"HEY! TODAY I WILL TELL YOU ABOUT THE WATER CYCLE!"

Variations of Language and Organizational Features in Third-Grade Science Explanation Writing

ABSTRACT

This study investigated third graders' use and variation of linguistic resources when writing a science explanation. Using systemic functional linguistics as a framework, we purposefully selected and analyzed writing samples of students with high and low scores to explore how the students' use of language features (i.e., lexicogrammatical resources) reflected those expected in the discipline, or register, of science, as well as alternative language patterns used to realize the cyclical explanation genre in science. The language features used in high-scored samples were more aligned with those of the discipline compared with the low-scored samples. Although the low-scored samples revealed that students possessed some valid scientific understandings, these understandings were not as evident due to the students' limited use of language features commonly found in the science register. This work fills important gaps in the literature concerning the contribution of lexicogrammatical resources in conveying elementary students' science knowledge through written explanations.

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THE Common Core State Standards (CCSS; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) for English language arts call for an integrated model of literacy across content areas, including science, and emphasize argument and informational/explanatory text types (Wiggs, 2011). College- and career-readiness "anchor standards" drive the CCSS, reflecting literacy expectations as students advance through the grades to enter and succeed in college or a career (Calkins, Ehrenworth, & Lehman, 2012; Wiggs, 2011); these anchor standards include a set of skills and processes related to writing proficiency. However, as schools become increasingly diverse, assisting teachers to support students of different racial, ethnic, and linguistic backgrounds and enhancing opportunities to learn are necessary. Achievement tests, such as the National Assessment of Educational Progress (National Center for Education Statistics, 2012), typically show that Black and Hispanic or Latino students tend to score lower than their Asian and White peers on school-based writing tasks. This suggests that some students may need additional supports and instruction for writing in standardized English, specifically for academic genres that are generally not experienced outside of school (Christie, 2002; Zwiers, 2008). Moreover, teachers may not be explicitly aware of the specific purpose of the genres emphasized by the CCSS or the language and organizational features that help to realize the purpose (Brisk, 2015; de Oliveira & Silva, 2013, 2016; Fang & Schleppegrell, 2008). To equitably address achievement differences, there is a need to simultaneously work toward culturally responsive teaching while making language features of different genres, such as science explanation writing, more transparent.

We conducted a secondary analysis of third graders' science explanation writing samples to explore students' language use in explanation writing. The writing samples were collected and scored using two rubrics (content and form) developed by researchers that were part of a larger study investigating a hands-on inquiry-based science intervention for diverse students in urban classrooms.[1] Writing samples were originally scored on a 4-point scale; to support our analysis, we considered pieces with scores of 3 or 4 for content and/or form to be high scored, and low-scored pieces were those that received a score of 1 or 2 for content and/or form. Using a systemic functional linguistics (SFL) framework (Halliday, 1978; Halliday & Matthiessen, 2004), we analyzed a subset of the writing samples for language and organizational features commonly found within the science explanation genre. We used the framework to explore both the lexicogrammatical (or interplay between lexis and syntax) and organizational resources of students with high- and low-scored written explanations to describe patterns of language and organization use between the two groups and in relation to patterns of language use characteristic of science explanation texts.[2]

What makes this work unique is that we bring both inside-out and outside-in perspectives to this secondary analysis of writing samples. Tower (2003, p. 15) explains that most informational writing studies at the primary level (K–2) focus on an inside-out perspective that "starts with the children's writing and moves outward toward the development of models to describe the writing," emphasizing development. The outside-in perspective is more common at the intermediate level and includes comparisons made between "predetermined rubrics, standards, or other expectations" (Tower, 2003, p. 15) to students' writing, emphasizing achievement. We began with achievement results to identify writing samples (outside-in) and then critically analyzed the students' writing to identify specific language and organization features used (inside-out). While both perspectives have made important contributions to the field, more research is needed that focuses on science writing to inform instruction that goes beyond rubric scores (Fang, 2004; Fang & Wang, 2011). This work specifically aims to contribute to the literature by demonstrating the importance of science discourse, or the language features typically used in science, to express science knowledge. This not only includes technical vocabulary but also language features at the discourse and sentence levels (Schleppegrell, 2004). In other words, displaying knowledge of science includes understanding and being able to use the discourse of science, and using the linguistic features found in typical science explanations helps to convey that knowledge (McQuitty, Dotger, & Khan, 2010; Seah, Clarke, & Hart, 2011). We explored the following research questions: (1) What lexicogrammatical and organizational resources characterize science explanation writing in high-scored versus low-scored third-grade science explanation writing samples? (2) What other language features, if any, did students use to realize explanations of the water cycle?

We explain a genre approach to writing science texts, focusing on elementary students' lexicogrammatical and organizational choices to effectively express or write science content and, specifically, science explanations. We follow this with a brief review of the literature that investigates science writing instruction; we then describe our methods and procedures, present findings and implications, and conclude with future research suggestions for the field.

Writing in Science: A Genre Approach

Genre, as defined by SFL theory, is a shared set of meanings within a particular culture that are used on a recurrent basis. Martin (2009, p. 13) describes this as a "staged goal-oriented social process" in which language is constructed to communicate meaning based on the needs or purposes of the particular society or group. Genre describes how language is mobilized, delineating "how we use language to live" (Martin, 2009, p. 13) and providing us with familiarity with what to expect when making decisions about language and organization use. According to this definition, a genre changes slowly, adding and dropping aspects to meet the needs of making meaning in a particular cultural context.

Students learn to use language for a variety of purposes both in and out of school (New London Group, 1996), and language choice is based on one's repertoire of linguistic resources. Language choices made by individuals reflect the context in which those choices are made. In this way, context shapes the language that is expected in order to communicate across language modalities (e.g., listening, speaking, reading, writing; Fang & Schleppegrell, 2008; Halliday & Matthiessen, 2004). Grounded in a sociocultural perspective of language and language learning, genre pedagogy posits that it is the teacher's responsibility to expand students' ability to use language in "more expert ways to accomplish specific kinds of work" (Gebhard, Willett, Jiménez Caicedo, & Piedra, 2011, p. 93). Although certain language features and organizational structures may overlap across content areas (i.e., may be common), a genre approach to teaching writing acknowledges that they are often used in ways that are specific to the discipline. Fang (2004) points out that the special lexicogrammatical and organizational features that characterize science writing differ from everyday oral language use. These special features enable efficiency in communicating scientific knowledge and understanding and, moreover, may be challenging for students who are acquiring the abstract language of science (as well as other disciplines) generally found in upper elementary- and secondary-level texts (Fang, 2014). Specifically, science texts include informational density (typically measured by the number of content words or technical vocabulary over total number of words), abstraction (theorized concrete experiences, which entail the use of nominalizations to synthesize, condense, and efficiently label processes while creating ambiguity and the need to infer meaning), technicality (specialized vocabulary with meaning specific to the discipline), and authoritativeness (objective presentation of information; Christie, 1989; Fang, 2004; Halliday & Matthiessen, 2004; Wollman-Bonilla, 2000). The resulting syntax, or sentence structure, enables greater precision in expressing complex ideas characterized by more formal uses of language, such as written texts, than informal oral language communication (Schleppegrell, 2002; Wells, 1994). Thus, learning science is, in essence, equivalent to learning the language of science because the two cannot be separated (Lemke, 1990; Wellington & Osborne, 2001).

According to Brisk (2015), the science writing genres used in elementary grades include procedure, procedural recount, report, explanation, and argument; these genres and the language features needed to effectively write them are detailed in Table 1. A procedure is the easiest genre for elementary students to master because it relies on a series of sequential statements that are generally recalled from concrete experiences to realize its goals (Brisk, 2015). Reading Table 1 from left to right demonstrates how the columns on the right for explanation and argument are the more challenging written genres for elementary students to master, given the need to use language in more formal, complex ways to build cohesion at the sentence and discourse levels and thus realize the genres' goals (Brisk, 2015).

In science texts, one typically finds the use of simple present tense to represent the timeless nature of science concepts; nominalizations and long, complex noun groups that effectively pack complex content within shorter sentences; lexical density through the use of terms that have specialized meanings in science; verb types that create abstractness; Theme/New Information or zig-zag patterns to effectively build on stated ideas; an authoritative tone to demonstrate authority of subject knowledge; and connectors associated with temporal sequencing that are intended to make conceptual links, technical procedures, and/or causal processes clear for the reader (Fang & Schleppegrell, 2008). A summary of the SFL constructs found in the research literature concerning the science explanation genre is provided in Table 2, along with definitions for each construct. For example, the term *Theme/New Information* is capitalized because it refers to the development of information through thematic progression and the choices a writer makes about what comes first in a clause, not to be confused with theme in the literary sense or deep meaning of a literary work (Brisk, 2015; Fang & Schleppegrell, 2008). Figure 1 illustrates examples of these constructs within an excerpt of science text, as well as other language features broadly found in academic texts.

Explanation Genre

Explanation writing from a science perspective is concerned with documenting change in understanding and knowledge (Chambliss, Christenson, & Parker, 2003), whereas from a genre-based literacy perspective, explanations are viewed functionally. That is, the function (or purpose) of an explanation is to explain phenomena in a linear or cyclical sequence, how a system works, or factors that contribute to an outcome (Brisk, 2015). It is generally easier for students to write an explanation of familiar phenomena and how something happens rather than why something happens (Brisk, 2015). Students would benefit from completing oral explanations as an introduction to this genre, with written explanations introduced following more exposure and experience with the explanation genre. Although a few different types of explanation genres are used for science writing, our focus in Table 1 is on cyclical explanations, since the analyzed writing samples were in response to a prompt that requested a cyclical explanation of the water cycle.

To summarize, language and content learning are interdependent within a genre framework and build on each other. Knowledge of the discipline's register facilitates expression of content knowledge, which in turn allows that knowledge to be more sharply expressed for intellectual and social purposes (Lemke, 1990; Shanahan, Shanahan, & Misischia, 2011). Alternatively, content knowledge facilitates language learning by creating the need for social conventions to express elaborations of ideas (e.g., vocabulary and other language-based artifacts), distinctions between concepts, negation of earlier held beliefs, restructuring and reorganizing of concepts, and the expression of new findings (Unsworth, 1997; Wells, 1994). It is precisely the discourse around scientific texts "that provides the means for the development of the 'higher mental functions'" (Wells, 1994, p. 82).

Review of the Literature

To date, there is little research investigating elementary students' writing in science that explores how knowledge of grammatical metaphor (i.e., the ability to manipulate lexical and syntactic forms) contributes to writing proficiency and expression of science content knowledge.

The available studies that examine explicit genre writing instruction have varied in findings ranging from few effects in relation to whether explicit instruction had an impact on students' writing (Purcell-Gates, Duke, & Martineau, 2007) to some effects (de Oliveira & Lan, 2014; Fang, 2014; Klein & Rose, 2010). The study by Purcell-Gates and colleagues (2007) showed little impact from explicit teaching of linguistic features on second- and third-grade students' information and procedural reading or writing proficiency. There was significant growth in second graders' effective use of language features typically found in procedural texts; however, this was not found in the third graders' procedural writing results. Also,

Table 1. Comparing Genres for Elementary Students' Science Writing (Based on Brisk, 2015)

	Easier to More Difficult for Elementary Students to Master				
Genre	Procedure	Procedural Recount	Report	Explanation	Argument
Purpose	Give directions to accomplish a goal	Tell what the writer observed	Organize factual knowledge or information about a concept	Explain how or why things come to be the way they are or how things work	Persuade others to accept your viewpoint or to take action
Example of genre for use in science	Write steps to set up a science experiment	Describe what happened while observing or carrying out a science experiment	Write a factual report about a class (dogs) or member of a class (German shepherd)	Explain the water cycle or phases of the moon (cyclical), how recycled paper is made (sequential), or how a volcano erupts (causal)	Write to persuade others why schools should offer healthy snacks
Structure	Title Goal or aim Materials needed Method (series of sequential steps needed to meet the goal) Evaluation or final comment (optional)	Title Orientation (aim) Sequence of events Conclusion	Title General statement (to identify topic of report) Information is organized/presented in subtopics (bundles) Conclusion	For cyclical explanations: Title Identify phenomenon Cyclical explanation sequence Conclusion (optional)	Title Thesis/claim (to include necessary background information and preview of reasons) Reasons supported by evidence Conclusion (reinforcement of position statement)
Appropriate tense	Imperative (typically the person carrying out the action is unnamed)	First, second, and/or third person, as appropriate: Past	Third person (typically most appropriate): Present	Third person: Present and use of passive voice (if participants, such as dinosaurs, are no longer living, past is used)	Third person: Present and/or future Past (for evidence) Use of modals

Vocabulary and/or language features typically found in effective writing for the genre	Precise action verbs Various adjectives to give specificity Adverbs (of place, manner) to make instructions specific Clause complexes with finite and nonfinite verbs pack information and specify instructions Use of numbers to sequence steps Reference the materials from the initial list that are needed throughout the steps	Variety of verb types (e.g., saying, thinking, feeling, relational) Noun groups to create complex clauses and pack information, use of adjectives and adverbs to describe with precision References to pronouns are clear and easy to follow	Generalized or specific participants (consistent use of terms) Lexical ties (i.e., collocations as technical vocabulary) semantically linked to the report topic Adjectivals with adjectives, prepositional phrases, embedded clauses with finite/nonfinite verbs, adjective group after a relational verb Clause complexes to pack information	Action verbs Passive voice Generalized participants (volcanoes, frogs) Adjectivals and adverbials to add details and descriptive language Clause complexes with appropriate use of conjunctions for tight logic-semantic relationships Text connectives to sequence time/event Lexical ties (collocations as technical vocabulary) semantically linked to the topic	Generalized participants Use of technical vocabulary for evidence Language choices should describe reasons and evidence to demonstrate awareness of audience Evaluative vocabulary to express attitude Grading
Sentence types	Imperative commands	Statements	Statements	Statements	Statements
Modality	NA	NA	NA	NA	Medium and low for adult audiences
Paragraph structure	NA	May be a single or multiple paragraph(s) following the above structure, depending on what is described	Macrotheme (discourse level) and hypertheme (paragraph level) organization using Theme/New Information to build cohesion	May be a single or multiple paragraph(s) following the above structure, depending on what is explained; Theme/New Information to build cohesion	Macrotheme (discourse level) and hypertheme (paragraph level) organization using Theme/New Information to build cohesion

Table 2. Glossary of Language Features Commonly Found in Science Explanation Genre

Term	Definition
Technical vocabulary	Words unique to science and everyday words with specialized science meanings
Theme/New Information	The Theme (capital *T*) refers to the author's choice about what information comes first in a clause. New Information (capital *N* and *I*) refers to the remainder of the message in the clause. Typical English clauses are structured so that the Theme reflects what is already established and the New Information represents the new information the author wishes to point out (Fang & Schleppegrell, 2008). Organizing clauses by Themes and New Information allows the topic to be logically developed and makes the text more cohesive and interesting to read.
Nominalization	Nominalization is the use of a verb, an adjective, or an adverb as the head of a noun phrase, with or without morphological transformation. The term can also refer specifically to the process of producing a noun from another part of speech via the addition of derivational affixes (e.g., *legalize* vs. *legalization*).
Present tense	Present tense refers to the form of the verb phrase, indicating the events are happening now.
Passive voice	Passive voice refers to when the object of an action is made into the subject of a sentence. That is, whoever or whatever is performing the action is not the grammatical subject of the sentence.
Temporal conjunctions and connectives	Temporal conjunctions/connectives are the words that serve to provide information about the sequence or order of events. These words link ideas together sequentially so that the reader can follow the order of processes or events that occur.
Conjunctions of cause/result associated with logical reasoning	Conjunctions of cause/result associated with logical reasoning provide the link between an independent and dependent clause based on reason or purpose. These conjunctions (i.e., *because, as, since, so that, in order to, as a result*) are used to show a causal link between the content in the independent and dependent clauses.

students in classrooms with more authentic science literacy materials for informational or procedural texts showed statistically significant growth in their ability to read and write the target genres. Time spent on reading and writing the target genres indicated that the amount of time alone was not as effective as the nature of what was experienced while reading and writing those genres. Writing instruction for the study by Purcell-Gates et al. (2007) focused on writing strategies shown to be effective in the literature rather than genre function and features; the authors were not able to track the degree of explicitness used by teachers and hypothesized that a greater degree of explicit teaching of language features with function as a focus (e.g., genre pedagogy) warrants further research. Other possible reasons for the minimal effects found may have included the cognitive and linguistic abilities of second and third graders to understand and transfer language feature instruction to their own writing or the limited familiarity younger children have with science procedural and information genres (e.g., as opposed to narrative genres).

Fang (2014) investigated third- through fifth-grade students' use of informational language features when writing science reports. The students in his study tended to use lexicogrammatical resources more commonly found in oral language but seemed to master academic writing features (i.e., timeless present tense, generic or nonparticularized participants). In addition, there was no clear developmental progression across the grade levels (third through fifth); for example, some third graders were more proficient in their use of nominalized forms and other features than fifth graders were. These findings were similar to those from a previous study (Fang, 2000) exploring the use of language for report writing with a smaller population of younger elementary students.

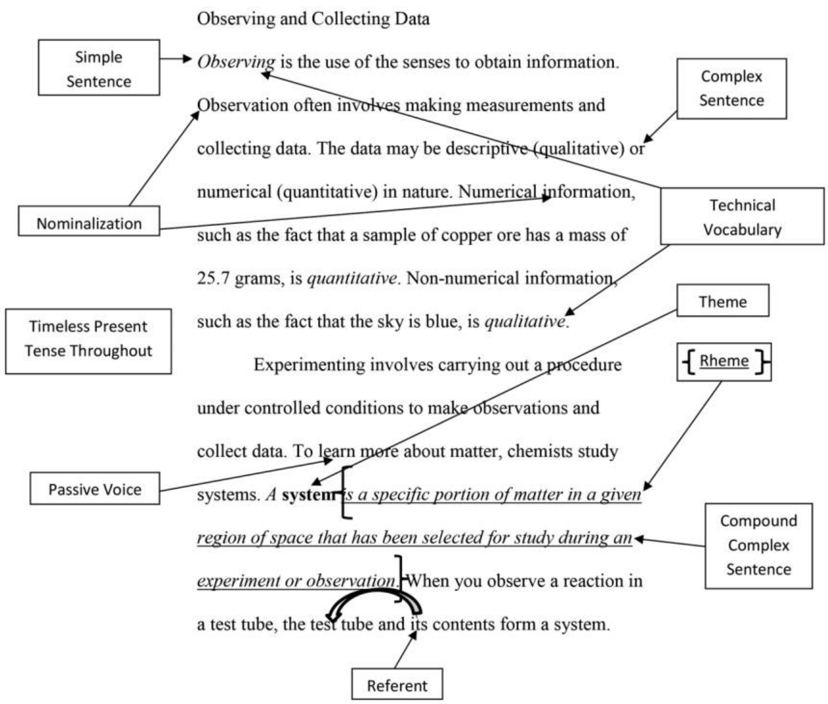

Figure 1. Excerpt of science text with identified language features (Davis, Frey, Sarquis, & Sarquis, 2006, p. 29).

De Oliveira and Lan (2014) found that using a genre-based pedagogy approach (i.e., the Sydney School, as described by Christie & Derewianka, 2008; Martin & Rose, 2005) with fourth-grade English-language learners (ELLs) improved their science writing of procedural recounts. Specifically, a focal student's writing demonstrated greater use of technical vocabulary and connectives when comparing pre- and postgenre instruction writing samples. Albeit for a different purpose, Chambliss et al. (2003) investigated fourth-grade teachers' science explanation writing instruction and students' resulting written explanations to demonstrate that writing explanations supported students' reasoning and understanding of a scientific causal model (e.g., effects of pollution on the ecosystem). The teacher provided explicit instruction using science explanations to teach content and genre features using mentor texts and jointly constructed an explanation with the class, and the children worked collaboratively as well as individually from the prewriting through final draft to write explanations for a third-grade audience of how one pollutant (oil spills, smog, or trash) affected the ecosystem. Chambliss et al. used T units (the smallest unit of a sentence considered to be a grammatically correct sentence) to examine whether there was evidence that the students used subexplanations (evidence or explanation of a certain phenomenon emphasizing a causal model) in a logical order to build to a larger explanation as they had been taught during the genre instruction component. They found that the students used expository language features for presenting information and narrative structures to describe scenarios. While expository language features are commonly found within written science texts, narrative structures are not. Chambliss et al. concluded that narrative structures were used as a way for students to draw on their own understanding of the causal model and enable reasoning about the science content. Ball (1992) also found that African American adolescents used characteristic features of familiar genres in their expository writing assignments. Finally, Seah et al. (2011) explored the lexicogrammatical resources of seventh graders writing about states of matter in response to a science task. Based on their analysis, the students faced challenges not only in using the language of school science when completing tasks but also interpreting the requirements and language of the science task to respond as expected.

In sum, the literature indicates that elementary students' writing and lexicogrammatical writing development varies greatly; however, there is a dearth of empirical research in this area. Our study helps to fill a void in the literature through its focus on the lexicogrammatical and organizational choices of third-grade students. Specifically, the study looks at the presence (or absence) of language and organization features within writing samples of a cyclical explanation for science and how the genre may be realized by language and organization features typically found in expository texts as well as language and organization features found in other genres.

Method

Cross-sectional research methods allow us to develop and explore some initial hypotheses about science writing proficiency on the basis of contrasts between two or more well-defined populations that vary along a single proxy for science writing development. Typically in child development research, this proxy has been age. In contrast, cognitive science research involving contrasts between experts and novices has unveiled opportunities to explore powerful mechanisms for cognitive development (Shanahan et al., 2011).

In this study, we adopted a cross-sectional paradigm whereby we contrasted students' low- and high-scored writing samples. By ensuring that we selected students of comparable age and English-language proficiency status who had engaged in the same science curriculum and received similar science instruction, we hoped to conduct a finer grained analysis of the genre characteristics of science writing that undergirds the ability of students to respond scientifically to an on-demand science explanation writing prompt. This enabled us to flesh out language and organizational features that contributed to making meaning in science. It is important to note that the prompt itself elicited a narrative response, asking students to pretend that they were drops of water going through the water cycle. This mismatch of genres (elicited narrative vs. expected explanation) is further addressed in the Discussion section, but it should be noted that this more than likely led to more narrative-structured responses, conflicting with explanation genre structures.

Insofar as there are similarities between the two populations in terms of age, English-language proficiency, and science curriculum and instruction, as described, we would hypothesize that those structural features are what distinguish less accomplished from more accomplished science explanation writing. To the extent that we find differences between less and more accomplished writers, we would hypothesize that future research might uncover some important developmental pathways that might prove amenable to curricular support and instructional interventions.

The Larger Study and Population

As part of a larger study, third-grade teachers in a large, urban school district located in the southeastern United States participated in a professional development intervention aimed at promoting science achievement in diverse urban contexts (Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera, 2009). Specially designed curriculum units and professional development focused on teaching science to diverse learners through an inquiry-based approach that integrated the use of mathematics. In addition, the curriculum integrated English-language and literacy development by (*a*) providing both science and general academic terms in three languages (English, Spanish, and Haitian Creole) at the start of each unit; (*b*) including a writing component, whereby students were expected to write expository paragraphs that described and explained the scientific concepts and processes under investigation;[3] and (*c*) including templates for the write-up of explanations and conclusions of science experiments conducted in class as supplementary materials. The third-grade curriculum materials incorporated initial writing experiences for the children; however, because the state assessment emphasized reading and mathematics in third grade, the integration of reading and mathematics received more instructional attention than writing.[4]

As part of the larger study, the intervention team administered a pre-post writing assessment to measure third graders' understanding of the water cycle. The writing assessment prompted students to do the following: "Pretend you are a drop of water. Before you begin writing, think about how water changes form in the water cycle. Now, explain to the reader how you are changed as a drop of water when you go through the water cycle." The pretest was given during the first 3 weeks of school, and the posttest was given at the end of the school year, after the intervention curriculum was completed. A total of 859 students completed both pre- and posttests.

The initial research team scored pre-post writing samples by using two project-developed rubrics informed by the statewide standardized writing assessment (Florida Department of Education, 2005). The first rubric focused on science content—that is, the extent to which the student (*a*) used technical vocabulary, (*b*) described change processes of the water and states of matter and the heating and cooling required for change processes to take place, and (*c*) demonstrated understanding of the relevance of a cycle. The second rubric focused on form (i.e., conventions, organization, style, and voice). Both rubrics were based on a 4-point scale. For science content, the mean pretest score was 0.32 ($SD = 0.61$), the mean posttest score was 1.36 ($SD = 1.00$), and the mean gain score was 1.04 ($SD = 1.01$). For form, the mean pretest score was 0.88 ($SD = 0.85$), the mean posttest score was 1.94 ($SD = 0.90$), and the mean gain score was 1.05 ($SD = 0.95$; see Lee et al., 2009, for more statistical results).

The Secondary Study: Science Explanation Writing

For this study, a secondary research team purposefully selected 56 postintervention writing samples to ensure a wider distribution of writing-sample quality than would likely be demonstrated among third graders at the beginning of the year. To purposefully select the samples, we were provided access to the larger study's deidentified data set in a spreadsheet format. We went down the list of random study-generated student IDs until we had a matched number of high- and low-scored writing samples (based on the primary research team's initial rubric scores). In addition, we selected samples from students who were identified as intermediate or advanced ELLs and those who had formerly or never received English for Speakers of Other Languages services to ensure representation of the district's diverse students. Selected samples that were considered to be high-scored pieces had received a score of 3 or 4 for content and/or form, and low-scored pieces had received a score of 1 or 2 for content and/or form (on a 4-point scale). Table 3 describes the English proficiency levels and scores for the student groups and demonstrates a roughly equivalent distribution of ELLs across the low- and high-scored students, as identified by the school district. Of this sample, most students qualified for the federal free or reduced-price lunch program (91%), and the ethnic makeup of the selected students, as reported by the school district, was 59% Hispanic; 36% Black, non-Hispanic; and 5% White, non-Hispanic. The home language backgrounds of students who completed the writing samples for this secondary analysis are unknown; however, the schools participating in the intervention study primarily served Spanish- and Creole-speaking students. The purposefully selected student samples reflect the larger study's student demographics, as described and in Lee et al. (2009). The distribution of male and female participating students was 52% and 48%, respectively.

Data Analysis

The previously described language features were used to create an SFL-informed coding framework (Brisk, 2015; Fang & Schleppegrell, 2008; Halliday, 1978) to identify language and organizational features expressed by the student groups. As explained earlier, functional language analysis is a social semiotic theory grounded in SFL that views language as a resource for making meaning in context. The SFL framework allowed us to analyze texts for prominent language and organizational features of science explanation writing within the student groups (intermediate, advanced, and fluent English proficiency). We began the process of developing the coding scheme by reviewing the literature on science writing. We grounded the work on Halliday's (1978) original text on SFL, Halliday and Martin's (1993) work on science text, and Lemke (1990) and Unsworth's (1997, 2005) work, and then

Table 3. Number of Third-Grade Students per Low- and High-Scored Science Writing Sample by Language Proficiency (ESOL) Level

	Scores (Content/Form)		
ESOL Level and Range of English Proficiency	Low	High	Subtotal
Level 4:			
Intermediate/advanced intermediate	2 (2/1)	1 (4/3)	3
Level 5:			
Exited ESOL within the past 2 years	15 (1/2 to 2/1)	13 (3/4 to 4/4)	28
Exited ESOL more than 2 years or never in ESOL	11 (1/1 to 2/1)	14 (3/4 to 4/4)	25
n	28	28	

Note.—ESOL = English for Speakers of Other Languages.

used more recent research on the language and organizational features found in typical science texts (reflected in Table 2), as noted in the literature (e.g., Fang & Schleppegrell, 2008; Mohan & Slater, 2004; Schleppegrell, 2002). Finally, we used the research on explanation writing and the features found in student work of science writing (Brisk, 2015; Christie, 2002; Fang, 2014; Fang & Wang, 2011) to identify the salient features typically found in science explanation writing as we coded the third graders' writing samples.

Two researchers from the second research team coded the set of 28 high-scored writing samples together, and a third member coded 20% of those samples separately at the onset of coding to check for agreement and calibration of the SFL framework. The set of 28 low-scored writing samples were then coded independently by two researchers, with calibration of coding taking place after 5 to 10 samples. The third researcher again coded 20% of the samples, with the three researchers meeting to review the five common writing samples together for calibration. We used Atlas.ti 6.2 (Muhr, 2011) qualitative data analysis software to code and analyze relevant scientific explanation language features. Figures 2 and 3 provide examples of our coding within high- and low-scored writing samples, respectively.

Grounded theory methods (Charmaz, 2006; Corbin & Strauss, 1990) were used to identify an initial set of emerging themes and salient patterns in the data, result-

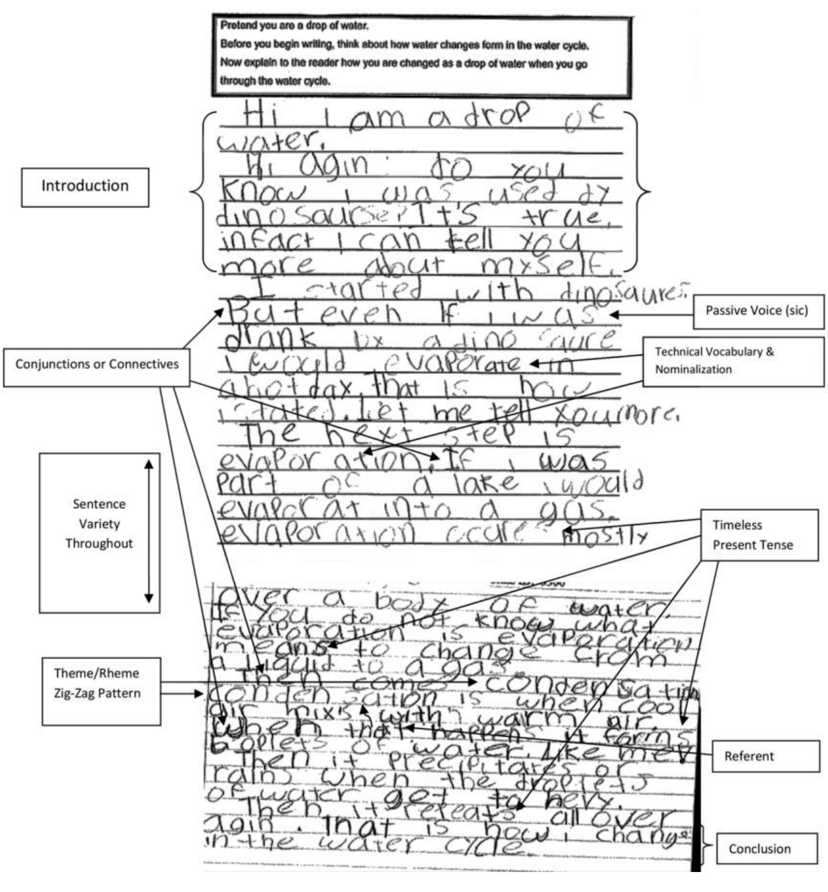

Figure 2. Example of high-scored sample language features.

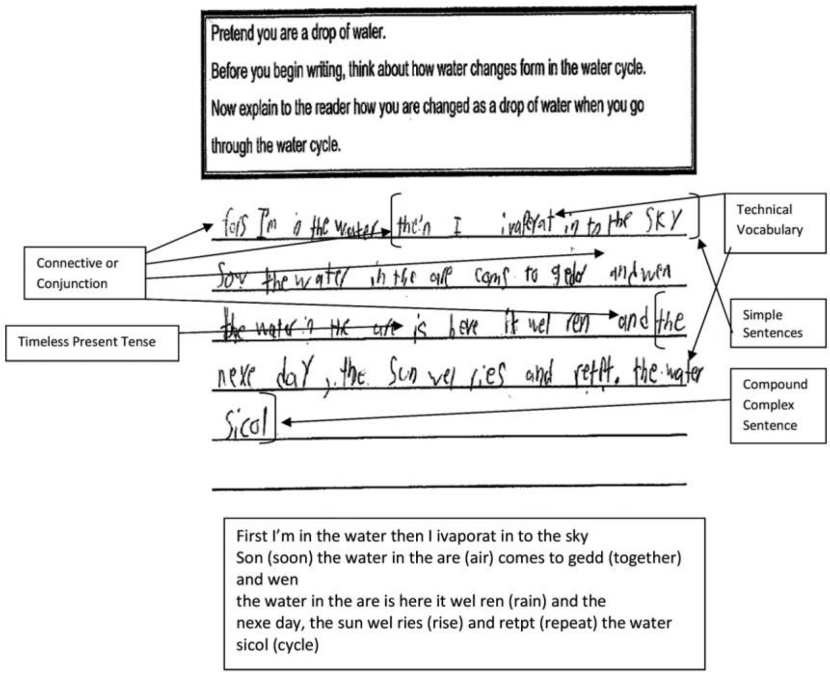

Figure 3. Example of low-scored sample language features.

ing in a focus of the features based on an SFL framework (see Table 2). For example, codes for introduction—what Brisk (2015) calls "statement of the phenomenon"—and conclusion—"generalization," as referred to by Brisk (2015)—emerged from our analysis as two organizational features that appeared to be important in the structure of the overall writing piece, differentiating the high- and low-scored writing samples that contained or did not contain strong introductions and/or conclusions.

In addition, we compared the frequency of each language and organizational feature across the high- and low-scored samples using a chi-square test to determine whether particular language and organizational features were represented significantly across the high- and low-scored writing samples. In other words, we sought to determine whether the quantities of language and organizational features coded for high- and low-scored samples showed a significant relationship with the rubric-measured scores of the primary research team. Therefore, our grouping variables for the chi-square test were the distribution of language features among the high- and low-scored samples. Moreover, our data met the requirements of the chi-square test in that we purposefully sampled an equal number of high- and low-scored students' responses to the same writing prompt.

Results

Both groups of students showed evidence of understanding the water cycle, yet the high-scored students' samples were more successful in using characteristic language features of science explanations relative to low-scored students' samples. Although the low-scored samples showed scientific knowledge of the water cycle by attending to the steps of the water cycle with some description of the processes, these samples demonstrated an emergent development of the written scientific discourse. For example, we found that the majority of high-scored samples included characteristic features of explanatory texts of the water cycle, beginning with an introduction that used the zero conditional or simple present tense to take on the role of a drop of water but quickly switched to a conventional explanatory sequence, continuing with present tense, that explained the processes involved in the water cycle. A typical introduction for the high-scored samples was, "I am a drop of water. I going to show you what happen [*sic*] to water when they go through the water cycle." The few high-scored samples that did not begin in this way used a question as a "hook" to interest the reader, such as, "Do you know the four steps water has to go through to do the water cycle?" Teaching students to use a hook in the introductory paragraph is a common narrative writing instructional practice. These semihybrid explanations included subexplanations of the processes of evaporation, condensation, and precipitation and then included more of the lexicogrammatical features found in traditional explanatory science texts. By contrast, the low-scored samples typically used the Type 2 conditional or simple past followed by the present conditional tense in the introduction (i.e., "If i was a drop of water i will fall down into a puddle and then i will evatponant [*sic*]"). Also, the low-scored samples remained in the imaginative narrative as a drop of water throughout the entire written piece, with only two using conventional explanatory sequences. Moreover, although the low-scored samples showed signs of understanding the processes (see Fig. 3), there were fewer details about the processes and fewer instances of lexicogrammatical features commonly found in science texts. The characteristic language features of high- and low-scored samples are highlighted in Figures 2 and 3.

We tested the relationship between the language features and the high- versus low-scored samples using a chi-square test of independence to determine the significance of the association between the language and organizational features and the samples' overall score classification of high- or low-scored samples. The results (see Table 4) showed significant relationships between high- and low-scored samples for the following categories: use of Theme/New Information, referents, timeless present tense, passive voice, conjunctions of cause/reason, conclusions, and sentence variety. In contrast, no significant relationships were found for certain language features, including the use of technical vocabulary, nominalization, conjunctions associated with logical reasoning (e.g., those showing temporal links), and introductions.

Technical Vocabulary

The use of technical vocabulary was evident in both high- and low-scored writing samples; however, due to the low variability of technical vocabulary found across both groups, the chi-square test did not show a significant relationship, $\chi^2(1) = 2.074$, $p < .150$, where it is expected that there would be more variability among the cells.

Qualitative analyses suggested varying patterns represented by the high- and low-scored samples with regard to the degree to which technical words were fol-

Table 4. Language Features Represented in High- and Low-Scored Student Writing Samples

	Percentage of Samples that Contain the Language Feature ($N = 56$)				
Language Feature	High	($n = 28$)	Low	($n = 28$)	p values, χ^2
Technical vocabulary	100	(28)	93	(26)	.150
Theme/New Information	39	(11)	7	(2)	.004
Nominalization	21	(6)	0	(0)	.010
Timeless present tense	68	(19)	46	(13)	.105
Passive voice	46	(13)	14	(4)	.009
Use and ambiguity of referents:					
Referring word within 1–5 words	57	(16)	32	(9)	.060
Referring word within 6–10 words	25	(7)	21	(6)	.752
Referring word within ≥11 words	39	(11)	11	(3)	.014
Referring word is ambiguous	32	(9)	39	(11)	.577
Conjunctions associated with logical reasoning:					
Cause/result	36	(10)	18	(5)	.131
Temporal connectors/conjunctions	100	(28)	89	(25)	.075
Introductions	46	(13)	32	(9)	.274
Conclusions	79	(22)	36	(10)	.001
Sentence variety (simple, compound, complex, compound-complex):					
Includes two types or less	46	(13)	75	(21)	.029
Includes three types or more	54	(15)	25	(7)	.029

lowed by elaborate explanations. High-scored samples tended to follow the introduction of technical vocabulary with more detailed explanations and examples of the three water cycle processes, whereas low-scored samples provided minimal descriptions. A representative high-scored sample follows with an italicized elaboration of *evaporate*: "If I were a drop of water the first thing I would do is evaporate. *When I evaporate the first thing that will happen is the sun will heat me, that's when I rise in the sky as water vapor*." By comparison, a typical low-scored sample used a technical vocabulary term (albeit with a morphological error) without explaining what the word means, making it unclear how well the student understood the concept: "First I'm the water then I evaporate into the sky. So the water in the air comes together and when the water in the air is heavy it will rain. The next day, the sun will rise and restart the water cycle." Although technical vocabulary was used in both high- and low-scored samples, the number of instances varied. High-scored samples averaged 8.5 technical vocabulary words per piece in contrast to 2.7 in the low-scored samples. This higher number could also be a result of the variability of the average total number of words. The high-scored samples ranged from 56 to 301 words per sample, whereas the low-scored samples ranged between 15 and 129 words per sample. To further assess the use or frequency of technical vocabulary in the high- and low-scored samples, we calculated the average number of technical vocabulary words in relation to the average number of overall words used per sample within each group to determine if the higher number of technical vocabulary words in the high-scored samples was based on the length of the writing sample. This metric for high-scored samples was 8.5 technical vocabulary words to 132 total words per sample compared with 2.7 technical vocabulary words to 62 total words per sample. These results demonstrated that the proportion of technical vocabulary words to overall words was approximately 1:15, on average, for the high-scored samples compared with 1:23 for the low-scored samples. Thus, even though the low-scored samples had fewer words per sample overall, the use of technical vocabulary in this group's writing samples was less, on average, than the high-scored samples.

Theme/New Information or Zig-Zag Pattern Combined with Technical Vocabulary

A chi-square test for independence showed a significant association between Theme/New Information and the scored classification, $\chi^2(1) = 8.114, p < .004$. Specifically, writing samples that scored high on the rubric (11 of 28) were able to make more effective use of this pattern than the low-scored samples (2 of 28). Therefore, it is clear that the use of Theme/New Information was associated with high-scored samples and was reflective of higher scores instead of left to chance. Again, the difference in the use of this feature in the low-scored samples was the lack of sufficient elaboration of the concept. The following high-scored sample included this feature (italics indicate a zig-zag pattern): "The first step in the water cycle is *evaporation. Evaporation* occurs when the suns energy hits the water and makes it change its state of matter (liquid-Gas)." In contrast, a representative low-scored sample demonstrated an emergent use of this feature, that is, a limited elaboration, with the writer leaving out what must occur to make the drop of water into vapor: "If I were a drop of water, I would be a tiny vapor, as vapor I would condense [into] invisible drops."

Nominalizations

Nominalizations result from changing a verb, for example, to a noun form. The water cycle is usually presented as a process involving evaporation, condensation, and precipitation. These processes are generally taught using these nominalized forms as key vocabulary to understanding the water cycle. In analyzing the writing samples, we only coded for this language feature if the use of both the verb and noun forms were present within the same writing sample. In other words, writers needed to include both *condense* and *condensation* because the technical vocabulary for the water cycle is generally learned in nominalized form (i.e., *evaporation*, *precipitation*). Otherwise, it was not clear whether the student knew that the noun form was derived from the verb form, thus making a conscious choice about the use of the nominalized form. Fang and Schleppegrell (2008, p. 34) and Brisk (2015) point out how the use of nominalization in connection with Theme/New Information helps create thematic progression: "Thematic progression creates a text that flows from one clause to the next, allowing the author to successively build the explanation and provide an accurate and coherent account" of the phenomenon. The use of the verb and noun forms indicates audience awareness and some choice in the specific language to represent the processes.

Results from the chi-square test did not show enough variability in this language feature category to result in significance, $\chi^2(1) = 6.720$, $p < .010$; however, high-scored samples used this feature, and none of the low-scored samples demonstrated the use of both verb and noun form of the same vocabulary word.

Qualitative analyses revealed that 6 of the 28 high-scored samples used nominalizations to pack information, as reflected in the following representative sample wherein the process of evaporating is "packed" within the nominalized form of "evaporation" (emphasis added): "If I was part of a lake I would evaporate into a gas. *Evaporation* occurs mostly over a body of water." Nominalizations that used both the verb and noun forms were not found in the low-scored samples, although low-scored samples did demonstrate morphological awareness, as 14 of the 28 low-scored samples used the verb forms of the technical words accurately (*evaporate*, *condense*, and *precipitate*) without the nominalized forms.

Use and Ambiguity of Referents

The most notable variation in the use of referents was whether the referent was clear and easily traceable (between one and five words from the referring word) or ambiguous and untraceable (distance of more than six words from referring word). High-scored samples were almost twice as likely (16 of 28) to include referents that were easily traceable as low-scored samples (9 of 28). Although this difference was notable, the variability was too low to interpret the chi-square with confidence, $\chi^2(1) = 3.541$, $p < .06$.

Following is an example of an easily traceable referent from a high-scored sample (*they* is the referent referring to *clouds*, emphasis added): "When *clouds* form and gain water *they* get heavy so the water that was once inside the clouds fall." In addition, there were more instances of ambiguous referents in the low-scored samples. Low-scored samples had 11 of 28 samples with ambiguous referents coded compared with the high-scored samples with 9 of 28. The following is an example of an ambiguous referent from a low-scored sample that includes "it" (italicized), which refers back to the water cycle; however, "water cycle" was never written in the sample, making this an ambiguous referent, or one that the reader must infer: "Then I wall [will] do *it* again, like avaprisn [evaporation]."

Timeless Present Tense

The chi-square test of independence did not show a significant relationship between the use of timeless present tense; however, there was more use of this feature in the high- than low-scored samples, $\chi^2(1) = 2.625$, $p < .105$. Nineteen of the 28 high-scored samples used timeless present tense. In contrast, 13 of the 28 low-scored samples used timeless present tense to explain the processes involved in the water cycle.

Interestingly, most of the writing samples began with a narrative, conditional tense ("If I were a drop of water"), following the directions from the prompt (i.e., focusing on action that might take place). However, most high-scored samples wove in and out of the conditional tense, moving to the timeless present when describing the water cycle, whereas fewer low-scored samples moved in and out of the tense structures, remaining in the narrative, conditional tense throughout the writing.

Passive Voice

Another language feature that stood out in comparing the high- and low-scored samples was the use of the passive voice. The chi-square test of independence showed a significant relationship among the use of this feature and high-scored samples versus low-scored samples, $\chi^2(1) = 6.842, p < .009$. Almost half of the high-scored samples (13 of 28) used the passive voice compared with 4 of 28 low-scored samples, as shown in the following representative example: "It's only because all the water is being recycled by the water cycle." In contrast, the simple past is used to describe a process in a representative low-scored sample: "Then after a while, we [water drops] fell down all together that's called precipitation." These two writers show familiarity with the water cycle and the ability to express this knowledge emphasizing the processes over the actors of the sentences (water in both cases).

Logical Conjunctions of Cause-Result and Temporal Conjunctions

The chi-square test of independence also showed a significant relationship between high-scored samples and the use of conjunctions of cause-result, $\chi^2(1) = 2.276, p < .131$. High-scored samples used more of the conjunctions of cause-result associated with logical reasoning to connect ideas (e.g., *because*) compared with low-scored samples (10 vs. 5 samples).

The use of temporal conjunctions, however, was not found to be significantly different between the high- and low-scored samples, as the variability was too low among the groups. All high-scored samples and most low-scored samples (28 vs. 25) used temporal conjunctions (e.g., first, second, last) to indicate the sequence in which the processes occurred.

Qualitative analyses showed variation in the amount and manner with which high- and low-scored samples made use of conjunctions, both those associated with logical reasoning and temporal sequencing. The high-scored samples tended to use conjunctions of cause-result accurately to join an independent clause and a dependent clause that provided additional information about the causal link between the clauses. By contrast, low-scored samples relied heavily on the coordinating conjunction *and*, and used it as a form of punctuation, which served to detract from the cohesion of the text. For example, one student with a low-scored sample wrote (italics added to emphasize conjunctions), "When people drink water *and* they swallow you *and* get stuck there for ever *and* for ex. I went to the beach *and* it started to rain, *and* the gas goes up to the clowd *and* It get's more darker *and* . . . ." Although the overuse of the conjunction *and* detracted from the overall flow of writing, we examined these samples for idea units in our analyses, keeping to the functional emphasis of analysis over the traditional grammatical emphasis on which the form scoring rubric was based.

The qualitative difference between the high- and low-scored samples was in the amount and variety of conjunctions used. The following high-scored sample included coordinating conjunctions of cause-result and temporal conjunctions to logically link ideas and provide evidence for claims made (italics added): "The *first* step in the water cycle is evaporation. Here let me give you an example. There's a puddle of water on the sidewalk. *And* the sun is hot today. In a few minutes poof the water evaporated or dried up *and* turned into water vapor." Low-scored samples also used coordinating conjunctions, as this example illustrates (italics added): "I will fall avery where [everywhere] *and* when the sun comes I will dry up *and* when it rains." While connectors are a common method for organizing content logically, another method of constructing logical sequence in explanatory texts is through the use of action verbs that serve to explain phenomenon. These were found in both high- and low-scored samples. For example, see the high-scored sample in Figure 2, "Condensation is when cool air *mixes* with water," and the low-scored sample in Figure 3, "Soon the water in the air *comes together* and when the water in the air is here it *will rain*" (italics added). The main difference between both groups was that the high-scored samples demonstrated construction of these sequences in the timeless present tense, found in more conventional explanatory texts, whereas the low-scored samples used a variety of tenses (mostly future but also modal progressive and past) to address the hypothetical nature of the prompt.

Sentence Variety

There were no significant differences between high- and low-scored samples for those who used two sentence types and those who used all four sentence types. When the type of sentence variety was collapsed into two or fewer varieties compared with three or more, the chi-square test of independence showed that there was a significant difference between the high- and low-scored samples and sentence variety, $\chi^2(1) = 4.791$, $p < .029$. That is, high-scored samples had three sentence types twice as many times (43%) as low-scored samples (21.5%). In addition, 21.5% of low-scored samples had only simple sentences, whereas there were no high-scored samples with only one type of sentence. To summarize, high-scored samples had a variety of sentences, which contributed to the overall cohesion of the text. Low-scored samples tended to have two or fewer varieties of sentences, rendering the samples redundant and simplistic. Some of the difference in sentence variety can also be attributed to the length of the explanations. Low-scored samples tended to be shorter (average of 55 words) than high-scored samples (average of 132 words).

Introductions, or Statements of Phenomenon, and Conclusions

Introductions, also known as "statements of phenomenon" (Brisk, 2015, p. 229), and conclusions emerged during data analysis as important categories of organizational features that could discriminate low-scored from high-scored writing samples. Although the number of high- and low-scored samples that contained an introduction were similar (13 of 28 vs. 9 of 28 samples), there were differences in the ways that students framed the introduction, distinguishing high- from low-scored writing. The most prevalent type of introduction demonstrated a direct response to the prompt, "If I were a drop of water." Yet high-scored samples also used questions to make a connection with the reader, for example: "Did you ever dream of being a drop of water? Where would you go? What would you do? If you read my story all questions will be answered." The low-scored samples that included introductions began addressing the imaginative prompt, "I am a drop of water in the water cycle" and "I think it will be scary to do that" (describing changes as a drop of water through the water cycle). However, the chi-square test of independence for the use of conclusions showed a significant relationship, $\chi^2(1) = 10.500$, $p < .001$. Specifically, 79% of high-scored samples included a conclusion compared with 36% of low-scored samples. Like the introductions, there was more variety of conclusion types used in high-scored samples than in low-scored samples. The most prevalent conclusion type across all samples was a simple summary stating that what was written was an explanation of the water cycle; however, high-scored samples also included conclusions that attempted to connect with the reader (e.g., "Well, now you know how a drop of water changes throughout the water cycle"). Moreover, conclusions that were not related to the water cycle were prevalent in low-scored samples (11%; e.g., "and being a [drop] of water is so so cool, thank you for my story") but not in high-scored samples (4%).

Discussion

Some of the language and organizational features that were derived from the SFL-developed framework were equally common across high- and low-scored written explanations. These included the use of technical vocabulary, referents placed within six words of each other, temporal conjunctions, and writing that included varying sentence constructions. The most striking finding across the two groups is that both (all 28 high-scored and 26 of 28 low-scored) used some forms of scientific vocabulary in their writing samples, regardless of the relative accuracy and sophistication of that vocabulary. While we did not study the relationship between student scores and instruction, the two groups' comparable inclusion of scientific vocabulary suggests that paired-associate vocabulary instruction—a dominant feature of conventional instruction in lower grades in science—is not enough to ensure that students' writing shows evidence of actually understanding the science they are being taught. That is, a focus on vocabulary use alone is not sufficient to show evidence of a relatively better quality of science writing; rather, our results show how different uses of the technical vocabulary, in conjunction with other organizational and language features, set the samples apart (McQuitty et al., 2010). As Halliday and Martin (1993, p. 71) explain, "The difficulty lies more with the grammar than with the vocabulary."

Students who used technical vocabulary in combination with other linguistic or grammatical and organizational features scored higher, substantiating previous work in this area, as these structures have been associated with high-quality science writing among older students (Fang & Schleppegrell, 2008; Halliday & Martin, 1993). To demonstrate this point (although rubric criteria for initial scoring included the extent of technical vocabulary used), one high-scored sample used only one technical vocabulary word to explain the processes involved in the water cycle. This student, however, used a variety of other resources that demonstrated an understanding of the concepts, such as elaboration of ideas that described the processes of evaporation, condensation, and precipitation (emphasis added):

> *First* I'm a little drop in a kind of body of water. I'll go ***condesated*** [condensed] **by the sun or heat**. *Then* I'll turn in to a gas. *And* I'll go up **into a cloud**. *Then* I'll

> turn into a drop of water again. *After* I'm turn into a drop of water I'll stay **in the cloud for a cupple [couple] of days**. *Then* when the clouds get **to [too] heavy** they let us drop **back to the Earth**. *And then* I'll go into a body of water. *And then* they will use me all over again.

Elaboration was achieved through the use of adverbial phrases (boldfaced) that provided information about where, when, and how the processes occurred. Finally, the student used a number of connectives (italicized) that organized the writing temporally, making it easier for the reader to understand the sequence of the processes. Thus, the fact that the student used only one technical vocabulary word (boldfaced and italicized) did not affect the overall effectiveness of the piece, whereas the low-scored samples typically included technical vocabulary but not necessarily the other grammatical resources listed earlier, ultimately limiting the students' ability to fully express their knowledge of the water cycle. The use of linguistic resources such as the Theme/New Information pattern and expanded noun groups (adverbial phrases) in high-scored writing samples supported students' elaboration on important water cycle concepts, making their understanding of the water cycle clearer to the reader.

We also found differential frequencies for other language and organizational features, though at times even high-scored writing samples showed little evidence of these features (e.g., nominalizations). On the one hand, the differential frequency of language features cannot be ascribed to a student's exposure to different curricula. On the other hand, because we did not gather direct evidence of instruction in writing generally or of incidental instruction in the writing of science (as when children were helped to edit their lab notebooks), we cannot rule out the possibility that these differences are due to students transferring writing conventions from more explicit writing instruction to these tasks or to incidental learning as these children worked through their science labs and wrote in their notebooks. Future work should help disentangle these two factors and identify the malleable characteristics of science writing that are possibly responsive to instruction.

Because of the structure of the prompt, most of the writing samples began with the use of the conditional tense (i.e., "If I were a drop of water"), but students who produced high-scored samples were able to move seamlessly into using the timeless present tense when explaining the water cycle, whereas most low-scored students' samples remained in the future tense throughout. Clear referents and passive voice were also used significantly more among high-scoring writers than low-scoring writers. A broader variety of sentences with more complex sentence types were found in the high-scored samples, indicating the importance of expanding on ideas via the use of adverbial or other noun phrases. According to Zwiers (2008) and Gebhard et al. (2011), such academic language features must be explicitly taught via a functional grammar approach while focusing on a specific genre or text structure (i.e., science explanation).

Our chi-square analyses demonstrated significant relationships between the high- and low-scored writing samples for certain language and organizational features (see Table 4), indicating significant associations between these language features and the overall classifications of high- versus low-scored samples. These relationships (or seeming lack of) make sense, given that either all the students used the feature (e.g., technical vocabulary and conjunctions) or only one of the groups (high-scored samples) used the feature, as was the case for nominalization. We used the chi-square analyses to determine whether the slight differences in the number of high- and low-scored samples that used a particular language or organizational feature was coincidental or whether the proportions differed from the hypothesized or expected proportions. The extent to which both groups used technical vocabulary and temporal conjunctions should indicate that minimal significant relationships exist, whereas only one group (high scored) using nominalizations indicates that variability cannot be calculated, as the expected hypothetical proportion should include use of nominalizations by low-scored samples.

Finally, we identified two organizational features that, at least within this population of third graders, discriminated higher from lower scored written explanations: the use of introductions or statements of the phenomenon and conclusions. Higher scored samples tended to use both an introduction and a conclusion to preview and subsequently summarize the content of the sample, thereby showing an emerging sense of audience (i.e., tenor, according to SFL theory); however, it should be noted that high-scored samples were, on average, longer than the low-scored samples, logically indicating the use of more language and organizational features.

Science Writing Proficiency

Our results show great heterogeneity within each group of students. Language and organizational features were not uniformly present or absent within each group. For example, the first rubric used within the larger study focused on science content or the extent to which the student used technical vocabulary; described change processes of the water and states of matter, and the heating and cooling required for change processes to take place; and demonstrated understanding of the relevance of a cycle. The larger study's first rubric seems related to our language and organizational features (see Tables 2 and 4) of technical vocabulary, the use of Theme/New Information to explicate technical vocabulary, the use of nominalizations to pack and unpack meaning, the use of conjunctions associated with logical reasoning, the use of connective conjunctions to make temporal and causal claims, and the use of conclusions. These language features were not all equally evident, even in the high-scored writing samples.

Using an SFL framework to assess linguistic features within the writing samples allowed the students' scientific understandings to surface and to become more evident in lower scored responses, thus demonstrating the constraints of traditional writing rubrics when assessing content knowledge through the writing of diverse learners (Fang & Wang, 2011; Honig, 2010; Mohan & Slater, 2004). However, although our identification of language features appears to provide a teacher with the linguistic knowledge that a student may (or may not yet) have to complete a task, these features are "not able to show *how well* that student uses that knowledge to construct the text as a whole" (Mohan & Slater, 2004, p. 268). Thus, the use of SFL to examine students' science writing revealed particular linguistic features that must be combined to construct the written discourse of science. Our study helped identify the features of language and organization that contribute to science writing proficiency and that serve to inform the creation of frameworks that assess students' expressive scientific language (Honig, 2010) and integrated writing and science instruction (McQuitty et al., 2010; Prain & Hand, 1996).

Future Research

These findings suggest that SFL is a useful tool for microanalytic analysis of students' written scientific explanations. The implications point to future research studies that use SFL as both a tool for assessment and analysis as well as for instructional interventions. For example, research might help us better understand whether young students can be explicitly shown how nominalization works in meaningful contexts, what it does, and how writers use nominalized forms to efficiently express a message when writing in a technical genre, or whether such efforts might result in the development of misconceptions about how to write in science. Thus, future research that uses SFL as a framework for designing instructional interventions to explore scientific writing would contribute to the field of content-area literacy for diverse students.

Cross-sectional research provides insights into how development might proceed. Ideally, we should study well-defined student populations over time, link their development to their instruction in science and in writing to get a better sense of how development takes place, and design interventions that support that development. We purposefully sampled across levels of English proficiency to help minimize the potential confound between language proficiency and students' ability to write in English. ELLs do not show the same levels of general writing proficiency in their second language as do their more English-proficient peers (Schleppegrell, 2002; Schleppegrell & Go, 2007). Indeed, in many states, as mandated by legislation, results of assessments used to label and classify students as English proficient (or according to a level of proficiency as they acquire English) include a writing component. Future research might profitably seek to explore whether the use of language features discriminates student performance based on levels of English and native language proficiency.

Our study population was predominantly composed of students who qualify for free or reduced-price lunch, thus we did not study social class differences. We hope future researchers seek to better understand the language resources—as features of writing—that some students learn implicitly and bring with them to school, so as not to fall into the trap of creating interventions that are inadvertently framed in deficit paradigms and low expectations for diverse students.

Instructional Interventions

As Honig (2010, p. 30) so aptly notes, "Fluency in scientific discourse is necessary for success in school science." Specifically in science writing, our findings suggest that students should be given opportunities to write for diverse purposes, in different genres, for various audiences, to meet diverse task demands, and with a focus on write-to-learn strategies (Prain & Hand, 1996). An instructional focus on the function of scientific explanations, the structural organization (genre), and language features that characterize this genre may help provide students with access to the "cultural and linguistic practices underpinning that [scientific] content knowledge" (Hammond & Macken-Horarik, 1999, p. 542).

With regard to instructional implications founded in previous genre work, the Theme/New Information pattern can be modeled using mentor texts (Eggins, 2004; Fang & Schleppegrell, 2008; Fang & Wang, 2011). Mentor texts might be used to deconstruct how introductions and conclusions are written, giving students examples for how to do this in science, which is inevitably different than other fictional genres with which they might be more familiar (Brisk, 2015; Donovan & Smolkin, 2002; Kamberelis & Bovino, 1999). Seah et al. (2011, p. 870) state that teachers need to explicitly define and "unpack" tasks when introducing students to new genres to understand the genre expectations and to effectively complete the tasks. They suggest explicit teaching of lexicogrammatical resources, such as connectives, and the difference between exophoric and endophoric references; the former depends on gestures and contextual cues for meaning, such as those used while speaking, and the latter on the more formal references that build coherence at the discourse level for written texts. Explicitly teaching vocabulary is another recommendation based on our results as well as those from the literature (Carlo et al., 2004). Moreover, Seah et al. (2011) specifically state that students need to learn the precise language of science, which may or may not be transferred across different contexts with the same meaning. For example, Seah and colleagues found that students used the word *expand* in a way that is more appropriate to describe individual particles' expansion when writing about a group of particles. In addition, allowing students to represent their understandings both visually or graphically as well as in writing would allow for teacher assessment of intended meaning and better capture the extent of students' knowledge for the topic (Seah et al., 2011). The notion of lexicogrammatical resources based on functions of language use (Halliday & Matthiessen, 2004) points out that not all students have the ability to make a choice regarding language use when they have not acquired the language of school or do not implicitly understand the functions of language within science disciplinary contexts (Seah et al., 2011).

Conclusion

This study addresses the growing need to understand the links between writing research within science inquiry frameworks in diverse twenty-first-century science classrooms. Our intent with this work was to describe differences in lexicogrammatical resources among and between students and to demonstrate how the discourse of science realizes and conveys students' science knowledge. We offer evidence that suggests that part of displaying knowledge of science is understanding and being able to use the discourse of science; that is, using the linguistic features found in typical science explanations helps to convey that knowledge. Our work lays a foundation for future work that can investigate, in much greater detail than is possible in this exploratory study, the disciplinary linguistic knowledge that teachers of diverse populations of students need to assist them in developing (cyclical) explanation writing proficiency in science. Despite the limitations associated with secondary analyses, our results begin to address the urgent need to better understand the linguistic and organizational features of successful and emergent elementary science writers. Thus, these findings inform the literature regarding integrated literacy and content-area instruction in an effort to give all students access to the written language features found in the discipline of science. If science teachers are not explicitly teaching the language of science, many students will not have access to the requisite discipline-specific features because their repertoire of linguistic resources does not include the academic language of the discipline. Though these results add to the knowledge base concerning pedagogical content knowledge, more work is needed to further inform the teaching and learning of scientific discourse to expand all students' knowledge, access, and participation in literacy and science.

Notes

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1. For this article, as for the initial study, we define diverse students as students who are culturally different and who may come to school speaking a primary language other than standard English (see Lee et al. 2009).

2. Language features are the structures of language that provide a function or purpose in texts (i.e., nouns, verbs, clauses) and contribute to creating meaning for the reader.

3. The primary function of the explanation genre is to explain, describe, or classify specific processes (Halliday & Martin, 1993).

4. The state's high-stakes assessment system included writing in fourth grade; the curriculum's fourth-grade materials placed a greater emphasis on writing.

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