowledge and communicate it with appropriate evidence (Alvermann et al., 2013; Fang & Schleppegrell, 2008). Functional linguists argue that the unfamiliarity and difficulty of science texts lie in their grammatical structures as well as words (e.g., Fang & Schleppegrell, 2008). They point out that grammatical features of science include abstraction, high propositional density, and tightly knit structures. In order to help students read science texts more effectively, these scholars encourage teachers to provide explicit instruction on the features of science texts and scaffolding for the in-depth analysis of science discourse and linguistic structure or focused discussion of “how meaning is constructed through language choices” (Fang & Schleppegrell, 2008, p. 9). For this, students need exposure to extended, authentic scientific written discourse.

As we have seen, however, such texts were generally missing in actual science classrooms. In contrast with portrayed ideals of disciplinary language and literacy instruction in science classrooms, only one of these teachers used textbooks regularly. Instead, extended texts had been supplanted by the telegraphic texts of PowerPoint slides and short web page

downloads. These are not the sort of texts that would allow teachers to teach the features of science grammar and discourse explicitly, nor allow students to engage and dig in. This absence of quality texts is true not only for these participating teachers but also the majority of teachers in the U.S. An informal survey (Guzzetti, Hynd, Skeels, & Williams, 1995) showed that approximately 70 percent of U.S. high school students never or rarely read textbooks other than to accomplish assigned tasks. Another study found that secondary students seldom engage in science reading involving any published texts in school (Wellington & Osborne, 2001). Why were such texts missing? For one thing, these teachers believed that the textbooks required a much higher reading level than the level of the students. For another, they noted that the extended texts at their disposal did not exactly match the standards and curricular sequence to which they were expected to conform. It is important to note that teachers did not choose these texts out of a lack of professional information or initiative. In fact, not using textbooks was quite a bit more work for them. Rather, teachers made rational and deliberate choices given the local constraints and populations they worked with. Under these conditions, ideas such as engaging in disciplinary social practices and understanding science language as scientists to create new knowledge and communicate it with appropriate evidence (Alvermann et al., 2013; Fang & Schleppegrell, 2008) come across as perhaps a bit utopian. The final effect was to deter the explicit reading instruction and analysis of science language and discourse.

Reading materials and reading activities. The teachers designed science activities requiring reading. The teachers were aware of a variety of genres in science texts. Amy addressed the genres of texts that her students read in her classes.

It's more like logical than lyrical, or it's not basic, it's more how-to-ish... It's not freestyle. There's process. There's an outline you have to go by. I do that when we teach

scientific method. I say, “Okay you have to, put down on your data. You have to be able to write step by step, what you did to get to this point...And that’s how is with science.

With this awareness, the teachers incorporated widely differing types of reading materials in their classes along with hands-on activities. In a typical class session, Amy spent 45-50 minutes of her 60 minute class on activities or projects. The activities were not for a specific text that she assigned or handed out, but required students to do research, find relevant readings, and read them to solve problems and complete tasks. For example, one activity was an Internet Scavenger Hunt in which students were asked to use the Internet to name five ingredients to be found in cigarettes; to define *cholesterol*; to find out how many chambers are in the heart; to find the symptoms of a heart attack, and six other questions. Her activities required students to read for specific purposes and to share what they found with others to complete tasks, two important components for active reading (Wellington & Osborne, 2003). She also used a reading log in which students responded to an assigned article or a question, and used the school online textbook to obtain ideas for reading assignments and questions.

Ethan also provided multiple types of reading activities. He explained how he selected readings.

Typically, I just use what’s available....I select them based on what I feel is the best representation of content and the standards. Sometimes, they are not as accessible as I like them to be. Sometimes that were written for more literate individuals but it is mostly selected based on how well I feel they addressed the standard.

On his website, he uploaded reading passages for each unit and reading comprehension questions. Notably, he consistently gave guiding questions along with the reading, facilitating his students’ engagement in reading with clear purposes. He often provided magazine articles with

guiding questions. He used varying types of questions as well. He made short answer and fill-in-the blank questions or asked students to sketch a picture and draw a timeline. The questions required students both to deconstruct and to reconstruct the text. Comprehension questions ranged from the literal to applied level requiring inferences or implications. Ethan allotted class time for students to visit his website in order to read and complete reading activities in class. However, he focused more on “derived sense literacy” (Yore, Hand, Goldman, Hildebrand, Osborne, Treagust, & Wallace, 2004), which refers to being knowledgeable in science content. He seemed to believe that “fundamental literacy” (Yore et al. 2004)—being knowledgeable in science language, discourse, and communication system—is developed naturally. He mentioned that he did not intend to develop the students’ reading skills or language skills, but to read biology. Accordingly, his class featured little deconstruction of the text with students, nor explicit instruction of specific features on a particular genre in the assigned text.

I think that any time you are reading you are picking up vocabulary and English. ... All of their assignments require reading comprehension, but none of this like for the purpose of learning English... We are going to read biology... There is enough biology that I have to get through, for me to worry about.

Steve’s main reading activity was choral reading of the textbook. Other than this activity, Steve provided science magazines that students could read if they had extra time after completing their assignments. Instead of assigning specific articles with guiding or comprehension check-up questions or other activities, he allowed students to pick from a menu of articles and orally asked questions about the content. Therefore, thanks to a small class of motivated students equipped with high levels of general literacy, he was able to individualize work with students to deconstruct the texts they were reading. He often used completion

activities and concept maps, but these were related to concept learning and seldom applied to reading texts.

Matthew incorporated the fewest reading activities in his lessons. He seemed to prefer conveying science information through videos over providing reading materials. He admitted that there was not much variety when it came to his reading materials and believed that the concise text in his textbook was beneficial to his students.

Even when he prepared reading materials for class, he tended to use the content of the reading as a discussion opener rather than as a text for reading. Therefore, he rarely included any accompanying guiding questions or activities that might have helped ELs or other students to interact with the text and develop language and literacy skills. For example, in a DNA unit, he distributed a news article about genetic diseases, and read it aloud while students followed along silently. As he read, he would stop and add other facts and point out ethical issues. He then asked students to share their opinions in whole class discussion without assigning tasks on the reading. During discussions, he often made links between readings and real world issues related to science concepts. He was a very knowledgeable teacher with a sociology background and experience in private industry. Drawing on this experience, he often told stories related to history and ethical and social issues. However, since he only delivered them orally and rarely created activities that allowed students to engage with the information in the texts and negotiate its meanings, the information seemed to evaporate for all except a few students who paid especially close attention and raised questions related to the topic. Finally, he collected the articles from students when they were done with the reading. While this preserved his class set of articles for future classes, at the same time it left students without any reviewable text to explore or dig into or study from. The ephemeral nature of spoken and written language in his classroom was

especially problematic for ELs, who often benefit from the retrievability and reviewability of written texts.

In all, then, scholars in science education proposed a variety of activities to promote active reading. Active reading occurs when reading goals are specific, not vague, and when reading is collaborative, not solitary (Wellington & Osborne, 2003). Active reading occurs along with in-depth engagement with texts and leads to develop thinking skills in addition to content understanding. In contrast with these research prescriptions, many reading goals in actual classrooms lacked specificity such as reading self-chosen magazine articles without completing any tasks related to the reading. Many were also solitary such as individual work without collaborating opportunities. Moreover, despite teachers' scaffolding strategies such as providing guiding questions and providing tasks to accomplish using reading, these activities did little to foster students' text engagement or critical thinking skills. In other words, even though teachers employed a plethora of practices to promote active reading to varying degrees, reading activities in actual science classrooms remained largely superficial tasks that only required students to skim the surface. This is in stark contrast with the ideals advanced in research literature that reading tasks should provide students opportunities to dig into and analyze reading materials in depth. Moreover, in contrast to the research recommending scaffolding and direct instruction, teachers did not offer explicit reading instruction on the ways in which science language and discourse are used that might have guided students' dynamic and dialogic negotiation and interaction with science texts (e.g., Lawrence & Snow, 2010). In all, this lack of direct reading instruction may cause considerable difficulty for ELs' development in both literacy and science.

Incorporation of language and literacy instruction and EL accommodations. The teachers generally agreed that it was their responsibility to assure that ELs learned the skills and

knowledge they needed to compete with non-ELs in school and the workplace outside. Since students' academic achievement is measured through standardized tests that require literacy skills as well as content area knowledge, reading and writing proficiency serves as "a gatekeeper to their further learning" (Greenleaf et al. 2011, p. 653). In line with this, the teachers expressed a belief that language and literacy are critical components in science education and ESOL instruction. They viewed language and literacy development and content learning as complementary. Amy even prioritized English language development over science content learning because she felt that lack of proficiency caused ELs major hurdles in accessing content and even in daily communication.

I think the only way that my content will work is if I can help them with their language... because they may need to learn more about how to structure a sentence, *the cat ran over to the hill* more so than *the cat is mammal* whatever... My job, all I'd teach them is how to communicate in day-to-day life. (Amy)

With that awareness and beliefs about the synergistic relation between teaching content and teaching language to ELs, the teachers incorporated a variety of instructional accommodations to differentiate instruction and provide opportunities for ELs' language learning. Accommodations made by teachers included making activities multimodal by incorporating supplemental audio and visual cues; translating science vocabulary into everyday language; using grouping strategies such as small group work and pair work; allowing native language use in class; reducing the amount of text on handouts; and having one-on-one conferences. They also adjusted teacher talk using frequent confirmation questions, repetition, and slower pacing; giving extra time; and providing sentence frames. Amy used cloze strategy, outlines, and guiding questions for EL accommodations. She explained her rationale for these strategies.

When I show videos like the Lion King video, [the outline] has specific things for them to look for and the reason that I do that is because they have to have a basis like they have to know what's expected of them.

The teachers concurred with the notion that a “well-designed and well-delivered lesson for ELs” (Bergman, 2010) will lead to successful learning in nearly every student (p.120). They explicitly mentioned that good teaching strategies for ELs help regular students. For example, Steve said,

I am seeing they [EL strategies] are ... helping our English second language students. I have seen just as important for some of my native English speakers... they need to know that too.

The accommodations teachers made for ELs were in line with precepts of linguistically and culturally responsive teaching and the concept of instructional congruence (Lee & Fradd, 1998; Lucas, et al. 2008), which would help both ELs and non-ELs.

Discussion

Mismatches between Ideal Literacy Practices in Science Standards and Real Practices in Science Classrooms

Unlike the congruence between research and standards-based recommendations and these teachers' vocabulary teaching practices, a significant gap was found between prescriptive and actual practices for reading lessons in these science classrooms. This study found two major mismatches between ideal literacy practices in science standards and real practices in classrooms. First, in contrast with researchers' emphasis on explicit reading instruction, these actual science classes had neither space in their curriculum, nor the time, nor any compelling reason to undertake direct instruction in reading. While the individual teachers in this study

differed considerably in terms of the ways they selected, used, and archived reading materials, science teachers in general have a more limited amount of quality reading materials readily available to them. Instead, then, left to their own devices, they chose an assortment of texts available to them from old textbooks, CD-ROM materials, science magazine, and even very short web-based texts that were topically appropriate but that might not be intended for reading or science instruction. Therefore, reading materials lack coherence and consistency in terms of level of language and depth of content knowledge. It is likely unrealistic to expect science teachers with differing training and little, if any, background in literacy instruction to be able to choose and adapt reading materials written for non-educational purposes with students' language and grade-level science language and discourse.

Accordingly, reading tasks based on such materials are unlikely to provide students with opportunities to develop the competence that the NGSS envisions. Without quality texts and/or any obligation and accountability to teach reading to learn science, teachers did not see the necessity to examine and analyze these supplementary materials beyond what standards they covered.

Moreover, immersed in science discourse teachers seemed largely unaware of this science literacy research knowledge about science-specific linguistic and discourse features. This may be because professional development for science teachers has rarely dealt with disciplinary language and discourse, and even more rarely provided models of how to teach science language using actual texts that science teachers use in their classes.

Despite science standards calling for high levels of language and literacy skills, teachers felt that high-stake tests and heavy-accountability systems did not emphasize those skills. This caused a major dilemma for the teachers:

Their [students'] knowledge of standards is not assessed based on their literacy... they are not writing or speaking, they are taking the EOC [End of Course (statewide) test] which is multiple choice questions. So it is hard for me sometimes justify evaluating their language. (Ethan)

These teachers worked in contexts where they constantly felt time pressure to cover all the standards. Moreover, their students were assessed by multiple-choice standardized tests, which are not measuring how well teachers teach literacy, and test results were the basis of teachers' accountability and pay. In this context, focusing on language and literacy was a luxury they could ill afford, and teaching science through reading was neither the most appealing nor efficient way to accomplish outcomes that they might gain through fact-delivering lectures in much less time (see Alvermann & Moje, 2013 for similar findings). Therefore, even though these science teachers generally agreed with the importance of reading instruction and developing literacy in science, they nevertheless had few incentives to make room for it in their already crowded curriculum and daily lessons.

The other mismatch between ideal standards and these actual classrooms lie in student readiness. For example, Ethan strongly believed that the assumptions of the standards regarding students' capabilities did not match those he could reasonably make about his students. Because he felt that the level of his students was lower than that assumed by the standards, he believed that the best thing he could do is to focus on content to the extent possible, and only secondarily to build vocabulary and basic skills.

The national standards are all about ... learning about science content through inquiry based methods and all that, which is wonderful sounding thing to do, but what you have to be able to do, take part in scientific inquiry, think critically, reading comprehension,

writing ability if you are writing a lab reports, ability to stay on the task, and follow directions, ...some kind of computational ability if you are dealing with data. All of that is assumed with those inquiry-based science standards... I cannot assume those things.... Just not reality.

This teacher illustrates a dilemma that many teachers at low-performing schools might feel. In an ideal classroom, the NGSS tend to assume that all students are equipped with the presumed grade level literacy and other skills required to engage in inquiry-based lessons and cognitively and linguistically demanding tasks to develop science content acquisition, science literacy, and critical thinking skills. However, in real classrooms, in an area known for chronically underperforming schools, real teachers cannot assume that real students have those skills.

This mismatch affects the science learning and language development of ELs even more seriously. There is another layer of mismatch between ideal EL instruction in science and actual EL accommodation in science.

Implications for ELs. The lack of explicit reading instruction and the absence of quality reading materials can be particularly detrimental for ELs. Second language learners benefit from explicit and conscious instruction on reading strategies such as metacognitive strategies (Genesee, Lindholm-Leary, Saunders, & Christian, 2005). The belief that ELs will naturally develop English language proficiency while they are reading may aggravate the situation because ELs learn more slowly than non-ELs and will fall behind even further without explicit reading instruction. Moreover, for ELs who lack exposure to written discourse to be used as model texts, the absence of a major reading text to analyze, engage with, and communicate about is particularly disadvantageous to the development of both English language and science literacy.

According to the six principles comprising the linguistic foundation for teaching ELs in content classrooms proposed by advocates of linguistically responsive teaching (Lucas et al., 2008), ELs need opportunities to interact with others, to produce outputs based on the text, and to focus on forms and functions explicitly. The teachers here provided specific and purposeful tasks requiring not only engagement with the text but also interaction with others and the production of a particular form of output— at the least, answers for comprehension questions; however, instruction for the explicit focus on forms and functions of science discourse rarely occurred. Moreover, some teachers seemed to provide individual help if necessary and when students seek help instead of providing a whole class reading lesson, which can imply that they may place reading instruction at a lower priority.

Therefore, another dimension of mismatch between research and real classrooms with respect to EL pedagogy evidently exists. Research in applied linguistics and ESOL pedagogy stresses explicit reading instruction and extended discussion and practice of reading in science, which develops a fundamental sense of literacy for science content and the English language. However, the types of accommodations tend to focus more on a derived sense of literacy for content delivery.

Conclusion and Implications

This study demonstrates a serious mismatch between ideal prescriptions about science literacy instruction in national standards and research studies, and real classrooms. Science educators, literacy scholars, and applied linguists/ESOL experts have studied and proposed a plethora of principles and strategies that reflect what they have determined as exemplary literacy-embedded science practices. Nevertheless, this work tends to presuppose an ideal classroom where students have the ability to engage in inquiry-based science and have grade-

level literacy skills, textbooks or other reading materials provide a variety of science genre texts, and the curriculum has room for explicit teaching of reading strategies and in-depth engagement with texts. This work fails to reckon with actual secondary science classrooms, where teachers are battling a number of obstacles to the implementation of research-based suggestions. Individual differences in approach and philosophy regarding ELs and science literacy education also contribute to this gap between the ideal and the real.

Meanwhile, ELs are being educated in those actual classrooms by actual teachers. Therefore, in ESOL professional development, this study shows a need to go beyond top-down approaches to science literacy professional development that tend to assume somewhat utopian classroom conditions. Instead, it highlights the importance of bottom-up approaches that begin by examining where teachers and classrooms actually are, investigating the existing classroom practices of actual secondary science classrooms, the mandates that they are required to follow, and established curricula, tests, rules, and norms regarding science, literacy, ELs, and types of supports.

Accordingly, in teacher education for ELs, this study shows a need to develop systematic implementation plans. The NGSS and the CCSS require that science teachers develop students' ability to read, write, and communicate in science (ACT, 2010; CCSSI, 2010; NRC, 2011). Researchers have identified the most successful reading practices in science (e.g., Norris & Phillip, 2003). A great number of research studies have developed strategies and activities for reading in science classrooms. However, there have been virtually no systematic and strategic plans for aligning them with the standards and tailoring them to varying levels of students so that teachers can accomplish such implementation. Researchers and teacher educators need to consider the questions such as how much language and literacy should be included, where in the

existing curriculum language and literacy should be included, what the structure of a literacy inclusive science classroom should look like, and what kind of preparation ESL teachers, science teachers, administrators need (Valdés, Kibler, & Walqui, 2014). Without such concrete plans, disciplinary literacy instruction will remain a mere slogan and an unrealized ideal (see Alvermann & Moje, 2013).

Instructional practices effective in one ideal context are unlikely to have the same effects in a social setting that has very different components. Instead of simply proposing ideal science literacy instruction, teacher educators and researchers need to consider practical ways to incorporate ideal science literacy instruction into teachers' existing practices. Policy makers and administrator should develop strategies for the systematic improvement of the environment in terms of instruction time, professional development opportunities, and assessments aligned with standards instead of urging teachers to follow model instruction that is not feasible in their current situations.

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CHAPTER 4
SECONDARY SCIENCE TEACHERS AND L2 WRITING INSTRUCTION⁶

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Abstract

Educators across the content areas have been aware of the close relationship between writing competence and academic success. Instructional standards in the U.S. emphasize writing as a key means to achieve multiple academic purposes. Nevertheless, researchers find that many secondary teachers are unprepared to teach writing and do not consider it their primary responsibility. Consequently, writing instruction in secondary content classrooms such as science classrooms tends to be very limited, contributing to poor student academic writing quality overall and significant underachievement by adolescent English learners (ELs) in particular. In order to address this issue, this multiple case study explored the efforts of six secondary science teachers to meet advanced writing demands. Data analysis yielded two major findings. For one, it suggested that these science teachers perceived writing as a skill critical to achievement in secondary school to be addressed across all content areas. Nevertheless, explicit writing instruction did not occur in teachers' own classrooms, and writing opportunities they provided were not aligned with what researchers advocate for science learning. Additionally, contextual barriers such as the predominance of multiple-choice standardized tests and low student literacy level discouraged them from teaching writing or providing feedback on students' writing. Implications are drawn for improving EL writing in secondary classrooms.

Introduction

Educators across the content areas are becoming more aware of the close relationship between writing competence and academic success (Graham & Hebert, 2010). In the U.S., the widely implemented Common Core State Standards (CCSS), especially the Standards for Literacy in History/Social studies, Science, and Technical Subjects 6-12, emphasize writing as a key means of communicating a variety of messages and preparing students to be “college and career-ready writers” for multiple academic purposes (CCSS Initiative, 2012, p. 63). The recently introduced Next Generation Science Standards (NGSS) demand such challenging tasks as well (Buxton & Lee, 2014; National Research Council [NRC], 2011). The NGSS aim to ensure that all students develop both a scientific conception of the world and the ability to make intensive use of language in order to engage in scientific and engineering practices. Science education researchers have expressed concern that “[engaging] with the full range of oral and written communication skills” to express scientific ideas and practices is linguistically demanding for all students, but it is particularly so for English learners (ELs) (Buxton & Lee, 2014, p. 206).

Along with the calls for developing students’ writing competence, secondary writing researchers have identified effective practices for writing instruction (e.g., Graham & Perrin, 2007), conducted intervention studies (e.g., Early & Sady, 2014; Matuchniak, Olson, & Scarcella, 2014), and investigated secondary teachers’ writing practices in content classrooms (Gillespie, Graham, Kiuahara, & Hebert, 2014; Graham, Capizzi, Harris, Hebert, & Morphy, 2014). They have found that many secondary teachers manifest a lack of preparation to teach writing and not consider teaching writing as their primary responsibility, leading to limited writing instruction in secondary content classrooms (Applebee & Langer, 2009; Kiuahara,

Graham, & Hawken, 2009). This lack of writing instruction in general, including in science classrooms, results in poor academic writing outcomes for many students in U.S. secondary schools, including significant underachievement by adolescent ELs. The 2011 National Assessment of Educational Progress (NAEP) data indicate that at both Grade 8 and Grade 12, only 1% of ELs were ranked at or above the level of proficient in writing, compared to 31% of non-ELs (NCES, n.d.). The pattern is mirrored in science, where 3% of ELs versus 36% of English-speaking students at the eighth grade level are ranked at or above proficient in science (NCES, n.d.).

Only 12.5 % of U.S. content teachers who have ELs in their classroom (National Center for Education Statistics, 2002) have participated in any EL-related professional development. The percentage might be much less when training specifically for writing instruction is considered since statistics concerned with this topic do not exist. Moreover, even research (Bentley, 2004) suggests that teachers who receive training in EL instruction may not actively use the strategies they learned in their classrooms.

Given the increased emphasis on writing to learn and do science, the underperformance of ELs in writing and science, and the reported unpreparedness of science teachers to incorporate writing instruction for ELs in science, this article investigates the efforts that science teachers in one US setting made to meet advanced writing demands, and the barriers that these science teachers encountered in their efforts to support writing instruction for ELs. The article draws implications for the supports that science teachers might provide for ELs to engage successfully in writing tasks.

Related Literature

Writing Practices and Instruction in Secondary Content Classrooms

Studies of writing-to-learn in content areas (Applebee & Langer, 2011; Graham, Harris, & Hebert, 2011; Klein, 2000) have consistently found a lack of extended writing practice in US secondary classrooms. Recent large-scale survey studies on writing instruction in secondary schools (Applebee & Langer, 2011; Gillespie et al., 2014; Graham et al., 2014) have yielded five major findings. First, they reveal that many teachers feel unprepared to teach writing. Seventy percent of high school teachers indicate that they received little to no preparation to teach writing in their preservice teacher education, and 56% indicate receiving inadequate preparation in their in-service training programs (Gillespie et al., 2014). Second, while content area teachers understand the benefits of writing to learn content, only 7.7% of classroom time is allocated to writing (Applebee & Langer, 2011). Science teachers report spending less than 2 minutes a day on writing instruction on average, and students report spending less than 5 minutes a day writing (Graham et al., 2014). Third, typical writing practices are either writing without composing, such as short answer responses, note taking, worksheets, and making lists; or “using writing to understand or remember content material or text” such as summary writing (Graham et al., 2014, p. 1040). These activities do not involve “analysis, interpretation, and personalization”, which are highly recommended by advocates for writing-to-learn (p. 1067). Fourth, while teachers use evidence-based writing practices (Graham & Perrin, 2007), explicit writing instruction rarely occurs. Fifth, use of technology and digital writing tools is very limited. These research studies note the discrepancy between writing practices in classrooms and the expectations in the CCSS and strongly urge teacher educators and the education system at the

state and district levels to prepare content teachers to teach writing. These studies, however, do not address whether EL-related professional development affects teachers' writing practices.

Research on Writing in Science

Ideally, science education researchers and policymakers hope that teachers view science writing as “a form of discovery” (Frost, 2010, p. 184). They believe that written communication in science “establishes detailed associations among evidence, warrants, and claims; makes utterances permanent; allows scientists time to reflect on their thoughts, mental images, and claims; and documents proprietorship of intellectual properties” (Yore et al. 2004, p. 339). Therefore, they argue that an expert science writer has and applies scientific knowledge, controls science discourse, and uses writing strategies for effective written communication (Yore, 2000). Based on this ideal, science education researchers have sought to integrate writing instruction with inquiry activities (e.g., Buxton, Salinas, Mahotiere, Lee, & Secada, 2014; Greenleaf, Litman, Hanson, Rosen, Boscardin, Herman, & Schneider, 2011). They encourage students to learn to write like a scientist by using different writing modes and encourage teachers to provide “guidance in understanding the different conventions of each type of writing, support in adopting them, and opportunities for practicing them” (Frost, 2010, p. 185).

Two distinctive approaches to writing-to-learn science include systemic functional linguistics (Klein & Unsworth, 2014) and pedagogical theory (Hand & Prain, 2002). Systemic functional linguists argue for the necessity of explicitly teaching the hidden rules and the linguistic features of traditional science genres, as well as of helping students to understand and reproduce those forms and functions of science writing (e.g., Martin, 1999; Veel, 1996). In contrast, pedagogical theorists argue for teaching different types of writing for diverse purposes and readerships (e.g., Bereiter & Scardamalia, 1987; Gunel, Hand, & McDermott, 2009) by

using multimodal representations (Prain, 2006) and by connecting emerging science knowledge and vocabulary to students' personal experiences and everyday language through communicative tasks in authentic contexts (e.g., Hand & Prain, 2002; Senn, McMurtrie, & Coleman, 2013; Towndrow, Ling, & Venthan, 2008). Additional group of researchers (e.g., Carter, Ferzli, & Wiebe, 2007; Sampson, Enderle, Grooms, & Witte, 2013) propose writing to learn by learning to write such as using a science writing heuristic (SWH), which provides opportunities for realistic but serious writing tasks in science classrooms, developing argumentative writing skills through inquiry.

In order to support teachers' implementation of writing-to-learn strategies, science literacy scholars have identified common writing genres in secondary science classrooms (Frost, 2010) and types of writing tasks (e.g., Hammerman & Musial, 2008; Hassard, 1992; Llewellyn, 2013), and proposed several frameworks and scaffolding strategies (Frost, 2010; Prain & Hand, 1996; Yore, Hand, & Prain, 1999). However, few research studies have investigated how those strategies and writing genres/tasks are actually practiced in science classrooms. This study addresses this gap and explores the strategies that individual science teachers use to teach writing, the genres and writing tasks that are used or not used, and how well this usage conforms with the recommendations of science education researchers.

Science and Writing Instruction for ELs

Most of ELs' socialization into academic literacy (i.e., academic norms for writing in English), which largely takes place in content-area classrooms rather than ESOL classes focusing on language development or sheltered content classes adapting language and content for ELs (Enright & Gilliland, 2011). However, contemporary standards and accountability-based policies that are intended to promote educational equity for diverse students have resulted in

standardization and marketization, which, in turn, result in limiting the diversity of curriculum and instruction (Skerrett & Hargreaves, 2008). In this context, writing instruction has been narrowed into teaching only the types of writing appearing in tests, which has constrained opportunities for ELs to learn norms for academic writing (Enright & Gilliland, 2011). Even though it is a common view that content knowledge and English language proficiency can be developed at the same time, only a few research studies have actually examined the simultaneous science and writing achievement of ELs (Amaral, Garrison, & Klentschy, 2002; Lee, Deaktor, Hart, Cuevas, & Enders, 2005). Lee and her colleagues (2011) conducted an intervention study incorporating science content and English language and literacy development for elementary school teachers and students and found that advanced ELs succeeded in developing both content and English literacy. Several studies have examined how writing is taught in science classrooms and how ELs engage in science writing: the instructional strategies of a high school science teacher to support ELs and their uptake (Swanson et al. 2014); adolescent ELs' different stances toward different content-area writings (Wilcox & Jeffery, 2015), bilingual learners' experiences of literacy and writing in different tracks of classes (Enright, 2013); and the discrepancy between the perceptions of adolescent second language (L2) writers regarding content area writing tasks and the expectations of their teachers (Kibler, 2011).

In all, while there is growing interest in writing instruction in US secondary classrooms, existing research is as yet thin, and findings often suggest a disconnect between pedagogical ideals and actual practices. Moreover, research has yet to make adequate connections among science education, writing instruction in content areas, and accommodations for ELs in L2 writing instruction in content classrooms. Existing research has also tended to take the form of broad surveys, and only a few qualitative studies exist that closely examine what writing

instruction looks like in secondary science classrooms. In order to have a substantial understanding of writing instruction in the U.S., it is necessary to conduct more in-depth longitudinal qualitative studies investigating how writing instruction serves diverse students and varies in each content area and in individual teachers' classrooms with different contextual factors. This study contributes to addressing this gap with a multiple case study of six secondary science teachers' writing instruction and practices with an emphasis on their affordances for ELs. The following research questions guided this work:

What is the nature of the science teachers' guidance/accommodations for ELs' language development in the context of science writing?

1. How do writing practices and instruction in the science teachers' classrooms converge toward and diverge from the principles of writing practices recommended by the CCSS and the NGSS?
2. What mediators and barriers impact science teachers' decision making in their writing instruction?
3. What are the implications of science teachers' writing instruction and practices in their classrooms for ELs' language and content learning?

Methods

Setting and Participants

The data used in the present study were collected within a university-based federally-funded three-course ESOL endorsement professional development (PD) program designed for in-service educators. Data were drawn from diverse secondary schools in one Southeastern U.S. community including two districts and one private school: 1) a rural district with a relatively small percentage of ELs (8.1%) and students from homes where a language other than English

was spoken (31.1%), 2) a small urban area district with an extremely high percentage of ELs (27%) and students from homes where a language other than English was spoken (80.6%) (New America Foundation, n.d.), and 3) a private secondary school with a high proportion (25%) of elite international students well-educated in their home countries.

Six secondary science teachers, four middle school teachers and two high school biology teachers, were selected for in-depth case study analysis. The teachers' careers ranged from two to sixteen years in K-12 schools. All teachers except one had additional certifications in other subjects including social studies, language arts, and reading. The diversity of settings and participants provided opportunities to explore a broad range of individual and school science writing contexts.

Data Collection

This article is based upon three main sources of data collected for one and a half years: ten to 20 class observations of each educator, each 35 to 90 minutes long; interviews lasting 60 – 80 minutes conducted with each teacher; documents comprising teachers' completed ESOL endorsement course assignments such as journals and classroom artifacts such as the handouts and quizzes for their own science classes. Supplementary data included three to five researcher visits to participants' ESOL endorsement professional development learning community group meetings each semester, pre- and post-ESOL endorsement program surveys for each participant, pre- and post-program classroom observations of each participant using the Biography-Driven Protocol (Herrera, Pérez, Kavimandan, Holmes, & Miller, 2011), and aggregated EL student school record data.

Data Analysis

A qualitative multiple case study method was selected because of its focus on investigating each individual case study comprising a whole study and seeking “convergent evidence of the facts and conclusions for the case” (Yin, 2014, p.59). As a first step, all interview data were audio-recorded and transcribed. Classroom observation data were audio-recorded and selectively transcribed with foci on writing practices and instruction including clues regarding science teachers’ beliefs about writing instruction, instances in which the teachers provided writing practice, and instances in which the teachers made specific accommodations for ELs’ writing during class. As a second step, the transcribed data, field notes from class observation and informal conversations, and documents were inductively coded using NVivo 10 software. An attribute coding method was used in order to record important information and characteristics of the teachers, their beliefs, and their practices, and the contexts. A simultaneous coding was also used since qualitative data are often coded under multiple themes (Saldaña, 2013). As a third step, with the constant iterative and comparative method within and between data sources, emerging themes and major themes related to the research questions were identified. As new confirming or disconfirming data were found, these themes were verified and modified. Concurrent data analysis informed and reformulated subsequent data collection.

Data analysis yielded three main areas of findings. For one, it suggested that these science teachers perceived writing as a skill critical to achievement in secondary school to be addressed across all content areas. Nevertheless, teachers did not offer explicit writing instruction in their own classrooms, and the forms of writing opportunities they provided were not aligned with what writing researchers advocate for science learning. Second, findings show that contextual barriers such as the prevalence of multiple-choice standardized tests and low

student literacy levels deterred teachers from investing time and effort to teach writing and provide feedback on students' writing. Finally, findings indicate that despite the opportunities of writing practices in science classrooms, lack of provision of specific language feedback would confuse what they are expected to perform and slow down ELs' learning English and science.

Findings and Discussion

Writing Practices and Instruction in Secondary Science Classrooms

Secondary science teachers in this study believed that the importance of writing should be addressed not only in science classrooms but also across all content area classrooms; however, at the same time, teachers struggled to make room for writing practice in science genre and explicit writing instruction.

Science teachers' perceptions of writing in science class. All participants believed that writing is a central skill that students need to develop in secondary schools. They recognized the complex process of writing, in which writers use information from multiple sources and reconstruct new meanings. They argued that every subject across the entire curriculum needs to teach how to write. For example, one teacher observed,

I think [writing] needs to be addressed earlier... That needs to be done in English, in history, in math, and in every area to get them practice in it, not just in science. (Kyle)

The science teachers' beliefs about the importance of writing in science class converge with the recommendations of writing researchers in content areas. They stress that writing may serve a variety of purposes: to teach students to communicate about content; to think critically; to construct new knowledge; and to enhance content learning (Klein, 1999; Klein & Krikpatrick, 2010). Proponents of writing-to-learn view writing as "creating texts that explore relationships among ideas," in contrast to "composing with restricted writing" such as copying information

(Klein, 1999, p. 204). Likewise, the Common Core State Standards (CCSS) for Literacy in History/Social Studies, Science, and Technical Subjects 6-12 emphasize writing as a key means of conducting and engaging in disciplinary practices and require students to be college and career ready-writers, who are able to select appropriate language and structure for a variety of tasks, purposes, and audiences. (CCSS, 2012, p. 63)

The teachers in the study also agreed that writing would play a critical role in their students' academic paths and future careers.

I really think that writing is something the students are gonna need the most when they move out of the high school, when they move out of middle school and then into high school, and beyond... So if we don't train them how to write, how to analyze data, and how to analyze text, and they are not going to be able to be successful beyond high school...I think writing should be across the entire curriculum. (Sarah)

These beliefs are in line with Enright's (2013) argument that writing can serve as a form of gatekeeping that limits access to advanced-track classes for immigrant youth who lack English literacy.

Yet, despite their consensus on the importance of writing in science, the case study teachers' actual writing instruction diverged significantly from the explicit writing instruction and implementation of writing practices that researchers might hope to see. Their practices and instructions seemed to share some implicit norms for literacy practices in secondary science, but also varied depending on their unique backgrounds and instructional environments.

Writing practices and instruction in individual teachers' science classrooms. In general, broad literacy norms in these secondary science classrooms seemed to require students to produce sentence-level written responses to demonstrate their understanding. The writing

genres participating teachers assigned to their students included a daily/weekly journal, lab report, science book report, research paper, essays, and narratives. Students were required to describe science concepts and processes and demonstrate evidence for their responses. Individual teachers' instantiations of these broad literacy norms in their local classroom contexts also depended upon their personal beliefs about literacy and science, the needs of their students and mandatory assessment systems.

The most common writing practice among all participating teachers was note-taking. Some teachers (Larry, Alex, and Sarah) provided explicit scaffolding for taking notes, while others (Kyle, Lauren, and Erin), provided more general directions. Larry taught in a private school where the majority of international students had a high level of L1 literacy skills and academic preparedness. He considered note-taking skills very important and explicitly guided his students in recognizing and extracting important information and organizing it in their notes. While students took turns reading aloud from their textbook, he stopped to explain key vocabulary words and concepts and guided the students in writing key words on the left side of their notes and definitions on the right side. He also guided them in rearranging the word order to write definitions in a grammatically correct way, not just to copy down what is said in the textbook. Alex taught biology in a public high school in a class with 5 to 7 ELs and another 5 to 7 special education (SPED) students. Since he understood his students' literacy level did not reach presumed grade-level for reading materials he assigned based on the demonstrated student performance in other science assignments, he provided many types of scaffolding. When his students took notes, he always provided guiding notes, which were the same texts on his PowerPoint slides but with blanks that students had to fill in and with questions that students had to answer. He marked the parts students had to copy down in different colors on his PowerPoint

slides. Sarah taught a support class that combined reading and science literacy for students who did not pass the state standardized tests for reading and science. Since her class had only 15 students, she could provide much more guidance and individual help to students. For ten minutes at the beginning of every class, she discussed vocabulary words using the Frayer Model (Frayer, Frederick, & Klausmeier, 1969), a graphic organizer comprising four squares labeled a Definition of the word, Facts or Characteristics of the word, Examples, and Nonexamples. Her students copied down what she wrote on her slides. Every week, she had a conference with each student to check their notes and their progress.

On the other hand, Kyle, who taught biology in a public high school and had only a couple of former ELs who were monitored, required students to take notes while he provided a lecture through PowerPoint slides; however, he did not always offer guiding notes, but allowed the students to judge the most important ideas from the slides. He provided support while they were working individually. The middle school teachers, Lauren, teaching mostly ELs, and Erin, teaching a few ELs and a majority of SPED students, did not address note-taking while they provided a lecture through PowerPoint slides. Notetaking did not seem like a class norm. Their class hours were devoted to more hands-on activities than lectures and note-taking.

Another common writing practice consisted of major writing assignments. Larry, for example, assigned his students to write a narrative from the perspective of a scientific entity. This is similar to perspective writing using the widely-used RAFT (Role of the Writer, Audience, Format, and Topic) writing strategy to help students to write from various perspectives (e.g., Grant & Fisher, 2010). For example, in a chapter on the electron spectrum, Larry had students personify one of the types of radiation (*radio wave*, *X-ray*, *ultra violet*) and then write a letter to a friend such as *another radio wave* or the *sun*. Kyle gave his students four major writing

assignments during the study. One was to describe a natural phenomenon. In order to make writing assignments manageable, he had students write a few sentences at a time in small chunks (rather than drafting an entire five-paragraph essay), while he emphasized that “[I] will look for proper sentences, proper English.” Erin’s writing assignments included writing lab reports, science book reports, and practice essays for the school benchmark test. She also collaborated with a language arts teacher and had her students work on four projects. One of them was a research report, in which students had to apply science concepts and include three citations using APA style.

Teachers who did not give major writing assignments generally included writing portions in a variety of hands-on activities and as part of reading comprehension activities. Lauren, for example, created a myriad of hands-on activities and projects related to life science. In a unit on body organs, she created a variety of activities that enabled students to feel and see their bodily responses. During or after each activity, she asked them to describe processes, summarize results, or analyze/justify answers in written form. The projects she created also included a great deal of writing, such as making a science brochure, writing a science poem, or creating a scientist’s Facebook page. Alex provided many reading materials with guiding questions that he made himself. His guiding questions for reading texts included short answer questions, which required students to write one or two sentence responses. The questions required students to describe, justify, summarize, explain, or infer. He emphasized the use of appropriate wording and vocabulary.

Overall, then, science teachers implemented a number of writing practices in their classrooms in order to address the advanced writing demands prescribed in research and standards. However, the types of writing practice they assigned were in nature quite different

from those recommended by writing researchers and science literacy scholars. The teachers generally did not require students to compose and write like a scientist by utilizing science language and discourse, incorporating higher order thinking skills and taking into consideration audience and context (e.g., Frost, 2010). Moreover, explicit writing instruction was generally missing in these classrooms.

Plentiful writing practice, but scant writing instruction. This study found two notable features in regards to writing in science classrooms. One is that the teachers here actually integrated a significant number and variety of writing practices in their classrooms. Previous research has found that content area teachers used a variety of writing practices; however, they used them infrequently (Applebee & Langer, 2011; Gillespie et al., 2014; Graham et al., 2014). In science classes, students reportedly spent less than 5 minutes a day writing (Graham et al., 2014). Unlike such findings, the teachers in this study provided considerable opportunities for their students to write; however, they seemed to favor non-traditional science genres, such as narratives, brochures, posters, or science book reports, rather than key scientific genres such as arguments and lab reports.

In addition, writing practices still focused on demonstration of student learning, and it was rare to see writing-to-learn practices. Researchers and the CCSS encourage teachers to make opportunities for adolescents to use writing as a learning tool to help them analyze and think about the content presented in subject areas. One core prescription of the NGSS is to use writing as a means of obtaining, evaluating and communicating scientific information. Scholars and standards advocate argumentative and explanatory writing to help students with learning content by analyzing and interpreting complex information. However, these expectations seem very distant from the reality of secondary science classrooms, where the majority of writing practices

were demonstrating or transferring knowledge in a couple of sentences. This finding is also in line with national survey results indicating that while teachers apply writing to support learning, a goal of the CCSS, students typically write reports and argumentative texts just once or twice a year (see Applebee & Langer, 2011; Graham, Harris, Hebert, 2011) .

Moreover, the CCSS encourage students to write like scientists. However, research on scientists indicates that they themselves may endorse a traditional knowledge-telling notion of writing (Yore, Hand, & Prain, 2002). Scientists tend not to be aware of the use of different genres, the interconnections between each stage of a writing process, the strategies for how to engage in readers' background knowledge, nor the full impact of rhetoric on their understanding of ideas. Therefore, they do not practice certain types of genres or execute certain stages of the writing process (Yore et al., 2002). Given that even scientists use a limited range of writing, it seems problematic to expect science teachers to teach writing like a scientist at a secondary level.

The other notable feature in regards to writing in these science classrooms was the absence of writing instruction despite frequent writing practice. Previous studies such as Applebee and Langer (2011) have likewise found that very little time in content areas is devoted to writing instruction. Graham and colleagues (2014) found that middle school science classes allocate less than 2 minutes of writing instruction per class on average. These teachers were aware of and used a variety of genres from non-fictional to fictional genres and from informational to imaginative/narrative genres. However, instruction on the dynamic relationship between content and rhetorical requirements was generally missing in the teachers' science classrooms. Most writing practice was short and sentence level. There were very few opportunities to compose a paragraph or an essay except for an occasional narrative or science brochure. In sum, there seemed to be no room for explicit writing instruction in secondary

science classrooms where students might be asked to consider writing purposes, readers, types, topic structure, and methods of text production (Prain & Hand, 1996; Prain & Hand, 2002).

Feedback. Another important element of science writing instruction, feedback, was also missing. Even though the teachers incorporated a variety of writing tasks, they were hesitant to provide detailed feedback on language. For example, when middle school students submitted their benchmark essays, teachers provided only general comments or stapled a model essay onto their essays.

In L2 writing research, feedback refers to the oral and written response given to student writing by peers, teachers, or computers (Hyland, 2009). It is widely considered essential to writing development. Extensive feedback and conferencing are crucial when students write multiple drafts. The majority of L2 feedback research, which has investigated advanced-level learners in multiple-draft writing in the U.S., has focused on process (Lee, 2008). However, Lee (2008) found that teachers' written feedback in single-draft writing mainly focused on error correction. She also found multiple factors influenced feedback practices, including teachers' beliefs and values of the role of writing, writing instruction, and feedback, (lack of) teacher training, exam orientation, the accountability system, and attitudes to standardized testing and socio-political issues (see also Casanave, 2003; Goldstein, 2004, 2005; Hyland & Hyland, 2006). Graham and colleagues (2014) found that content-area teachers in middle schools provided written feedback on students' papers weekly or more often; however, they assumed that language arts teachers provided much more written feedback than other content area teachers since they did not differentiate disciplines.

These findings align with this study. The teachers all agreed with the necessity of developing writing skills in science class as well as other content areas and were indeed

implementing writing in their classes; however, they had difficulty giving feedback on students' writing beyond confirming the accuracy of the content and giving completion points. The science teachers were rather reluctant to give detailed comments on students' language. Teachers provided two major reasons for their hesitance to provide linguistic feedback. For one, they did not perceive it as their responsibility. Lauren explicitly mentioned that she did not want to "bleed red all over their papers," because she was not an English teacher, but a science teacher. She was concerned about the emotional effects of excessive negative feedback. Kyle and Alex pointed out that they did not give feedback on grammar or syntax, but only on the accuracy of content. Some teachers even supposed that they should not provide detailed feedback, since they believed that "micromanaging their language was not really what they were supposed to do." The other reason teachers gave for their lack of feedback was that the students, in general, did not learn from it. Alex mentioned that even when he provided specific feedback, his students did not look at it nor take advantage of it, giving him little incentive to put much time into it. Thus, he usually limited himself to a completion grade.

One exception was Larry, who was willing to give feedback even about mechanics as well as structures and writing processes.

[Writing a weekly journal] will do a number of things to help them and their writing skills, help them in their communication, developing ideas, because I will give them feedback on that, and that also helps them to summarize what they have been doing for the week... it gives a chance for me to see their writing and give them some, "hey, your punctuation is not so good, or your, don't forget the capitalization," and things like that. Larry's students were much more academically prepared, and their L1 literacy level was much higher than those in public schools. This may have led him to believe that his students were able

to use and learn from his detailed feedback. Also, his emphasis on organization and meticulous guidance on students' note-taking suggests that he tended to underscore form as well as content in writing.

Even though teachers were reluctant to give feedback on students' writing, they still used strategies to assist students with their writing. Sarah and Alex used a rubric. Sarah offered oral feedback in a small group setting and one-on-one conferencing with individual students. Larry used peer-feedback and whole class feedback and had a dialogue with a whole class after he gathered common errors in students' assignments. Rubrics, group feedback, and conferences helped micro-level writing skills such as academic vocabulary or grammatical sentences. However, they did not provide a big-picture look at written communication in science (see Enright & Gilliland, 2011).

The teachers noted that the ESOL professional development had helped them to provide feedback on their students' writing. Knowledge of second language acquisition helped the teachers to understand how they could approach the special needs of ELs, such as strengths, weaknesses, or errors they should pay more attention to in ELs' language acquisition. Sarah, for example, mentioned the urgent need for further professional development in how to offer effective feedback without "breaking students down." In addition, teachers' concept of feedback tended to have a focus limited to spelling, word choice, or grammar. Since composition and multi-draft writing is not common in secondary science classrooms, feedback on planning, revising, and paragraph writing is unlikely to occur.

Overall, the science teachers in this study implemented a range of writing practices in their classrooms; however, the tasks focused on demonstrating knowledge rather than composing, writing-to-learn, or writing-like-a-scientist, which writing researchers, the CCSS,

and the NGSS envision for teaching writing in secondary science classrooms. Additionally, direct writing instruction and feedback on students' writing were generally missing.

Mediating Factors and Contextual Barriers

Individual teachers constructed their writing instruction based on their beliefs about good science teaching and the role of writing in content areas, students' literacy level, and mandatory standardized tests.

First, the teachers' beliefs about science and good science teaching in secondary school influenced the implementation of writing in their classrooms. Science education researchers expect students to learn writing like a scientist, expressing developing understandings of science inquiry practices (i.e., to describe cause and effect, to propose a hypothesis, to build argument with evidence) (e.g., Buxton, Alleksaht-Snider, Suriel, & Gabbitas, 2013). However, one teacher pointed out that there is a "difference between how they [the students] are engaging with science and how a scientist does." Students were more frequently asked to write a few sentences to justify their answers on previous questions. Both of the high school teachers, Alex and Kyle, believed that science has "less grey areas" and is "cut and dried," "right or wrong," and "fact-based." Accordingly, their students were rarely invited to establish arguments or evaluate information. The teachers thought that these practices were unattainable in a high school level science classroom, which in turn resulted in a lack of such writing tasks. Larry and Lauren, the middle school teachers, believed that science is a hands-on exploration. In comparison to the high school science classes, this exploration aspect of science described by Larry and Lauren seemed to create more spaces for core scientific practices such as asking questions; engaging in argument from evidence; and obtaining evaluating, and communicating information, which in turn may accompany such writing tasks. Kyle and Erin believed that science classes should be

enjoyable. Kyle believed that the most important thing for him was to “make students at ease,” since most students presume science is “difficult and no fun.” He aimed for writing assignments that were not too overwhelming. Erin sought to lower anxiety about writing and make writing more fun, engaging, and meaningful. For example, she used pre-writing activities, such as gathering information directly in the field and having students explain orally what they observed before they wrote.

Second, differences in students’ perceived literacy levels mediated individual teachers’ writing instruction. The majority of Kyle’s students were native English speaking students, with a few monitored ELs, and no special education students, which seemed to lead him to think that his students were capable of deciding on and writing down the key phrases in his PowerPoint slides by themselves. On the other hand, the majority of Alex’s students’ home language was not English. He had several ELs and special education students, which led him to structure his slides and notes very carefully with multiple scaffolding strategies. With elite international students who were academically well prepared and highly literate in their L1, Larry used a combination of discussion and lecture without PowerPoint slides or guiding notes. Other middle school teachers managed different levels of supports depending on the levels of students in each class.

The students’ low literacy level particularly worked as a colossal barrier to implementing writing instruction in low-performing schools. Alex adamantly addressed this issue. He contended that many of his students needed a great deal of practice to write even one complete sentence. He thought that writing lessons were feasible for general or honors levels, but not for his students.

I think it is something that you should do, absolutely. I think how realistic that is, once again, questionable. ..Those writing tasks [are] a beast to try to incorporate, because I

know they [students] can't really do it right now. So, if I decide to start, that's a whole new battle [that] I am gonna have to fight. It's not a matter [anymore of] teaching them the content. I would have to teach them how to write a sentence, because they can't do that.

Some previous studies provide some support for these teachers' avoidance of writing with low proficiency students. Bereiter and Scadamalia (1987), for example, found that only skilled writers can learn from content area writing. Rivard (2004) found that achievement status is an important factor mediating the effects of language-based activities, such as talking, reading, and writing, on learning science. Low achievers indicated a better understanding of science concepts from verbal discussions with peers than through writing. According to these studies, students with low literacy levels benefit only marginally from writing intensive tasks. It is even less likely that ELs, who are still developing their literacy skills, will improve their learning in writing-heavy environments. Without extensive scaffolding, these research findings raise questions about whether it is feasible for science teachers to make an effort and take time to incorporate writing with virtually no extra institutional support for low-literacy level students.

Third, mandatory assessments shaped how teachers designed writing practice in their classrooms. State standardized tests in middle school, newly implemented, involved a writing portion in every major subject with both short-answer and paragraph-length responses. Moreover, district benchmark science tests consisted of multiple-choice content tests and two essay writings. In order to write two essays, students needed not only reading skills to understand a long paragraph of prompts involving tables or graphs but also sophisticated academic writing skills and content knowledge to write a page-length explanation and description of science concepts. With the sudden advent of these writing tests, the teachers had started to consider

writing more pressingly and felt the urgency to train their students to write scientific ideas more effectively and clearly. They developed model essays and set up class time for the students to practice writing in class before the tests. Students practiced writing a page-long essay for the benchmark tests during the class hour, which usually took thirty to sixty minutes. However, Bangert –Drowns and colleagues (2004) found mixed effects of writing-to-learn programs. They found that students in Grades 6 to 8 did not learn from writing-intensive curricula, while those in other grades did, and allocating more than 15 minutes to writing tasks per class had less positive effects on learning. According to Bangert –Drowns and colleagues (2004), it is unlikely that middle grade students will show positive results on such extended writing tasks. It is even less likely that ELs learn and achieve well from writing-heavy tasks and tests.

With the awareness of ELs' hardship in this new writing-intensive test, teachers made test accommodations for ELs and struggling learners. Lauren gave only one essay question, while other teachers gave two essay questions for the benchmark test. She also administered the test later than other teachers so that the students could prepare more. Also, she accepted shorter essays as well. Nevertheless, students still had little explicit instruction on how to write an essay and little detailed feedback on how they wrote, even though the writing skills required in these essays were linguistically and conceptually sophisticated. Those students who had not already acquired the norms of academic writing and discourse did not seem to have opportunities to be socialized into those norms or learn how to become a more proficient writer to perform and display content knowledge. As a way to accommodate ELs and struggling learners, teachers prioritized the display of content knowledge rather than critical thinking and communicative purposes behind science texts. For example, they graded only for accuracy of content over science discourse. Moreover, the test prompts themselves typically asked students to identify or

describe scientific concepts and processes instead of making an argument, which, accordingly, had not been practiced in class even though it has been highly emphasized in science education research and standards. This finding that the benchmark tests' focus on identification and description limited the types of writing practices in science classrooms is in line with that of Enright and Gilliland (2011). The macro-level national context of standards-based curriculum and accountability mandates has constrained writing practices and norms at the classroom level, and multilingual adolescents in content-area classrooms experienced restrictive socialization into academic literacy (Enright & Gilliland, 2011). They further argued that the norms and practices resulting from standards-based curricula, externally-designed pacing guides, and policy-driven writing practices constrained opportunities for authentic communicative writing and instruction on writing processes and strategies by emphasizing only compliance with assessment rubrics.

In contrast to the inclusion of essay tests in middle school assessments, high school benchmark tests required only writing short responses of a couple of sentences, and the state standardized tests in biology used a multiple-choice format. This type of assessment provided little motivation for the high school science teachers to teach writing or include writing activities in their classrooms. Alex mentioned that the emphasis on writing in the CCSS did not extend to biology standards in the state. He observed,

Our biology standards are the same. They don't necessarily emphasize writing... All the common core stuff they did emphasize writing; none of that has hit science. ... Their knowledge of standards is not assessed based on their literacy. It's what it is. They are not writing or speaking. They are taking EOC [End of Course exam], which is multiple choice questions. So, it is hard for me, sometimes, to justify evaluating their language. Time is the biggest issue there. So, I think I am kind of restricted to constructed response

questions on tests and match your projects.... There are not very many incentives for me to put a lot of time into it....

In all, then, Alex felt that the state curriculum and exam orientation did not give him sufficient justification to allocate time for writing instruction. Alex's concern is supported by an earlier study by Boyles and colleagues (1994). Even though advocates for the writing-to-learn approach argue that writing facilitates learning science content, Boyles and colleagues (1994) found that writing assignments and strategies to complete them did not improve learning outcomes on a comprehensive multiple-choice final examination. If writing does not enhance students' multiple-choice exam results, then it is perhaps unrealistic to expect science teachers to implement writing in their time-pressed curricula in a high-stakes teacher evaluation environment, where teachers' job stability and wages are determined by students' test results.

Fourth, in line with previous findings (e.g., Klein, 1999), time constraints, along with large class sizes, were the most significant obstacles restricting teachers from implementing writing instruction. Teachers noted that time was a major constraint preventing them from making any innovations in their instruction, let alone incorporating writing instruction. Larry called students' writing assignments his "weekend homework." Alex indicated a very tight schedule to teach mandatory standards, which did not allow any room for anything else, saying "when you have one semester to teach all of biology content, your time is very valuable. It's kinda difficult to get everything in." Kyle pointed out time and large class size to prevent him from providing quality feedback, saying "it comes down to the quality of that feedback really deals with my time... We are talking about class of 30 students and there's only so much time I can't give to one or two individuals."

In all, teachers' beliefs about science and good science teaching, students' literacy levels, types of mandatory tests, and limited instructional time and large class sizes mediated the nature of writing practices and instruction in each teacher's classroom. Contextual barriers discouraged the teachers from incorporating writing instruction in science classrooms, and left fewer opportunities for ELs' literacy development and content learning.

Implications for ELs

The teachers used scaffolding strategies to make writing practices more accessible and enjoyable, and these were beneficial to ELs. First, all teachers incorporated multimodal aspects in writing practices. For example, one of Larry's main activities was a mini poster in which the students summarized a chapter by depicting key information through pictures. Kyle allowed his students to use illustrations in their writing. Alex likewise incorporated multiple modalities to transfer information such as drawing a timeline or sketching a picture of island ecology. Lauren, Erin, and Sarah also used foldables, mind maps, and graphic organizers, frequently. The teachers' incorporation of multiple modalities seemed to help lower ELs' anxiety when it came to writing assignments.

Second, Sarah and Erin used sentence frames, a common literacy scaffold. Writing frames refer to "flexible and provisional forms of scaffolding to help young children develop a sense of genre when introducing them to non-fictional writing" (Hyland, 2009, p. 119). Writing frames are composed of outlines, which in turn consist of key words and phrases in a particular genre. The frames give learners a ready-made cohesive structure for learners to communicate content. Sarah mentioned that by using sentence frames she helped her EL students not to have to write everything by themselves, saying "I gave them part of the sentences they have to finish it. So they are not having to come up with all by themselves." Erin provided sentence frames for

her students to help them get started, saying “when I have them answer in full sentences, I put part of it on the board, so they know how to answer.”

On the other hand, the overall lack of composing opportunities, explicit writing instruction, or language/discourse-oriented feedback in these classrooms created linguistically impoverished environments for ELs. Since ELs had limited opportunities to produce written discourse, they had few occasions to learn science genres and general literacy skills. The lack of explicit writing instruction resulted in unclear expectations for students’ writing. Kibler (2011) suggests that teachers’ expectations for writing are implicitly communicated through written feedback rather than focused writing lessons. The lack of language-related feedback could be damaging to ELs’ language development and science content learning. In addition to the feedback on general language feedback they can receive from language arts teachers and ESOL teachers, they need feedback on science specific language and discourse. Illiteracy in the conventions used in science could prevent them from expressing their understanding of science concepts.

In all, the teachers’ scaffolding strategies to make writing practices more accessible were likely beneficial to ELs’ literacy development and science content learning; however, the lack of composing opportunities, direct writing instruction, or provisions of specific language/discourse feedback did not facilitate ELs’ learning of English and science.

Conclusion

The science teachers believed that writing is an essential skill to acquire in secondary schools as the CCSS and the NGSS envisioned. While the CCSS and the NGSS do not specify how writing is taught, this study found that unlike the previous research findings, the teachers incorporated a great deal of writing practices and strived to maximize its potential impact even

under multiple obstacles. In particular, at the middle school level, the teachers incorporated various types of writing, including both transactional and imaginative genres. However, these writing practices are quite distinct from those of a literature-based vision of science writing. While the two main components in science education literature are inquiry and argumentation, arguments based on evidence effectively are not highlighted in science classrooms. Most writing practices are a form of knowledge expression rather than a form of knowledge formation/transformation as a learning tool, which emphasizes a dynamic between content and rhetorical requirements within a specific context. Moreover, the science teachers did not provide specific instruction on their rhetorical components, generic features, or authorial voice, depending on the audience and the purpose of the writing assignments. National policies and state- and district-level policies regarding the standards and standardized tests shaped the amount of writing, types of writing, and assessment priorities. The current standards and standardized tests, especially at the high school level, are far from the NGSS and the CCSS, which imply writing like a scientist.

These findings suggest ways in which teacher educators and researchers can further explore useful professional supports for science teachers and other content area teachers to develop realistic writing-inclusive content lessons. First, this study draws implication to developing language-oriented training for science teachers. Professional development programs on science language might help teachers to expand the depth and breadth of writing practices and instruction in science classrooms. Even though science teachers acquired the common types of science writing through their disciplinary education and training, they might not be able to recognize and articulate how science language are structured and used to construct knowledge and texts. As studies (Applebee & Langer, 2011; Gillespie et al., 2014; Graham et al., 2014) have

found, a majority of teachers feel that teacher education programs in college and after college are inappropriate for preparing them to teach writing. Teacher training focusing on disciplinary language would help teachers improve writing instruction and make informed decisions about the methods and materials to use for writing instruction (see Hyland, 2007).

Second, while L2 writing research has conducted extensive studies on corrective feedback, writing in science education has done little research on feedback on science writing. While the teachers did incorporate writing and were willing to practice writing more extensively, they provided virtually no feedback on students' writing. This study points to the necessity of further research on providing informed feedback on disciplinary writing. Such topics include the following: a variety of ways to assess students' writing in science, the ways to balance content feedback and language feedback, the effective ways to provide feedback on discourse and larger communication beyond grammar and vocabulary, and the ways to provide encouraging and learning-oriented feedback.

Last, research suggests that in order to learn from content area writing, students need to be skilled writers or high achievers (Bereiter & Scadamalia, 1987; Klein & Kirkpatrick, 2010; Rivard, 2004). These ambiguous findings about the benefits and learning outcome of a writing-intensive curriculum in content area classrooms could mislead science teachers about the extent to which writing is beneficial for low-literacy students including ELs. Therefore, this study has implication for classroom practices. Administrators and teachers should implement writing instruction in local schools and classrooms with careful consideration of the level of scaffolding needed according to the level of their students, exam orientations, and standards demands. Moreover, further research should reconsider glib slogans about learning through writing and address in more nuanced ways the logistics of incorporating writing in content areas. It might

not automatically be beneficial to low-performing students and ELs with low literacy skills such as the majority of students that teachers in this study taught. Such study would contribute to reconceptualizing and recontextualizing science writing instruction and disciplinary writing instruction in ways that give due consideration to the challenges that both teachers and EL students face.

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CHAPTER 5

CONCLUSION

In all, this study finds multiple mismatches in each of the layers involved in ESOL education in science classrooms. The first article documents the mismatch between science teachers' indicated new professional identities and the enactment of their extended identities in their classrooms. This article examines science teachers' entry into the ESOL field by drawing on the concept of boundary crossing and its influences on their professional identities and classroom practices. As a result of participation in the long-term ESOL endorsement program, the four science teachers developed a new hybrid identity as science and ESOL/language teachers. However, their extended identity did not match their classroom practices. Even though they indicated their adoption of a new professional identity, they swung back to their science teacher identities in their classrooms and were unwilling to take major responsibility or be accountable for ELs. In addition, they all perceived good science instruction and good ESOL instruction as not conflicting, and they favored incorporating culture and language into science classes; however, their actual classroom practices did not match their beliefs. The teachers rarely constructed an instructional congruence of science instruction for ELs.

The second article demonstrates a significant disparity between real classroom practices and ideal prescriptions about science literacy instruction in national standards and research studies. Scholars in science education, literacy research, and applied linguistics/ESOL have offered a plethora of principles and strategies as exemplary literacy-inclusive science practices. Nevertheless, this work tends to presuppose a somewhat utopian classroom regarding students'

literacy levels, quality reading materials, curriculum, and instructional time. This work fails to take account of a number of obstacles to the implementation of research-based suggestions of science literacy instruction for ELs in actual secondary science classrooms.

The third article reveals the imbalance between writing practices and writing instruction in secondary science classrooms. Unlike the previous research findings, this study found that the teachers strived to maximize writing practices and their potential impact on science learning while they encountered multiple barriers. However, the writing practices of a literature-based vision of science writing, which are inquiry and argumentation, are not emphasized in science classrooms. Teachers used writing only as a tool for students to express their understanding of science concepts, not as a tool by which they learn science by understanding how language constructs content. Moreover, the science teachers did not provide explicit instruction on the specific features of science language and discourse, which has negative impacts on both ELs' content learning and language development.

All three articles addressed the issues of the barriers in the school system and larger educational context such as time pressure in terms of coverage of standards that is demanded from middle and high school curricula, lack of space within teachers' day to plan according to how they would like to incorporate language and literacy into their science classrooms, limited quality materials and readily available resources, and lack of supports from schools and districts. These barriers prevent teachers from enacting their new add-on professional identity of language teacher and implementation of exemplary science literacy instruction in actual classrooms. These barriers also include multiple mismatches in different levels of research, policies, standards, assessments, practices, and instruction around ESOL education in secondary science classrooms.

The findings of this study have implications for future research involving researchers, teacher educators, ESOL professional development providers, and other stake-holders.

First, there is a need for more ethnography-oriented qualitative research documenting actual classroom conditions, established curriculum and assessment, and the norms and culture of secondary science classrooms and schools. Without reconciling these contextual factors, it will be difficult to successfully realize the teaching of science language and literacy in actual classrooms. It is also important to listen to teachers' voices more attentively to understand the particular challenges they face when working with ELs and implementing language and literacy instruction. Research on real classrooms will lead to the development of more realistic strategies for the implementation of research recommendations.

Second, teacher educators need to make quality reading materials, writing tasks, and example feedback readily available to teachers. The materials should provide model texts including technical vocabulary, grammatical features, formats and organization, communicative functions, multiple modalities, etc., which will help make science texts and common genres more accessible to students. Moreover, the materials and tasks should be differentiated according to the different levels of students, the variety of science topics, the difficulty of language, and the depth of science content knowledge. Teachers struggled to provide feedback on students' writing. Example feedback with writing tasks will help teachers judge the appropriate amount of feedback and reduce the workload.

Third, professional development providers need to consider the variety of backgrounds of science teachers and offer more targeted and focused support according to individual teachers' needs and contexts. Some teachers have expert science knowledge and extensive lab experience, while others have extensive knowledge across the curriculum with certification in multiple

subjects. Teachers displayed starkly different enactments of their learning in the program depending on their instructional histories, personal backgrounds, previous learning and teaching experience, and current instructional circumstances including mandatory standardized tests and students' literacy levels. In particular, since the teachers' comfort levels in dealing with language and literacy in science would affect their instruction for ELs, professional development programs should be differentiated accordingly.

Last, this study urges other stakeholders like administrators and district level personnel to participate in ESOL professional development. Many issues in providing ESOL education to science teachers lie in contextual and system-wide problems rather than individual teachers' instruction. In order to improve ESOL education and ESOL teacher education, it is crucial to create joint efforts across multiple stakeholders who are involved in developing and using standards and standardized tests, teacher evaluation, and a variety of EL supports.

These six teachers' experiences of ESOL professional development and classroom practices in this study present a broad range of affordances and constraints of ESOL professional learning for science teachers related to teaching science literacy and working with ELs. The study reveals the complex and multi-layered process of each science educator's new professional identity development and the widely varying instantiation of language and literacy instruction in actual science classrooms.

This study contributes to the development of more focused and systematic ESOL education for science educators and, eventually, will help to attract more educators to ESOL professional development. In addition, this study will enrich culturally responsive pedagogy, Content-Based Instruction (CBI)/Content and Language Integrated Learning (CLIL), and genre/discourse studies and will contribute to the improvement of the growing number of

language education contexts worldwide in which students are taught English by content area teachers with no background in second language acquisition (SLA) and TESOL and with no opportunities to develop their identities as language teachers.