Analyzing Diverse Learners' Writing in Mathematics: Systemic Functional Linguistics in Secondary Pre-Service Teacher Education

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This article analyses the experiences of 55 secondary pre-service teachers (PSTs) in a mandated professional development course that used Halliday's systemic functional linguistics (SFL) and related pedagogical practices to support PSTs' development of disciplinary linguistic knowledge for working with linguistically diverse students in the United States. Of specific interest is how the course influenced the manner in which PSTs responded to a student's attempt at writing a mathematical explanation. We begin with a brief description of Halliday's theory of language and learning with particular reference to the semiotic demands of mathematics. Next, we provide a description of the professional development course and the mixed methods approach to analysing changes in PSTs' pre- and post-course responses to a student writing sample about linear equations. Third, we discuss findings that suggest PSTs' emerging understanding of the linguistic and multimodal demands of mathematical explanations, supported them in providing more cogent and precise written feedback. We conclude by discussing the potential of SFL conceptual and pedagogical tools to support PSTs' professional development in the context of globalization.

Keywords: disciplinary writing in mathematics, systemic functional linguistics, teacher professional development, ELLs, school reform, CCSS

Introduction

My discipline is math...it used to be that math didn't include any writing outside of calculations, but now the expectation is that students will write at some length using math language or they won't graduate. That said, I don't know how to make sure that all my students have access to the resources necessary to learn written math language.

– "Ruth Barrett," pre-service secondary math teacher

The work of secondary math teachers is changing rapidly as the forces of globalization and related school reforms place new demands on teachers and their students, especially in schools attended by large numbers of language learners and speakers of minoritized varieties of world languages. These forces include rapid demographic changes, the replacement of manufacturing jobs with service ones, the use of new technologies, and the rise of standardization and accountability systems imported from the private sector (e.g., Adamson, Arstran, & Darling Hammond, 2016; Blommaert, 2010; Council of Chief State School Officers [CCSSO], 2010). Therefore, teachers of mathematics must develop a greater capacity to teach a changing student population in the context of rapidly shifting social, economic, and political forces (e.g., Gorgorió & Planas, 2001). This task is

particularly daunting for pre-service teachers (PSTs) because teacher education programs, especially at the secondary level, do not typically include course-work in language learning and disciplinary literacy development (e.g., Gebhard & Harman, 2011; Lucas & Villegas, 2011; Turkan, de Oliveira, Lee, & Phelps, 2014; Zeichner, 2005).

An analysis of the development and implementation of the Common Core State Standards (CCSS) in the United States provides an example of a policy initiative designed to respond to the changing nature of teaching and learning in the context of globalization (CCSSO, 2010). These default national standards are part of a federal educational reform movement designed to prepare all students to be "college and career ready" in the twenty-first century (CCSSO, 2010, p. 4). In the domain of mathematics, the CCSS call for greater focus, rigor, and coherence as a way of ensuring students develop "conceptual understanding of key concepts" and an ability to apply "math in situations that require mathematical knowledge of algebra, functions, geometry, statistics, and probability through talk, print, and multimodal representation systems" (p. 6). According to the CCSS, mathematically proficient students should be able to apply the mathematics they know to solve problems arising in everyday life, society, and the workplace through the use of equations, graphs, computer tools, reading, and writing. Therefore, to meet these new standards, students must demonstrate mathematical content knowledge and critical thinking abilities through their ability to comprehend and produce longer and more complex multimodal texts, such as explanations and arguments involving mathematical concepts (e.g., Turkan & Schramm-Possinger, 2014).

As a number of educational researchers have remarked, the CCSS mean mathematics can no longer be conceived of and taught as a set of discrete skills. Rather, the CCSS require teachers in all content areas to know how to teach all students how to read, write, and critically discuss the types of extended texts students are routinely required to read and write in school as a way of developing students' content knowledge and disciplinary literacies. The CCSS also require teachers to develop the ability to apprentice all students to be able to use talk, print, and other meaning-making systems such as equations, graphs, maps, charts, diagrams, and computer-mediated tools to construct content knowledge specific to the subject area and grade level they teach. Moreover, teaching "all students" means that teachers are required to take responsibility for ensuring students, including language learners and minoritized[1] speakers of world languages and varieties of languages, move along an academic pathway that prepares them to participate more equitably in a rapidly changing and increasingly multilingual, multicultural, and computer-mediated world (CCSSO, 2010).

This emphasis on disciplinary writing is new for many secondary math teachers and their students (Shanahan & Shanahan, 2012). Studies indicate that math teachers tend to view their primary responsibility as content teaching and often pay little attention to language, particularly writing instruction (Arkoudis, 2005; Kosko, 2016; Tan, 2011). In response, a number of educational researchers have cautioned that the writing demands associated with the CCSS may present significant challenges for students, especially language learners, because most of their teachers have not been prepared to teach the

[1] Following Flores & Rosa (2015), this paper uses the term *minoritized* in place of terms such as *minority*, *non-dominant*, *non-standard*, and so on to highlight the social processes by which some students' linguistic practices come to be valued less than others. They note "many so-called minority linguistic practices are actually quite normative and/or prevalent in [their respective] contexts" (p. 169).

literacy practices associated with their discipline in a developmental way (Bunch, Kibler, & Pimentel, 2012; Gebhard & Harman, 2011; Lee, Quinn, & Valdés, 2013; van Lier & Walqui, 2012). This lack of support for language learners is especially acute because many states require all students to demonstrate they have met either state or CCSS standards or they may not be able to graduate from high school (e.g., Menken, 2008; Nichols & Berliner, 2007). As a result, teachers' inabilities to support linguistically diverse learners can have long-lasting effects on these students' social, academic, and economic futures (August & Shanahan, 2006; Gebhard & Harman, 2011; Scarcella, 2003).

To counter unintended consequences of current school reforms, educational linguists argue that all teachers need to develop *disciplinary linguistic knowledge* to support students in analyzing how language and other meaning-making tools construct disciplinary knowledge in their content area (Turkan et al., 2014, p, 3). Moreover, teachers need to be able to design curriculum, instruction, and assessments to apprentice students to these disciplinary literacy practices in ways that simultaneously develop students' content knowledge and the literacy practices that construct these new ways of knowing over time (e.g., Christie & Derewianka, 2008). These scholars maintain that the ability to teach the meaning-making system of mathematics allows teachers to support students' simultaneous development of mathematical thinking *and* disciplinary ways of reading, writing, and discussing mathematical concepts that are fundamentally different from everyday ways of making sense of numeracy.

To take action on this call for a change in the knowledge base of teaching, some states, such as Massachusetts, have mandated that all pre- and in-service teachers must complete a professional development course to prepare them to teach disciplinary literacies to the growing number of students designated as "English language learners" (ELLs) in their classes if they wish to earn or retain their state teaching licenses.[2] This regulation was put into effect in 2013 because a previous state mandate in 2002 eliminated support for bilingual education. As a result, language learners in Massachusetts are often: (1) pushed into mainstream content classes, where they have inadequate instructional supports, or (2) tracked into English as a second language (ESL) programs, where they do not have access to grade-level content instruction (e.g., Harklau, 1994, 2000).

In response to these reforms, several colleges of education in Massachusetts have turned to a sociocultural perspective of language and learning grounded in Halliday's theory of systemic functional linguistics (SFL) (Brisk, 2015; Gebhard, Chen, Graham, & Gunawan, 2013) and with reference to math (Gebhard, Habana-Hafner, & Wright, 2004). Broadly defined, SFL attempts to explain how language users expand the nature of meaning-making resources available to them as they mature and expand their functional

[2] Massachusetts requires teachers to complete a course in "sheltered English instruction" (SEI) as part of a mandate known as Rethinking Equity in the Teaching of English Language Learners (RETELL). SEI is often vaguely defined as a teaching strategy that uses language and content to make academic subject matter more comprehensible to ELLs. However, explanations of the phrase "sheltered English instruction" rarely provide specifics regarding what ELLs should be "sheltered" from or how to make dense texts comprehensible when ELLs are immersed in the academic reading and writing demands of high-stakes school reforms (e.g., CCSS). Therefore, the SEI course described in this study was designed using systemic functional linguistics (SFL) and the findings from SFL studies of students' disciplinary literacy development (e.g., Accurso, Gebhard, & Selden, 2016; Achugar & Carpenter, 2014; de Oliveira & Silva, 2013; Gebhard et al., 2013; Schulze, 2016).

uses of languages and the contexts in which they interact—first within their homes, then in their communities, then in different content areas in school, and later in the world of work (Martin & Rose, 2008). This social semiotic perspective of teaching and learning disciplinary literacies, first developed in Australia (e.g., Rose & Martin, 2012), has gained traction in teacher education programs in the United States (e.g., de Oliveira, & Iddings, 2014), within the European Union through the Content and Language Integrated Learning Project (CLIL) (e.g., Llinares, Morton, & Whittaker, 2012), and in many college-level world language departments based on impressive results from empirical studies conducted at Georgetown University (e.g., Byrnes, Maxim, & Norris, 2010).

To contribute to scholarship regarding the potential of Halliday's SFL to inform teacher education, the purpose of this study is to analyse the experiences of 55 secondary PSTs enrolled in a 14-week, mandated professional development (PD) course that introduced SFL theory and pedagogical practices to support PSTs' development of disciplinary linguistic knowledge for working with linguistically diverse students in the United States. Of specific interest is how participation in the PD influenced the manner in which PSTs responded to a student's attempt at writing a mathematical explanation. We begin with a brief description of Halliday's theory of language and learning with particular reference to semiotic demands of mathematics. Next, we provide a description of the PD and our mixed methods approach to data collection and analysis. Third, we present the findings and discuss data displays regarding changes in PSTs' abilities to respond to a student writing sample about linear equations before and after their participation in the PD. We conclude with a discussion of the implications this study has for PST professional development and the application of SFL theory in PST education in the context of globalization.

Conceptual Framework: A Social Theory of Meaning Making in Mathematics

A review of the literature regarding the role of language in mathematics education reveals that it has been treated reductively as belonging to the domain of teaching vocabulary and improving students' ability to write formally correct sentences (e.g., Cavanagh, 2005; Moschkovich, 2012). In contrast, educational linguists have argued for a more expansive and functional view of mathematical language (e.g., Barwell, Leung, Morgan, & Street, 2005; Crowhurst, 1994; Gorgorió & Planas, 2001; Herbel-Eisenmann & Otten, 2011; Morgan, 2006; Moschkovich, 2007; Pimm & Keynes, 1994; Schleppegrell, 2007). These scholars maintain that language in the mathematics classroom should be understood as a unique register characterized by particular discursive practices and patterns that operate at the word, sentence, and discourse semantic levels. In this article, we adopt this view by drawing on Halliday's theory of SFL (1975, 1993). Halliday argues that language is a functional meaning-making system that is flexible, adaptive, and context-sensitive. In addition, it cannot be reduced to a fixed set of technical vocabulary items or prescriptive grammar rules (e.g., never use *I*, split an infinitive, or end a sentence with a preposition). Rather, language and other semiotic systems are best understood as a dynamic set of resources for thinking mathematically, participating in mathematical discourse with others, and making mathematical meanings coherent when constructing extended oral, written, and multimodal texts in different situations.

Halliday's Systemic Functional Linguistics

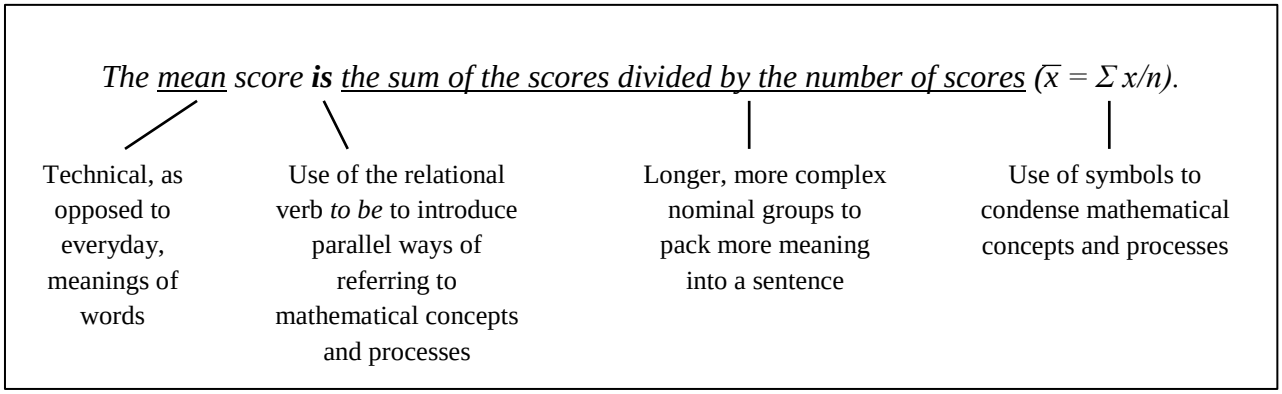

Figure 1. Features of the register of mathematics (adapted from Schleppegrell, 2004; Veel, 1999)

Halliday's functional perspective of grammar attempts to explain how people use language and other meaning-making resources to accomplish cognitive, social, and textual activities (Halliday & Matthiessen, 2004; Martin & Rose, 2008). This conceptualization of language as a social semiotic is built on the assumption that "language is not realized in the abstract; it is realized as the activity of people in situations" (Halliday, McIntosh, & Strevens, 1964, p. 89). Depending on the culture of a specific situation in which people are using language, they make functional choices from a system of choices at the sound, word, sentence, and discourse levels. As outlined in Schleppegrell (2004), when people use language, they consciously and unconsciously choose certain ways of pronouncing or graphically rendering words, making grammatical constructions, and creating coherence across extended discourse depending on: (1) the *field,* or content they are attempting to construct (e.g., an everyday experience versus a more discipline-specific one), (2) the *tenor,* or relationships they are attempting to construct or maintain with others (e.g., social distance and authority), and (3) the *mode*, or how they manage the flow of information in either oral, written, or computer-mediated communication. These terms—*field*, *tenor*, *mode*—are part of a functional metalanguage that allows for an analysis of the resources an individual and a language have for constructing disciplinary knowledge, enacting social relationships, and managing the flow of information over stretches of multimodal discourse. The broader term *register* encompasses field, tenor, and mode, and is used to distinguish varieties of language that differ in relationship to the different contexts in which they are used (Halliday et al., 1964). In secondary schools, students are likely to encounter registers needed to make sense of literary, historical, scientific, and mathematical discourses (Schleppegrell, 2004).

Mathematical registers in school. Register choices used to construct mathematical knowledge in school include technical words and phrases packed into dense nominal phrases and relational clauses as shown in Figure 1. Schleppegrell (2004, p. 138) explains how these register choices function within the context of the math classroom in specific ways. She writes:

> Technical lexis realized in grammatical metaphor creates quantifiable entities for the purposes of calculation (e.g., *it changes often* can be re-construed as a nominal group *the amount of change*; Veel, 1999, p. 194). Relational clauses are important for taxonomizing (e.g., *A square is a quadrilateral*), for introducing technical terms (e.g., *The mean, or average, score is the sum of the scores divided by the number of scores*); or for providing parallel ways of talking about algebraic formulas (e.g., *the mean score is the sum of the scores divided by the number of scores* is a way of talking about the formula $\bar{x} = \Sigma x/n$; Veel, 1999, p. 196).

These linguistic resources are often combined with meaning-making resources from other multimodal semiotic systems (e.g., graphs, equations, drawings) in ways that make the register used to make mathematic meanings at the secondary level unique and very distant from the way language is used to construct more everyday meanings in daily interactions (Morgan, 1996; O'Halloran, 2003).

Martin's Genre Theory and Genre Pedagogy

Halliday's notion of register has been expanded by Martin (e.g., 1992), who proposed the notion of *genre* for analysing recurrent language patterns people encounter within social contexts. Martin defined genres as "staged, goal-oriented social process[es]" (1992, p. 505), emphasizing that goals coordinate field, tenor, and mode resources into recurrent patterns of language use. Within the context of secondary mathematics classrooms, these goals may include the recounting of problem-solving procedures, describing a mathematical property, explaining a mathematical solution, or arguing a mathematical proof (Schleppegrell, 2004). Martin's conception of genre captures how learning disciplinary knowledge reflects and constructs cultural ways of knowing, being, and doing through the use of reoccurring semiotic patterns (Gee, 2009; Martin & Rose, 2008). For example, research has demonstrated that canonical explanations of mathematical problem-solving procedures in English have a set of expected genre stages including: identification of the mathematical concept that will be explained, definition of key terms, and an explanatory sequence that presents problem-solving steps and why they happened in that order (Moschkovich, 2010; O'Halloran, 2008). However, individual texts vary depending on the local context or situation in which they are constructed. This variation is reflected in grammatical choices that are made depending on the purpose, the audience, and the channel through which the explanation unfolds. For instance, a procedural explanation a student provides to a peer in face-to-face group work is apt to be grammatically different from one a student writes on a unit test for a teacher.

With regard to SFL pedagogy, Rose and Martin's (2012, pp. 64–67) genre-based instruction gives considerable attention to the importance of scaffolding students' disciplinary language development through the implementation of a six-part instructional cycle known as the "teaching and learning cycle." Part one prepares students for a challenging reading or writing task by activating students' prior knowledge/language resources and building a shared experience of a new disciplinary concept through collaborative participation in an activity. Second, teachers focus students' attention on key features of the task to support students' development of a specific disciplinary concept and an explicit understanding of how language and other meaning-making resources work in particular ways to construct this concept. Third, teachers guide or "co-construct" students' engagement in completing tasks using new concepts and literacy practices. Fourth, teachers give students feedback on their work and ability to use new disciplinary literacies as they evolve. Fifth, teachers elaborate and expand on students' contributions to actively scaffold more expert disciplinary language and practices over time. Last, teachers reflect on student learning and their teaching practices to support the design of future curriculum, instruction, and assessment practices.

Of particular interest in this article is how PSTs provided written feedback on one student's attempt at writing a mathematical explanation. While research on written feedback suggests it can be a valuable pedagogical tool and that secondary students tend to improve written drafts after receiving clear and detailed feedback (Beason, 1993; Ferris,

1997, 2002; Zamel, 1985), significant concerns remain regarding many teachers' inability to provide this type of feedback on student writing (e.g., Ferris, 2014; Keh, 1990).

SFL, Genre Theory, and Sociocultural Perspectives of Teacher Learning

Drawing on Halliday's SFL and Martin's genre theory as frames for theorizing the development of disciplinary linguistic knowledge (e.g., Gebhard et al., 2013), we maintain that as PSTs participate in expanding social networks, they expand their uses of different genres and registers at home, in school, at work, and through online communication. Through this expansion of contexts and associated literacy practices, PSTs are socialized into new ways of knowing, being, and doing, and they develop an increasingly diverse set of meaning-making resources for participating in these different educational contexts, first as students and then as teachers (e.g., Borg, 2003; Johnson, 2009; Lortie, 1975). However, this process of socialization does not take place through simple exposure to different genres and registers alone. Rather, it happens through an explicit, critical, and sustained apprenticeship in which PSTs gain a critical awareness of how language and other semiotic resources work in their disciplines. For example, most secondary PSTs have had a long apprenticeship in valued ways of using language in the math classroom over the course of their K-12 and post-secondary education (e.g., Lortie, 1975). They also have, to varying degrees, developed mathematical concepts and the semiotic resources needed to construct these concepts through their routine use of mathematical genres and registers in school. However, this linguistic knowledge tends to be tacit and therefore difficult to teach in any systematic and functional way to novices, especially ELLs or those who struggle with meaning-making systems used in math classes.

To respond to this difficulty, the goal of the PD described in this study was to support PSTs to close the opportunity gap between dominant and minoritized students by making disciplinary literacy practices less tacit, more explicit, and more open to critical reflection through carefully designed instructional tasks that explicitly scaffold disciplinary literacy practices and conceptual understandings. In addition, the PD fulfilled a state requirement established to support the capacity of teachers to work with the growing number of ELLs assigned to their content area classes. To this end, PSTs were introduced to SFL as a framework for developing disciplinary linguistic knowledge. In sum, the course aimed to capitalize on PSTs' existing linguistic repertoires while simultaneously providing them with metalinguistic awareness and pedagogic tools required for: (1) analysing the demands of disciplinary curricular materials; (2) designing tasks that target and scaffold specific content and language goals simultaneously; and (3) providing all students, including ELLs and other language-minoritized students, with explicit linguistic feedback to support their ability to produce more expert disciplinary texts. As part of a larger project investigating SFL-based teacher education, the following research question guided this study: *To what extent does instruction in SFL theory and practice influence the manner in which secondary pre-service teachers respond to a student's attempt to write a mathematical explanation?*

Methods

A qualitatively-driven mixed methods approach was used to investigate this research question (Creswell, 2014). Fifty-five content area PSTs enrolled in a 14-week, SFL-based professional development course required by the state were asked to numerically score and provide written feedback on a sample of student math writing at the beginning and end of

the professional development. We analysed PSTs' written feedback from an interpretive perspective (Glesne, 2016), while descriptive quantitative results provided additional context for understanding the emergent qualitative themes and changes in the nature of PSTs' feedback on student writing in mathematics. In addition, we used Wilcoxon's signed-rank test to identify any statistically significant change in PSTs' numeric feedback (Gravetter & Wallnau, 2013). The multiple and complementary data sources and types allowed for triangulation and the potential for convergence of results (Greene, Caracelli, & Graham, 1989).

Participants

Participants in this study were 55 PSTs pursuing a Master of Education degree and secondary content area licensure at a large, public university in the Northeast United States. While over 70 PSTs were enrolled in the course, those who did not submit feedback on student writing samples or whose feedback could not be matched from the beginning and end of the PD were removed from consideration for this study. The final group of participants included 10 PSTs pursuing math teaching careers, 12 PSTs pursuing science teaching careers, 15 PSTs pursuing social studies teaching careers, and 18 PSTs pursuing English language arts careers. At the time of the study (September to December, 2015), all participants were completing pre-practicum observations in public rural, suburban, or urban secondary schools. While PSTs began the school year observing the teaching of their cooperating teachers and learning about their students, by December, most were preparing lessons, teaching classes, and grading papers.

Professional Development Content and Structure

The PD was organized into three modules. Module 1 introduced PSTs to sociocultural conceptions of language, teaching, and learning drawing on Vygotsky and Halliday's complementary perspectives of language and development (e.g., Gibbons, 2015). Module 2 asked PSTs to use the tools of SFL to analyse authentic classroom texts and develop recommendations for practice using principles of genre pedagogy and the SFL teaching and learning cycle (Rose & Martin, 2012). Module 3 required PSTs to use insights from Modules 1 and 2 to outline curricular units of study to support diverse students in meeting specific disciplinary standards. Each of the modules explored pedagogical applications of SFL and genre theory, while the second and third modules also introduced PSTs to the concept of Understanding by Design and backwards design (Wiggins & McTighe, 2005). Table 1 summarizes the content of each module.

Within each module, class sessions lasted 90 minutes and began with a structured free-write related to the content being presented that day to activate PSTs' thinking and elicit their existing knowledge on each week's topic. This task was followed by whole-class lecture and discussion. Following the presentation of theoretical concepts and classroom examples, PSTs separated into 60-minute discipline-specific workshop sessions led by doctoral student teaching assistants. In these workshop sessions, PSTs focused on the application of theoretical concepts through small group tasks they completed and presented to their peers (e.g., literacy demands of new content area standards, analysis of disciplinary texts, instructional ideas for explicitly scaffolding disciplinary language).

Table 1

Summary of SFL-based PD Content by Module

	Summary of PD content
Module 1 (3 weeks)	• Introduction to the new knowledge base of teaching and the need for disciplinary linguistic knowledge • Introduction to theories of language and language learning (e.g., behaviorism, innatism, sociocultural theory)

Module 2
(6 weeks)
	• Introduction to SFL and genre theory as an approach to developing disciplinary linguistic knowledge
	  ○ Language use varies according to context, purpose, and audience
	  ○ Introduction to the SFL teaching and learning cycle
	• Introduction to SFL metalanguage
	  ○ *Genre*
	  ○ *Register*
	  ▪ *field, tenor, mode*
	• Analysis of model disciplinary texts to highlight genre and register-level expectations (e.g., features of effective math explanations)
	  ○ Organizational stages for writing an effective explanation
	  ○ Technical and/or dense noun phrases to construct field of content
	  ○ Relational verbs (e.g., *is*) to define terms
	  ○ Declarative mood to establish authority/construct a knowledgeable self
	  ○ Logical cohesive devices to create flow and explain reasoning (e.g., *because)*
	  ○ Temporal cohesive devices to create flow and sequentially recount problem-solving steps (e.g., *first, next*)
	  ○ Multimodal representations (e.g., graphs, symbols)
	• Analysis of student writing samples to identify strengths, areas for growth, and teachable disciplinary linguistic features

Module 3
(5 weeks)
	• Introduction to SFL-based pedagogy and Understanding by Design (Wiggins & McTighe, 2005)
	  ○ Writing content and language objectives
	  ○ Connecting objectives to students' lives
	  ○ Designing classroom tasks to support diverse students' simultaneous development of disciplinary content knowledge and literacy practices
	  ○ Creating genre-based rubrics
	• Content-area unit design drawing on SFL and Understanding by Design

Data Sources and Analysis

Pre- and post-tests were administered to better understand PSTs' development of disciplinary linguistic knowledge, particularly how they were applying this knowledge to the practice of giving feedback on student writing samples. In these tests, PSTs were asked to respond to one 8th-grade student's written response to an algebra assignment (Figure 2) by giving written feedback and assigning a numeric score on a scale of 1 to 3 (e.g., a score of 1 approaches expectations, 2 meets expectations, and 3 exceeds expectations). PSTs were also asked to provide some reasons for their numeric score. Pre- and post- tests were identical and administered twelve weeks apart during the second and final class sessions as free-writes. PSTs submitted their responses electronically. Quantitative and qualitative data from the tests were then analysed to determine the degree of change in how PSTs evaluated and responded to an authentic student writing sample in mathematics.

It is important to note that not all 55 participants were aspiring math teachers. Nonetheless, this writing sample was selected because it represents a struggling student's attempt to write a staged response to a challenging task and it includes the types of formal errors language learners often make (e.g., missing subject in "because goes on forever"). Moreover, it was selected for this activity because successful completion of the prompt required the student to produce a multimodal explanation, a genre common across math and science and frequently called for on high-stakes state exams.[3] While we were aware that many PSTs did not have the background knowledge to assess the student's writing for demonstration of mathematical knowledge, we did expect all participants to have had sufficient exposure to the genre of explanation to assess whether or not the student fulfilled the expectations of this type of writing.

Quantitative data from the pre- and post-tests were first compared to assess the degree to which the numeric scores participants assigned the student writing sample as part of their pre- and post-test feedback differed. 38% of PSTs assigned different numeric scores to the writing sample in their pre- and post-test feedback. Therefore, the data were further analysed using the Wilcoxon signed-rank test (Gravetter & Wallnau, 2013), a non-parametric test that compared PSTs' matched numeric scores of the writing sample to assess whether, as a group, PSTs' numeric scores were significantly different at the beginning and end of the PD. This test generated a p-value of .9442, indicating that the change in PSTs' numeric scores was not statistically significant. As a result, subsequent analysis focused largely on qualitative data sources.

Qualitative data from the pre- and post-tests (PSTs' written feedback to the student writing sample) were analysed using a constant comparative method that was inductive, data driven, and iterative (Creswell, 2014). First, each author independently coded the pre-tests from this qualitative data set to identify emerging patterns. In this 'open coding' stage, we each read through PSTs' pre-test feedback to gain an overall impression and characterized the feedback by recording a concise summary and analytical comments to generate preliminary codes for each PST. We then compiled the preliminary codes and discussed supporting evidence from the data set for each code identified. Next, we compared the results from our initial coding by collectively rereading the data set and

[3] PSTs practiced giving written feedback on additional student writing samples in their respective content areas during discipline-specific workshop sessions in Module 2. However, due to limited class time, pre- and post-test data were only collected from all PSTs on the single student writing sample shown in Figure 2.

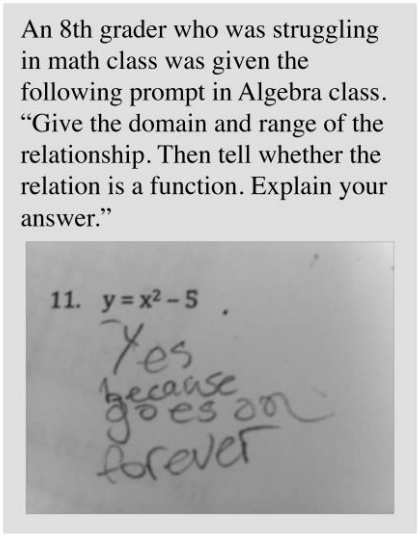

Figure 2. Pre- and post-test prompt and student math writing sample

discussing how our preliminary codes could be reconciled, enriched, expanded, contracted, or collapsed. This procedure allowed us to develop more refined codes that corresponded to the data. We then reviewed PSTs' pre-test feedback a third time to apply the refined codes and look across participants to identify recurring patterns and themes that characterized PSTs' feedback practices on student math writing. Four major themes emerged from this analysis. The analytical process was then replicated on the post-test data set. The same four themes emerged from the post-test data, as well as two new themes.

Limitations

There are several limitations regarding the methods of this study. First, we recognize that the data were collected within the confines of a state-mandated PD that required participants to earn a minimum threshold grade before applying for licensure. Therefore, there is the potential for a social bias effect. We attempted to minimize these effects by keeping the pre- and post-test activities ungraded, waiting to analyse the data until final grades for the PD were submitted, and then doing so anonymously. Second, we recognize the self-reported nature of the data. PSTs' feedback in the context of the PD was hypothetical and directed toward an imagined student they did not know, rather than given in the context of actual classroom practice to a student with whom they shared an instructional history. However, at the time of the study, PSTs had no actual extended classroom practice. Therefore, self-reported data is an appropriate way to gain insight into PSTs' thinking and the practices they anticipate putting into place in their future work in classrooms (Shavelson, Webb, & Burstein, 1986).

Findings

Results of the pre- and post-test analysis reveal a shift in PSTs' use of disciplinary linguistic knowledge to assess student math writing, specifically in the nature of written feedback they provided the student regarding linguistic strengths, areas for improvement related to purpose and audience, and specific steps for revision. As Table 2 shows, PSTs' pre-test feedback can be characterized by four predominant types of feedback:

Table 2

Types of PST Feedback on Student Math Writing Before and After SFL-based PD

	PRE-TEST (Sept. 2015)		POST-TEST (Dec. 2015)	
Type of Feedback	Number of PSTs (n=55)	Percentage of Participants	Number of PSTs (n=55)	Percentage of Participants
Vocabulary-oriented	23	42%	4	7%
Broad prompt for more detail	13	24%	9	16%
General encouragement with caveats	15	27%	17	31%
Prompt for oral feedback session	12	22%	6	11%
Purpose-oriented	0	0%	20	36%
Genre-oriented	0	0%	16	29%
Register-level advice				
• Field/content resources			15	27%
• Tenor/voice resources			3	5%
• Mode/flow resources			3	5%
• Use of graphic elements			9	16%

(1) vocabulary-oriented feedback that encouraged the student to use specific disciplinary vocabulary to improve their response (e.g., *domain, range, function*), (2) broad feedback that directed the student to "be more specific" or "give more details" to improve their response, (3) general encouragement followed by a list of questions or broad, but non-directive feedback (e.g., *good try, but…*), and (4) prompts for oral feedback sessions (e.g., *Let's talk after class*). We found these types of feedback were not mutually exclusive; rather, some PSTs combined multiple feedback techniques in their responses to the student (e.g., *You're right, but you need to include the domain and range*).

Following twelve weeks of PD, in which PSTs developed disciplinary linguistic knowledge through the study of SFL and genre pedagogy, instances of the four types of feedback provided on pre-tests generally decreased. In their place, as shown in Table 2, many PSTs shifted toward the use of purpose-oriented feedback and feedback that incorporated SFL concepts and metalanguage to explicitly address the genre and/or register expectations for a written mathematical explanation. Of particular interest given the purposes of the PD were PSTs' shifts away from vocabulary-oriented feedback (42% of PSTs used this type of feedback on pre-tests, while 7% of PSTs on post-tests) and vague prompts to "add details" (24% pre- to 16% post-test). Interestingly, the number of PSTs who used of prompts for oral feedback meetings (e.g., "*Let's talk after class*") also decreased from 22% pre- to 11% post-test. In addition, post-test results show that PSTs began prompting the student to consider the purpose of their writing and use genre stages that would support a more coherent and well developed mathematical explanation that included specific vocabulary items. For example, the percentage of PSTs who used

purpose-oriented feedback increased from 0% pre- to 36% post-test, and those who used genre-oriented feedback increased from 0% to 29%. These types of feedback and PSTs' use of them will be further described in the following analysis of pre- and post-test results.

Pre-Test Feedback on Student Math Writing

"Use vocabulary." The main type of feedback PSTs gave on the writing sample at the beginning of the PD was vocabulary-oriented or word-level feedback (42% of PSTs). Feedback in this category either: (1) identified "words" or "terms" as the problem and encouraged the use of math vocabulary or "math language" as a means of fixing the student's writing, or (2) identified specific vocabulary items the student needed to use to earn a higher score. For example, one participant diagnosed the student's work directly, stating, "*I can see you're having trouble finding the right words to communicate [your math understanding] in writing*." Another participant agreed, writing, "[*You're*] *missing math vocabulary.*" Meanwhile, other PSTs offered the student solutions to an implied word-level problem, such as those who wrote, "*Include vocabulary that we use in class*" and "*You want to use more technical vocabulary.*" A third subset of PSTs whose feedback fell into this category prompted the student to include specific "math terms" in their writing. Some participants conceived of math terms broadly as numbers, such as one PST who responded: "*To meet the expectations, I would tell the student that the answer needs to be in math language; the answer must include numbers.*" However, other PSTs identified specific vocabulary items they thought of as essential for writing an effective response to the prompt. For example, a number of participants directed the student to "*use the words 'domain' and 'range' to specify the domain and range of the function*," "*define function*," "*use terminology (function, relation, etc.)*," or simply "*use the vocabulary words used in the question*." The predominance of this type of feedback is not surprising given that prior research shows many teachers think of disciplinary language as a specific set of vocabulary items that will allow a student to comprehend a textbook and write specific explanations of the mathematical concepts and/or procedures associated with those vocabulary (e.g., Cavanagh, 2005; Draper, 2002; Moschkovich, 2012).

"Add more details." A second type of feedback PSTs provided at the beginning of the PD was the general prompt for more "detail" in the student's response (24% of PSTs). In contrast with PSTs whose vocabulary-oriented feedback included explicit reference to words they expected the student to use to increase specificity in their mathematical explanation, PSTs whose feedback fell in this category made broad and rather vague comments about the need for specificity. For example, one PST supposed he would "*tell the student to be more specific with answering the questions [in the prompt]*," as another PST did in directing the student to "*please be more specific*." In fact, the phrase "*be more specific*" was used by 18% of PSTs in pre-test feedback, the majority of those whose feedback fell into this category. Other responses to student writing that fell into this category included those that vaguely diagnosed the problem as a "*lack of detail*" or prompted the student to "*provide more detail.*" This type of feedback is common on student writing across disciplines (Ferris, 2003). However, this type of feedback is overly general, requesting specificity from the student without providing specific suggestions, and rests on the underlying assumption that student writers have the requisite conceptual knowledge and linguistic repertoires to meet expectations for writing in a particular discipline and genre. As Schleppegrell (2004) notes, literacy instruction built on this assumption privileges students who have been socialized into more disciplinary ways of

using language through school and home encounters and marginalizes students who have not.

Praise: "Good attempt." A third type of feedback PSTs gave at the beginning of the PD was general praise or encouragement, at times followed by criticism, questions, or other caveats related to praise (27% of PSTs). One PST's response that exemplifies this approach to feedback was: "*Good attempt, I'm proud of you.* [*You get a*] *1 for effort and trying your best, but the answer wasn't enough. You could do better, and I expect more*." Another PST wrote: "*Great! Almost...but I need to see your work. How did you know if the relation was/wasn't a function? What steps did you take to reach this answer?*" In a number of cases, this type of feedback was combined with vocabulary-oriented feedback or general prompts for detail, as in these PST responses: "*You are off to a good start in understanding how the function is continuous, but when trying to answer a question like this, you need to understand how to properly answer using the terms 'domain' and 'range*,'" and "*Good attempt, but you need to be more specific*."

Ferris (2014) explains this phenomenon as the result of teachers' goals in giving written feedback, reporting that many teachers are less focused on improving students' disciplinary writing and more focused on encouraging students, building confidence, and softening the blow of direct criticism. Therefore, they tend to frontload positive evaluation in feedback on student writing. This supports the perception that teachers have a care orientation that dominates their responses to students (Pajares & Graham, 1998). New teachers in particular (<3 years of experience) tend to be non-directive "idealists" in giving written feedback (Ferris, 2014). However, this feedback strategy can mislead students to believe their work is essentially correct, and their content knowledge and disciplinary writing skills are adequate for the task, as many students process the feedback as generally positive and do not read or reflect on the rest of the assessment of their work (Hyland & Hyland, 2001). Other students have reported that they understand this type of feedback is meant to serve as positive reinforcement for their efforts at engaging with a disciplinary writing assignment, but they find it unhelpful and insincere (Hyland, 1998). Further, students may be especially suspicious of positive feedback that comes with very low scores. In sum, while teachers may feel that they are being supportive and encouraging, students may feel misled or confused by this kind of positive feedback.

"Let's talk after class." A fourth type of feedback that frequently occurred in PSTs' pre-test responses was the prompt for oral feedback sessions (22% of PSTs). Feedback that fell in this category was most often brief. It hinted at the inadequacy of the response, but did not provide feedback on the writing itself. It also directed the student to arrange an in-person meeting with the teacher. For example, "*Clearly you are having trouble understanding the material. Meet me for extra help when you have some time.*" Some PSTs refrained from including negative written feedback, but combined low numeric scores with prompts to meet after class, as in these two responses which were paired with scores of 0 and 1, respectively: "*Let's talk after class so I can hear more about your answer*;" and "*Let's talk about this kind of problem after class*." A small subset of responses in this category combined calls for in-person meetings with other types of feedback, such as requests for more detail: "*Please be more specific. If you do not understand the problem, please talk to me at the end of class so we can arrange a time to meet and discuss it*." Generally, oral feedback sessions can allow for effective individualized instruction (e.g., providing clarity and scaffolding to meet particular students' needs). However, teachers should have a clear approach for oral feedback sessions to scaffold the writing process

most effectively for their students (Ferris, 2014). PST responses in this category offer little insight into the type of oral feedback they would provide if the student elected to arrange a meeting. Further, this type of response to student writing can delay feedback and might result in no feedback unless follow-up meetings are required by the teacher (Perrine, 1999).

Post-Test Feedback on Student Math Writing

After twelve weeks and PSTs' completion of the three PD modules, PSTs' use of three of the four types of feedback described in Table 2 shifted notably. Specifically, PSTs' use of vague calls for more vocabulary and added details, as well as prompts for face-to-face feedback sessions, decreased markedly. Responses that began with general encouragement increased slightly. Moreover, it appeared that as PSTs' disciplinary linguistic knowledge developed, their feedback on student math writing became more purpose-oriented and they exhibited an ability to use SFL concepts to explicitly address the genre and/or register features expected in a well written mathematical explanation.

A decrease in calls for more vocabulary. The decrease in PSTs' use of vocabulary-oriented feedback (42% → 7%) is interesting because there was a dramatic shift from giving broad advice (e.g., *use vocabulary from class*) and decontextualized lists of terms to an embedding of word-level advice in feedback specifically related to the purpose and audience the mathematical writing task at hand. This is not to say that PSTs were no longer focused on the specific mathematical vocabulary they expected students to use, but as will be further discussed in a subsequent section, post-test feedback shifted toward being goal-oriented, meaning word-level advice was explicitly linked to an awareness that authors make vocabulary choices to construct certain content for a certain audience to accomplish the social goals associated with a particular genre—in this case, the genre of written math explanations. As one PST remarked in the score rationale that accompanied her post-test feedback, "*It's not just that* [*the student*] *needs to use the word 'function,' but they need to define the word and then explain why or why not this is a function because you can't assume the reader knows the material.*"

Greater linguistic precision regarding "Add details." Similarly, there was a decrease in PSTs' post-test use of vague calls for more detail (24% → 16%). For example, as PSTs developed the ability to be more linguistically precise about the kinds of "details" they expected to see in effective math explanations, we found fewer instances of PSTs prompting the student to simply "*be more specific*." Instead, post-test feedback showed more elaboration on how the student could increase mathematical specificity through the use of more precise linguistic choices. For example, one math PST who wrote "*explain more of what you mean*" in his pre-test feedback was able to articulate more precise expectations in his post-test response: "[*Your answer*] *needs to be taken further. Be more specific with what is going on forever, and why that shows this is a function or not. You can explain through both sentences and showing your work.*"

Slight increase in praise. The slight increase in encouraging feedback in post-tests (27% → 31%) could be attributed to the idealist novice teacher profile described by Ferris (2014). However, it may also be a by-product of the PD's emphasis on using disciplinary linguistic knowledge to explicitly identify students' linguistic strengths as well as areas for growth. In other words, while PSTs were explicitly discouraged in the PD from giving vague feedback such as "add details" and "be more specific," they were encouraged to practice using SFL concepts and metalanguage to provide positive feedback regarding

students' uses of disciplinary language. For example, one math PST wrote, "*You have a strong start here, using 'because' to explain your understanding of this topic. But your response is not complete. Here are some suggestions to think about when re-writing your response…*"

Fewer instances of "Let's talk after class." Post-test results show half as many prompts for a face-to-face meeting to discuss the student's response in one-on-one setting (22% → 11%). In interpreting these results, it may be that this "see me" response was less necessary as PSTs developed new ways of responding with greater precision to student writing, as illustrated in Table 3. In other words, because PSTs were able to provide more clear and concrete feedback to the student, the somewhat default and expedient response "see me" may have been less necessary. This interpretation, however, is highly speculative.

A new type of feedback: Focus on purpose. One new type of feedback that emerged in PSTs' responses by the end of the PD was general purpose-oriented feedback (36% of PSTs). Feedback in this category addressed the appropriateness of the student's writing to the request of the specific writing prompt (Figure 2), but did not explicitly name the genre the student was expected to produce. In the pre-test data, no PSTs explicitly connected their feedback to the purpose for which the student was writing. However, after the PD, which emphasized linguistic choices as a function of context, purpose, and audience, more than a third of PSTs framed their feedback in this way. For example, one PST, whose pre-test feedback was "*I suspect at this point that the student doesn't know the terms*," addressed the student directly in his post-test feedback, and connected his expectations explicitly to the prompt: "*Start by reading the prompt and noticing what it is asking you to do - explain your thinking and show your 'evidence' or 'proof.' In this case, the prompt is asking you two questions and you probably want to tackle them one at a time.*" SFL scholars have argued that one role of the classroom teacher is to make their implicit knowledge of text types explicit by showing students how all texts are "produced in response to, and out of, particular social situations and their specific structures" (Kress & Knapp, 1992, p. 5). The emergence of this type of feedback in post-test responses suggests some PSTs developed an ability to recognize a recurring type of text that has been conventionalized in secondary math classrooms and has a distinct purpose (e.g., to demonstrate knowledge of key concepts and explain how and why a conclusion was arrived at on an exam). PSTs whose post-test feedback fell into this category attempted to make this purpose explicit to the student in their written feedback.

A second new type of feedback: Focus on genre expectations. The second new type of feedback that emerged in post-test feedback was genre-oriented feedback (29% of PSTs). This category refers to feedback that named the genre students were expected to produce in response to the prompt (i.e., math explanation) and explicitly outlined the expected stages for accomplishing the purpose of this genre (i.e., general statement identifying the mathematical concept to be explained, definition of key terms, explanatory sequence; see Moschkovich, 2010; O'Halloran, 2008). This feedback category is distinct from the purpose-oriented feedback because PSTs in this category explicitly attempted to address the purpose *and* linguistic features needed to realize this specific purpose in their feedback. In one particularly dramatic shift in feedback from pre-test to post-test, a PST who had initially invited the student to "*talk after class*" gave the genre-oriented post-test feedback illustrated in Table 3. This feedback, and other instances like it, suggests that some PSTs enrolled in the PD were able to develop sufficient disciplinary linguistic knowledge in 12 weeks to give explicit genre-based feedback on student math writing regardless of whether

Table 3

Examples of Functional Feedback on Student Writing in Mathematics Following SFL-based PD

Genre-Oriented Feedback	Feedback on the Use of Mode/Flow Resources	Feedback on the Use of Graphic Elements
There are a few steps you can follow to make sure you answer this question clearly and thoroughly with a math explanation. Try following the following steps: *Define the domain and range. In order to do this, you should write in full sentences and use relational verbs (is/are).* *The domain IS _____.* *The range IS _____.* *Tell whether the relationship is a function. In order to do this, you should write in full sentences.* *The relationship is a function because _____. OR* *The relationship is not a function because_____.* *Explain your answer: after the word "because," you can explain your answer better by showing that you understand what a function is. This would be a good place to write the definition of a function using terminology we learned in class.* *For an even more amazing response, you can even draw an arrow to the graph, or otherwise graphically represent what you meant in your explanation.*	*In order to decide if this is a function, you must first define function.* *Next, you must explain your thought process step by step to prove that the relationship is or is not a function. In the explanation, you must include vocabulary that we use in class and transition words that provide flow and sequence to your explanation.*	*- You can enhance your response by including words like "relation," "domain," "range," and "function." You can also enhance your response by using math symbols. Using symbols will show your knowledge about the topic. They also keep your solutions organized and accurate.* *- Draw visuals: drawing a visual, like a graph or table, to represent this relation will enhance your response and also be helpful in generating a precise and accurate solution.*

or not math was their discipline. This feedback explicitly attended to the steps a student could follow to produce a math explanation that meets expectations and effectively communicates content knowledge. As such, genre-oriented feedback can serve to support students in negotiating the demands on high-stakes exams. This trend is a notable shift given findings from other studies that suggest only 1–2% of teachers report providing students with written feedback on the organization of their texts (Ferris, 2014).

Of the PSTs whose post-test feedback was genre-oriented, some also included explicit register-level advice, meaning they attended to particular aspects of field, tenor, or mode at the sentence level in their written feedback. The most common register-level advice PSTs gave emphasized field resources (27% of PSTs), or language choices the student could make to more effectively construct the content of their response. This type of feedback most often included contextualized vocabulary advice, such as that in Table 3: "*You can explain your answer better by showing that you understand what a function is. This would be a good place to write the definition of a function using terminology we learned in class*." This type of feedback differs from that categorized as vocabulary-oriented in that it talks about vocabulary use in relation to the purpose of the text and the expectations of a specific genre. For example, another PST who gave register-level advice focused on field resources wrote: "*You have the beginning of a math explanation, but you've failed to give the domain and range. Your explanation should use content-specific nouns and verbs to show that you have knowledge of the field*." Both of these feedback examples demonstrate PSTs' developing understanding that the kinds of meaning made in the discipline and discourse of math require particular ways of using grammatical resources (e.g., mathematical definitions require content-specific nouns and relational verbs). The data suggest that the emergence of this type of feedback may have contributed to the post-test decrease in vocabulary-oriented feedback.

In addition to register-level advice focused on field resources, PSTs' post-test feedback also included a few examples of advice focused on tenor and mode resources (10% of PSTs collectively). Tenor refers to the language choices an author makes to construct the social roles between themselves and their audience, and is one aspect of language few teachers emphasize in disciplinary literacy instruction (Aguirre-Muñoz, Park, Amabisca, & Boscardin, 2008). Nevertheless, three PSTs attempted to inform the student's use of tenor resources, such as one PST who encouraged the student to use a more authoritative voice by positioning him as a mathematical thinker and writer: "*As mathematicians we always want to be sure to explain how we come to our conclusions. How did you know for sure that this goes on forever?*" Three PSTs also gave feedback regarding the use of mode resources, or those language resources that would enable the student to control the flow of information in their explanation. For example, as exhibited in Table 3, one PST pursuing a career in math teaching encouraged the student to use sequential organization and transition words to create flow in their response.

A final type of register-level advice that emerged in PSTs' post-test feedback focused on the use of a graph or mathematical symbols as meaning-making resources (16% of PSTs). This feedback was categorized separately from other register-level advice because PSTs encouraged the use of these graphic elements in the student's response in different ways: as a means of constructing content (field), constructing themselves as a mathematical expert (tenor), and/or as a means of building up information needed by their reader to follow their response (mode). Thus, though this feedback was categorized separately from other aspects of register, the following examples illustrate that the different

register resources are always working simultaneously. For example, one PST focused on the graph as a means of making it clear to the reader what is being talked about: "*Include vocabulary words and a graph (that we have learned in class) to explain your response*." Another PST gave relatively similar advice but framed the use of particular vocabulary and a graph as a means of constructing an authoritative self: "*State the range and domain and then use a graph to 'show' you understand it.*" A third PST, who was pursuing a career in math teaching, made connections between the use of graphic elements and content, field, tenor, and mode goals in her feedback (see Table 3).

Collectively, the post-test feedback data demonstrate that as PSTs studied SFL and genre theory, many of them were able to recognize explicitly and begin to talk about the multiple semiotic systems that comprise register in the math classroom (e.g., linguistic resources, symbolic representations, visual images). While this development was likely also impacted by factors external to the study (e.g., increased observation and student teaching time at practicum sites over the course of the semester; other program coursework), the specific types of feedback that emerged in the post-test data suggest a relationship between the Module 2 content of the PD and PSTs' developing disciplinary linguistic knowledge as evidenced in their changed feedback practices.

Implications

PSTs' ability to explicitly scaffold disciplinary writing and respond to students' disciplinary texts with greater expertise and specificity is a pressing educational priority for a number of reasons related to the rapidly changing nature of schooling in the context of globalization (e.g., Canagarajah, 2013). First, population flows and demographic changes worldwide have resulted in calls for educators at all institutional levels to know how to teach linguistically diverse students how to read and write more powerfully and critically in their disciplines (e.g., Gebhard & Willett, 2015). Second, reforms such as CCSS are mandating K-12 schools and colleges of education do a much better job of preparing all students and teachers to be "college and career ready" in a rapidly changing social, economic, and political world—a world that values and rewards multilinguals who are able to apply mathematical thinking to solving real world problems creatively through their use of "*talk, print, and multimodal representation systems*" (CCSSO, 2010, p. 6, italics added). These reforms, and the high-stakes accountability systems associated with them, necessitate that teachers be able to make their tacit understanding of the semiotic systems they use to make mathematical meanings more explicit to students. This ability will allow teachers to better apprentice students to learning how to use technical language, signs, and multimodal representations more expertly over time.

Central to this type of apprenticeship is a teacher's ability to design curriculum, instruction, and assessments that support students in writing specific high-stakes genres more expertly (e.g., procedures, descriptions, explanations, arguments). However, past reforms regarding academic writing instruction in the United States have largely failed (O'Brien, Stewart, & Moje, 1995). In the recent past, writing instruction has been characterized by a disconnect between teachers' intentions and students' experiences (Applebee, 1984; Zamel, 1985). This disconnect has been attributed in part to teachers' lack of knowledge and pedagogical skills (National Commission on Teaching America's Future, 1996), as well as professional development efforts that "fall short of [their] objectives and rarely improve professional practice" (Calvert, 2016, p. 2). While this study does not present longitudinal findings regarding whether or how PSTs operationalized

disciplinary linguistic knowledge in their actual classroom practices with diverse secondary students, the data suggests PSTs were able to incorporate disciplinary linguistic knowledge into writing instruction within their pre-service coursework. Moreover, the data suggest that PSTs were able to make sense of SFL tools in ways that have the potential to support their emerging pedagogical practices in the future, specifically their ability to reflect on student learning and provide more concrete feedback.

As SFL scholars have argued, explicit genre and register-level feedback can "enhance the knowledge co-construction between teacher and student...and bring to the foreground the preferred linguistic choices in a given context, as well as reinforce instructional points discussed during whole-class instruction" (Aguirre-Muñoz et al., 2008, p. 316). Further, functional written feedback has been shown to support emergent student writers in developing their own metalinguistic awareness of disciplinary literacy practices, which in turn helps them gain command of these practices (Gebhard, Chen & Britton, 2014; Patthey-Chávez, Matsumura, & Valdés, 2004; Schleppegrell, 2013). Last, international math education scholars have recently argued that effectively incorporating writing into math instruction can support students in thinking more deeply and clearly about mathematical content, improve student attitudes towards mathematics, and serve as an invaluable assessment tool of student learning (e.g., Adu-Gyamfi, Bossé, & Faulconer, 2010; Burns, 2004; Morgan, 2001; Pugalee, 2001). The arguments of these scholars, coupled with the findings from this small-scale study, suggest that SFL theory and practice can play a productive role in preparing future teachers.

As a coda to this article, approximately one month after the PD ended, as participants began their student teaching experiences in earnest, one PST reflected on the usefulness of the PD for building disciplinary linguistic knowledge and operationalizing that knowledge in his classroom practice. He said:

> *Knowing more about the language of my discipline, I think I was better able to convey my expectations to students. At the end of [the PD] I felt like that anyway. And there were things that—like learning to talk about my discipline language—I didn't know before. I didn't have any strategies to do that specifically before. But now I think I have a little bit better grip on that and some more strategies as far as talking about specific types of writing.*

As this PST indicates, knowledge of disciplinary literacy practices allowed him to be clearer in his expectations for student work. This clarity is key to designing instructional tasks, assessing students' learning, and reflecting on one's teaching.

Of course, the challenges of mathematics teaching in the United States and around the globe extend well beyond the issue of disciplinary writing described in this article. Nevertheless, the professional expectations of secondary teachers in the United States and many international contexts increasingly include the design and implementation of curriculum that supports students in developing advanced disciplinary literacies (e.g., Gleeson, 2015; Gorgorió & Planas, 2001; Love, 2010; Morgan, 2001, regarding international contexts). Therefore, PSTs need professional development that explicitly targets their development of disciplinary linguistic knowledge to support students in constructing knowledge about mathematics in ways that are seen as successful (Thwaite, 2015). This means PSTs must develop an understanding of and ability to operationalize an awareness of how language constructs knowledge in their disciplines. Though PSTs will necessarily have differing levels of disciplinary knowledge as a basis for building disciplinary linguistic knowledge, findings from this study suggest that PD structured around building knowledge of particular high-stakes genres can help prepare new teachers

for work in the context of new standards. Further, findings from this study suggest SFL provides a promising theoretical basis for this type of PD. The findings reported above add to the growing body of evidence that SFL-based PD can support PSTs' development of disciplinary linguistic knowledge in ways that influence their ability to provide specific and functional feedback on student writing (e.g., Aguirre-Muñoz et al., 2008; Fang & Wang, 2011; O'Hallaron & Schleppegrell, 2016). We recommend further research in this area to explore PSTs' responses to a range of student writing samples across disciplinary genres, longitudinal development of PSTs' disciplinary linguistic knowledge to see how this knowledge becomes incorporated into classroom practice (or not), and students' interactions with SFL-informed feedback to track the impact of this feedback on their development of valued disciplinary literacy practices.

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