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Teaching The Language Of A Lab Report: A Guide For Science Teachers

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TEACHING LANGUAGE IN THE REGISTER OF SCIENCE:

A GUIDE FOR SCIENCE TEACHERS

by

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To the memory of Dr. Loren Anderson who first ignited my scientific curiosities.
To Zachariah, Jeffer, Jeison, Pedro, and José who inspire me to keep learning,
even when it is hard.
And to Chris whose devoted love compels me to communicate well.

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CHAPTER ONE

INTRODUCTION

The Challenge of Language in Science

Science is an exciting field for study full of wonder and amazement at the natural world. At the center of science education is inquiry and experimentation (Kiuhara, Graham, & Hawken, 2009). Students are encouraged to examine, hypothesize and test their ideas in the laboratory and in the world. As they engage scientific exploration students are expected to discuss and report upon their process and findings. Since language functions differently for different purposes specialized features of language are needed to communicate in register of science (Halliday & Matthiessen, 2004; Schleppegrell, 2001). Even within a science lab report, which is one of the many forms of writing in science, different language structures are needed in different sections in order to meet the demands of the communicative task. My project will explore this question: What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports?

In this chapter I will introduce my interest in the development of language skills in science education. My work as a language support teacher in secondary science classes has given me opportunity to witness some challenges firsthand. I will describe the context and situations from which this work and the questions for this project began to emerge. Then I will introduce some of the issues related to language instruction in the science classroom, specifically, the needs of science teachers for education and training. Finally, as a guide to the content of my project, I will introduce the expectations placed on students in writing a science lab report.

Background of the Researcher

As the Language Support Coordinator at international school in South Korea where English is the language of instruction, I have regular opportunities to work with teachers and students as they struggle to learn and teach how to write scientifically. I have been supporting English learners in secondary science classes for seven years. As bright, eager learners they give all that they can to learn about the world in which they live and expand their scientific knowledge while simultaneously developing their English language proficiency.

Our school uses the International Baccalaureate Organization Middle Years Program (IB MYP) as a framework for teaching and learning. Inquiry is foundational to learning in IB MYP classrooms, giving students ample opportunities to experiment with their own scientific wonderings around particular topics in global contexts. Students are expected to design their own experiments with increasing independence and competence. In order to reach the highest levels of academic achievement, students are expected to develop a question for their inquiry, formulate hypotheses, explain scientific ideas, use correct scientific reasoning, interpret data and evaluate the validity of their hypothesis and method (MYP sciences guide, 2014, p. 42). These academic demands of a science lab report require careful use of language to communicate. While their teachers can distinguish which writing sounds scientific, they have not been able to describe the language they are looking for beyond identifying a list of vocabulary words. These teachers are not prepared to analyze and teach the language functions required in a science lab report. A frustration for teachers is their students' lack of writing proficiency in the register of science. By *register of science* I mean the overall pattern of grammar and vocabulary found in scientific text and expected in student writing for science (Schleppegrell, 2001, p.431). Although they are frustrated, my colleagues feel they do not have time to add language lessons to their already full science curriculum and they do not feel confident to teach the language structures even if they felt they had the time. By *language structures* I mean the specific features of academic language used for specific purposes within the register of science, like explanation, hypothesis, procedure, and analysis.

In a meeting with my secondary science teacher colleagues attempting to provide scaffolds for early intermediate proficiency English learners to write a scientific hypothesis, I recommended the use of a simple sentence frame "I think _____ will (happen)." One teacher was adamant that we could not use first person pronouns in writing science. He then wrote an example hypothesis on the whiteboard for us to analyze together. "As the slope of the ramp increases, the distance the car travels will also increase." It became clear that this sentence was loaded with relationships, qualifiers, and technical vocabulary. While it was simple for the science teacher to create the sentence, he could not think of any ways to help students work from "I think…" statements to scientifically stated hypotheses. This lengthy discussion was focused on only one short piece of a science lab report: the hypothesis. We did not broach any of the other writing sections within the science lab report, which include questioning, explaining, instructing, and analyzing. While the science teachers and I brainstormed formulas for writing hypotheses, which can be simply one or two sentences in length and quite formulaic, I began thinking about the structures needed to write a conclusion or analysis which are more complex. When we looked at lab report samples from both our English proficient and English learning students, we recognized that they all need direct instruction to teach them how to write in the register of science.

My initial conversation with two science teachers was followed up by four sessions of professional development meetings with our full science department to discuss some ways they could address language development in science. It was clear that student writing was not reaching the desired goals, and that the teachers were either perpetually frustrated by it or finally resigned that this was the way it was going to be. So that I could get a sense of the science teachers' understanding of English grammar, we looked at a couple of sentences together to see if they could identify the subjects and predicates and recognize nominalization. Working together they could do that. I proposed several graphic organizers and other teaching and learning strategies related to language in science that could help their students communicate scientific ideas with limited language. These helpful tools, however, did not help science teachers understand language any better than they already did, they did not actually help students learn how to write in specific scientific language structures. Furthermore, our discussions did not convince the science teachers of the need to devote precious instructional time to teaching language in science classes.

According to Kiuhara, et al. (2009), my colleagues and I were not alone in our lack of understanding of the functional language of scientific writing; science teachers across the United States report that they do not explicitly teach scientific writing to their students nor do they feel adequately prepared to do so.

Science Teachers as Language Teachers

While it is clear that language in science is complex and unique, research indicates that secondary science teachers are not teaching students how to write in the register of science and feel themselves underprepared for this task (Kiuhara, et al., 2009). The research is consistent with the experience of my science teacher colleagues as well. Science teachers in the United States give little attention to teaching writing (Sampson, Enderle, Grooms, & Witte, 2013). Science teachers across the United States report being less prepared to teach writing than their social studies and language arts counterparts. While 84% agree that writing is an essential skill for after high school, 47% reported that their students did not have adequate writing skills in their subject area, though more than half use essay writing as assessment of learning (Kiuhara, et al., 2009). Science teachers indicated the least amount of writing instruction compared to language arts and social studies teachers; in fact, over 50% of the science teachers reported never using each of the following writing instruction strategies: editing, revising, emulating good models, and combining sentences (Kiuhara, et al., 2009).

Fang (2004) elevates the role of language in science,

> Unlike the language of everyday spontaneous speech, which is functional for construing commonsense knowledge in the context of everyday ordinary life, scientific language is functional for construing special realms of scientific knowledge and beliefs. As such, it embodies a unique worldview and way of thinking and reasoning (p. 337).

If increased mastery of language in the register of science can contribute to deepening students' scientific knowledge and understanding, adding language instruction to science classes may be more appealing to science teachers. Blending authentic science inquiry with careful instruction on language in sciences may be a powerful combination to support student achievement in science.

Expectations for Written Lab Reports

My context necessitates following the objectives of the IB MYP Sciences Guide which determines the overarching aim and objectives for the study of science in the middle years (International Baccalaureate Organization [IBO], 2014). According to these expectations students doing scientific inquiry must formulate a problem or question to be tested. They must then develop a hypothesis and use scientific reading to explain it. An explanation of how the variables will be manipulated and how the data will be collected comes next. Students must then design an investigation with an appropriate method, materials and equipment. After they have completed the investigation, students must organize, present, and explain the data with scientific reasoning. Finally, the hypothesis and method must be evaluated and analyzed for successes, errors, and improvements. These expectations represent a variety of language structures within the same written product: a science lab report.

Guiding Questions

Given the challenges that teachers face in understanding language in science and finding time to teach it, and given the complexity of the language structures within the language structures of scientific writing, my project is guided by these questions: How is language in the register of science different from everyday language? What are the language structures inherent to the language structures within a science lab report? How can science teachers understand the language in a way that they could then teach it to their students? How can language instruction be embedded in the teaching and learning of science classrooms? Exploring the questions above lead to answering my primary question: What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports?

Summary

In Chapter One I have shown the development of my interest to create a project to support teaching language in science, specifically in the writing science lab reports to meet the requirements of the IB MYP objectives. I have introduced the lack of both practice and preparedness science teachers have for teaching language in science classrooms, and I have given an overview of the student expectations in writing a science lab report. Finally, I have proposed some questions to guide my project.

In Chapter Two I will provide a review of the literature relevant to the writing in the register of science. First, I will explore how language in the register of science is different from everyday language and demonstrate some of the particular features of the scientific register. Then I will look more closely at the different language structures of a science lab report to discover the language structures that are needed to communicate proficiently. Next I will look at the challenges science teachers are facing in teaching language and some possible avenues for providing support to them. Finally, I will explore the value and some methods of integrating language instruction with science education.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a review of the literature addressing the question, What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports?

First is a look at the differences between language in the register of science and language that is commonly used in everyday circumstances. This section reports on research that demonstrates a number of language structures which are used to communicate in the register of science but are missing or significantly different in other registers. The research indicates that these language structures not only contribute to clear communication of scientific information, but that in negotiating the language, students have the opportunity to wrestle with their understanding of the science itself, thus providing a rationale for teaching language within the science classroom (Gillespie, Graham, Kiuhara, & Hebert, 2013; Klein & Unsworth, 2014; Sampson, Enderle, Grooms, & Witte, 2013; Seah, Clarke and Hart, 2014; Stoddart, Pinal, Latzke, & Canaday, 2002).

The next section discusses the science lab report as a genre within the register of science. It explores the various sections of the lab report and the language structures used to accomplish the function of each section. The research here provides the framework of the content for the project by outlining the knowledge that science teachers need to know about language in order to teach it to their students.

The final section examines research that demonstrates the challenges teachers face teaching language in science classes. It shows the need science teachers have for professional development in order to teach language in the science classroom; this research provides guidance to the approach needed to contribute positively to the professional development of secondary teachers. These studies provide the researcher with an understanding of the audience and recommendations for communicating effectively with it (Gillespie, et al., 2013; Wolfe, 2011). Then it will look at research evidencing effective strategies for teaching and learning language within content area courses, and, where possible, specifically in science classrooms (Holstein, Mickley Steinmetz, & Miles, 2015; Klein & Unsworth, 2014; Kucan & Boliha, 2016; Sampson, et al, 2013; Subramaniam, 2010). The methodology discussed here will contribute to the suggested learning activities included in the project.

The Register of Science

The register of science refers to the language used to communicate effectively within the wider conversation of the scientific community. Like any register, the register of science uses a particular level of formality, choices of vocabulary, and syntax, the arrangements of words in order to convey meaning. The research I use compares academic language with everyday language and describe some of the specific features in the register of science. Evidence from the research follows to support the proposition that in science, the organization and use of language can contribute to understanding the science being studied.

Academic Language and Everyday Language

The language of school differs significantly from everyday language. Everyday language could look like this: Scientists study the sea ice and the animals that live on it. They have found that the ice is melting. Seals and walruses hunt for fish and mussels near the sea ice. They climb on the ice to rest while they are fishing. Since the ice is melting, there is a smaller platform for seals and walruses to use when they rest. Scientific language looks like this: “According to scientists, the retreat of sea ice has reduced the platform that seals and walruses traditionally use to rest between searches for fish and mussels” (Walpole, Merson-Davies, & Dann, 1999, p. 111).

Unlike conversational English, the language of schooling is generally constructed for a non-interactive audience, it is lexically dense, and is grammatically complex (Halliday & Matthiessen, 2004). In everyday conversation interlocutors frequently make generic lexical choices (e.g., a lot of things, those guys, people) and use pronominal subjects (i.e. he, she, it, they); however, academic language requires specific, technical vocabulary. Nominalization, the conversion of a verb or an adjective or a phrase to function as a noun, is greatly utilized in academic writing as are expanded noun phrases (Schleppegrell, 2001). Consider these examples:

1. The human body *resists* infection.
2. *Resistance to an infection* is called immunity.

In Example 1, *resists* is the verb and functions as the process, showing the action. In Example 2, *resistance to an infection* has become a noun phrase and functions as a participant in the clause. Grammatically, academic writing is more lexically dense, utilizing precise conjunctions to join ideas together, and clauses embedded within other clauses (Halliday & Matthiessen, 2004).

Since language structures are embedded with lexical and grammatical expectations that vary according to the diverse registers of academic purposes, students must learn the various genres of academic texts (Schleppegrell, 2001). Reading textbooks or other published material within the register of a particular subject provide models for students learning the genres. When examining aspects of language used in academic registers, many researchers have analyzed the writing in a published texts to understand how it might affect the readers (Fang, 2004; Kazemian, Behnam, & Ghafoori, 2013; Kucan & Boliha, 2016; O'Hallaron, Palincsar, & Schleppegrell, 2015; Wignell, 1994). The application of the information about the language register found in such research is helpful in teaching students to decode and comprehend written texts; however, academic standards also require students to encode or create discourse in appropriate registers (IBO, 2014). Learning to write in science "involves learning a technical language and a set of written text types or genres which encode scientific principles and procedures" (Christie & Derewianka, 2008, p. 149). While reading models of academic text can support students' development of academic writing skills (Fang, 2004), the linguistic structures necessary for producing these registers are not often made explicit to students (Schleppegrell, 2001).

Characteristics of the Register of Science

What are some of the characteristics of the register of science? The following literature will show that authoritativeness, informational density, technicality, and nominalization are key structures of writing in science.

Authoritativeness. Scientists are careful to use language like "hypothesis" and "theory" indicating that there is room in scientific ideas for change and development; nevertheless the general tone of scientific writing is authoritative (Fang, 2004). Authoritativeness refers to the typical tone of scientific writing that is both objective and assertive. Scientists tend to distance themselves from the text by avoiding the use of first person pronouns, references to personal thinking processes, direct quotations, vagueness and hedges. An authoritative tone is often accomplished through the use of the passive voice in which the responsibility and agency of the actor is obscured. The more complicated passive voice is achieved grammatically by marking with a form of *get* or *be* plus an *-en* ending on the verb (Halliday & Matthiessen, 2004). For example:

3. PH changes *can break* ionic bonds.
4. Ionic bonds *can be broken by* changes in pH.

In Example 3, pH changes are the actors doing the breaking; the active voice places the actor before the action. In Example 4, *ionic bonds* take the lead in the sentence though they are receiving the action. The passive voice can also aid scientific arguments by placing known information or more important information first in the sentence.

Informational density. A second feature of scientific text is informational density (Fang, 2004; Schleppegrell, 2001). Informationally dense clauses include a high number of technical words, extended noun phrases, embedded clauses, and long, complex subjects and objects (Fang, 2004). This dense text requires a great deal of unpacking and cognitive effort to decode, and some practiced skills to encode. In addition to making good use of the lexicon, including transforming the function of the words with prefixes and suffixes, students can become more economical in their writing making use of subordinate clauses (Fang, 2006). Subordinate clauses share a subject with the main clause and are usually introduced with a conjunction like *while, as if, once* and followed by a verb ending in *-ed* or *-ing* (Fang, 2006). For example, Example 5 can be reduced to Example 6:

5. The beaker can be returned to the shelf once it has cooled
6. Once cooled, the beaker can be returned to the shelf.

Technicality. First, technicality in science refers to using vocabulary that is specific to the field of science (Fang, 2006; Kazemian et al., 2013). Readers of science textbooks expect to find a list of new terms at the beginning of each section or bolded throughout the text, which is one indication of the vast volume of technical terms specific to the field. Often the technical terms have Greek or Latin roots which forms the base of the meaning denoted. Furthermore, scientific terms tend to be multi-morphemic, taking on different affixes in order to function flexibly in discourse (Fang, 2006). Student understanding of science can benefit from direct instruction of the roots and affixes that compose the technical vocabulary they are studying (Fang, 2006).

Second, technicality in science refers to the use of particular processes (or verbs) for particular purposes (Kazemian, et al., 2013). Of the six different types of processes that are identified in Systemic Functional Linguistics (SFL), the research of Kazemian, et al. provides evidence that the majority of the processes are mental (doing) and relational (being) processes in the register of science (2013, p. 213). Relational processes verbs are used to define, compare, contrast, classify, or characterize (e.g., *become, remain, appear, differ, function as, comprise, exclude*) (Halliday & Matthiessen, 2004).

While the meanings of technical terms are limited and can be illustrated or described in a glossary, there are countless ways to structure the discourse to communicate ideas that are dependent upon the particular purpose and situation. Material and relational processes are used in coordination with scientific vocabulary to achieve the purpose of a particular communicative task. The difficulty of scientific language moves beyond vocabulary to grammar (Halliday & Martin, 1993).

Nominalization. Kazemian, et al. (2013) argue for the necessity for nominalization for writing in the register of science. In science there is a development of a particular kind of argument that requires a chain of reasoning such that one notion builds on another in a chain of sequential, connected ideas. In order for the argument to continue, often information from the previous statement has to be included in the new idea. Nominalization enables this kind of restatement and provides a platform to launch the next argument (Kazemian, et al., 2013; Unsworth, 1999). Nominalization is essential to scientific writing because it allows for this kind of rationality and engages the technicality of the language (Kazemian, et al., 2013). For example:

7. There are three different ways in which a molecule *can be oxidized or reduced* (Walpole, et al., 2011).

8. In biological *oxidation* reactions, addition of oxygen atoms is an alternative to removal of hydrogen atoms (Walpole, et al., 2011).

In Example 7 *can be oxidized* functions as an action working on a molecule. In Example 8, the verb *oxidize* has been nominalized by the addition of the suffix *-ion* and is now part of the noun phrase *biological oxidation reactions*. Further, the phrases *addition of oxygen atoms* and *removal of hydrogen atoms* in Example 6 have been nominalized as well.

To create an authoritative and impersonal mood scientific texts often include rankshifted clauses which occur when a clause fulfills the role of a participant (Halliday & Matthiessen, 2004). In this way nominalization hides the agency of the action and creates ambiguities (Fang, 2004) . Consider this sentence: *Composting and recycling have prevented millions of tons of waste being dumped.* The nominalized compound subject *composting and recycling* do not tell anything about who is to credit for the prevention of dumped waste, and therefore obscure certain aspects of the information.

Authoritativeness, informational density, technicality, and nominalization are all functional characteristics of scientific writing can be complicated and challenging for all students to both comprehend and write, and even more so for English learners (Fang, 2006).

Language as a Vehicle for Learning Science

There may be some who argue for the use of more for the use of more everyday language in science classrooms for the sake of student engagement because language in the register of science is complex and difficult for students in science class to understand (Lemke, 1990, p. 136). However, current educational research explores the connection between learning to write about science and writing to learn science itself (Gillespie, et al., 2013; Klein & Unsworth, 2014; Sampson, et al., 2013; Seah, et al., 2014; Stoddart, et al., 2002), indicating that students who do not have access to scientific language in learning scientific concepts may be missing critical information. Language and science are interdependent: students learn the language of science and learn science through language (Gillespie, et al., 2013; Klein & Unsworth, 2014; Sampson, et al., 2013; Seah, et al., 2014; Stoddart, et al., 2002). Stoddart, et al. (2002) describe the relationship between learning science and learning language as "reciprocal and synergistic," allowing students to "practice complex language forms and functions" while enhancing their understanding of scientific concepts (p. 667). The language of science does not merely describe the scientific world, but contributes to the understanding of it.

In their study of the language grade 7 students used to describe density, Seah, et al. (2015) establish a connection between the grammar used to communicate and the idea being communicated. When students described density they failed to include the per unit volume (e.g. grams per liter). This phrase provides a conditional circumstance in which one measurement is set in relationship with another measurement. Failing to include this relationship in their writing contributed to the difficulty students had understanding the concept. Students could easily mistake a simple measurement of mass (grams) or volume (liters) for the density measurement if they do not understand that "density" requires measurements of both mass and volume and the calculation of the ratio. Insisting on the use of the lexis-grammatical phrase "grams per liter" in student writing would not only help students express their knowledge but actually contribute to the students' conceptual understanding of density (Seah, et al., 2015).

Fang (2004) argues for balance between inquiry and attention to the language of science in reading and writing. Writing through the lens of SFL he purports that in the process of making linguistic choices within an open-ended system of language, speakers and writers are engaging their ideas and sorting through meaning. "From the perspective of functional linguistics, learning the specialized language of science is synonymous with learning science" (p. 337). Learning to unpack or encode the language structures found in science empowers students for robust engagement with scientific discourse (p. 343).

It is difficult to separate the features of language in the register of science from the field of study itself. Authoritativeness, often accomplished through the use of passive voice, compacting of the language into dense clauses in order to build logical arguments, the use of science-specific technical language, and the functional rearranging of ideas through nominalization all enable scientists to organize their thinking and understanding of the natural world. These structures function for specific purposes within the register of science and are different from the structures of language in everyday conversation and even in other academic subjects.

Synthesis

In science language is utilized for specific purposes and functions that are different from everyday conversation. Therefore, the register of science employs specific lexical and grammatical features to accomplish the unique communicative tasks in the field of study. Some of the features of scientific language include authoritativeness, informational density, technicality, and nominalization. These features enable scientific discourse to make logical arguments that build on each other and describe the natural world in careful, specific ways. In fact, many argue that the particularities of language in the register of science not only ague, explain, and describe scientific understandings but the language itself contributes to scientific knowledge through the lexicon and grammatical structures.

The Genre of Science Lab Reports

Within the broader register of science, this project is specifically concerned with the language structures for the genre of a science lab report. *Genres* are specific uses of language for particular contexts (Schleppegrell, 2001). Science lab reports are designed particularly for the context of designing and reporting on scientific investigations done in the science lab and beyond.

Approaches to Lab Reports as a Genre

Carter, Ferzli, and Wiebe (2004) designed and tested LabWrite, an online instructional site to support first year university students in understanding the concept of the lab experiment and to learn to apply scientific reasoning. In post-tests they found their tool to be effective in achieving these goals as well as supporting a more positive attitude in students for writing reports (Carter, et al., 2004). The website provides content and structural support for organizing and writing a lab report; it does not, however, provide linguistic support for writing in the register of science (N. C. State University, 2004).

Wignell (1994) used SFL to contrast the genres of writing in two different content areas: applied science and history. He demonstrates the ways language shifts differently between these fields. In science the movement is from reflection and questioning to active experience; in history the logical move is from individual experience to interpretation (Wignell, 1994). This difference is significant in the way that the language functions in the different subject areas. That science moves from general to specific can be seen in various scientific classifications where subjects are related as parts of a whole or in a science investigation where a general hypothesis is put to a specific, ordered test with particular materials and tools (Wignell, 1994).

Wolfe (2011) suggests that the entire lab report is a series of prescribed arguments that implicitly make their claims.

> The introduction supports the unstated claim "this is a worthwhile question," and the methods section supports the unstated claim "these methods are valid." The results and discussion sections together make an argument with the empirical results providing the reasons and the discussion setting forth key claims (p. 198).

Wignell takes a slightly different approach when he describes an argument used in science as a means of convincing the audience to act (1994). An argument begins with a thesis which is then elaborated; it is organized logically, uses nominalization, makes general (rather than specific) references, and describes general (rather than specific) participants in the declarative mood (Wignell, 1994). This particular kind of argument functions to set up the aim or *starting question* of the inquiry. It forms the general background of the inquiry that moves toward more specific results.

Specific Language Features of the Genre

An IB MYP Sciences lab report includes the explanation of the aim or *starting question;* the formulation of a *hypothesis* and explanation of the manipulation of *variables*; the design of the investigation including an explanation of the data collection plan, sometimes called the *method*; the presentation of *data*; interpretation and explanation of the *results*; an *evaluation* of the validity of hypothesis and method, and an *analysis* of possible improvements or extensions to the method (IBO, 2014, p. 10). Each of these sections functions particularly for its part in the lab report.

A *method* in science tells the audience how to conduct the investigation in a way that achieve the aim or answer the *starting question*. It includes tools and materials that are exophoric, or known specifically in the science lab and not necessarily described within the writing (Wignell, 1994). It temporally orders step-by-step instructions, making specific (rather than general) reference to the immediate context. The method is written in the imperative mood and utilizes mostly material processes which are written in the active voice, where the actor enacts the process (Halliday & Matthiessen, 2004). Consider these examples:

9. Label 2 Petri dishes, Solution A and Solution B.
10. Measure the mass of each dish and record it on Table 1.
11. Using a pipette, transfer 10 mL of salt solution A to the corresponding labeled Petri dish; do the same for salt solution B.

Petri dish, solution, mass, table, and *pipette* are all technical terms that are used for specific purposes in this method. *Petri dish* and *pipette* are terms unique to the science lab; *solution, mass,* and *table* all have uses in other contexts but are used in particular ways in this text. These sentences are listed in sequential order. Notice that none of the sentences indicates the actor; it is implied that the reader will enact the material processes *label, measure,* and *transfer,* which are instructions given in the imperative mood.

When reporting or explaining *results* and interpreting data in a science lab report, there is significant use of technical language and general references presented in the timeless simple present mood (Derewianka, 1991; Wignell, 1994). The use of extended noun phrases and the abstraction of verbs and adverbs into participants (nominalization) are key features of scientific writing (Fang, 2004) and likely to be found in a written scientific *evaluation* or *analysis*.

Synthesis

The lab report is a specific genre that functions within the wider register of scientific writing. It is a structured argument that sets up a problem, designs a procedure to test the problem, then reports on and analyzes the results. Each section of the lab report utilizes slightly different linguistic structures to accomplish its role in the overall argument.

Science Teachers Teaching Language

Since learning and using the language of science is so deeply connected to the understanding of science itself, science teachers have a huge responsibility when it comes to teaching language. IBO considers every teacher, no matter their subject specialty, a language teacher (IBO, 2014). Nevertheless, there are currently obstacles for science teachers to achieve these lofty goals.

The Challenge of Language for Science Teachers

One challenge for science teachers is their lack of skill and preparation to teach language. Gillespie, et al. (2013) surveyed teachers throughout the United States to discover if and how they were supporting students writing across content area curriculum. Science teachers made up about a quarter of the participants (Gillespie, et al., 2013). About half of the teachers reported being under prepared in their teacher preparation programs to teach writing in the content classroom whereas a quarter of them reported adequate preparedness (Gillespie, et al., 2013). In service professional development added minimal support (Gillespie, et al., 2013). The researchers concluded that the majority of the writing activities used by teachers did not involve students composing information on their own; analysis and interpretation were mostly missing (Gillespie, et al., 2013). This is a concern for the purposes of writing a science lab report which requires these higher levels of thinking and composition.

Driver, Newton, and Osborne argue that because teachers are not conversant with pedagogy to teach writing, and because students' opportunity to practice writing arguments in science are limited, progress in the overall field of science is hindered (as cited by Wolfe, 2011). Again, the connection between learning science and learning to write in science is evident (Wolfe, 2011).

The lack of understanding of the connection between writing science and learning science, specifically in the lab report genre, is another challenge facing science teachers. Lerner (2007) chronicles the history of writing in science and argues for the importance of the lab report as a genre within the register of science. He cites a number of articles that champion the need for writing instruction in science yet, he contends, they do not address the genre of the lab report even though as a genre it provides the strongest link for students between "*doing* science and communicating what they are doing" (Lerner, 2007, p. 214 emphasis in the original). Even in studies that give evidence of the value of laboratory experiences for students developing scientific understandings, there was no mention of writing as a means of developing or communicating this learning (Lerner, 2007). Lerner further argues (2007) that the separation between writing studies and science education makes the problem worse. "Researchers, theorists, and educators in science and writing studies seem often largely unaware of what they have in common" (p. 217). Science teachers must understand and respond to the value of strong, scientific writing if their students are going to write well in science.

Effectively managing instructional time is an additional challenge that science teachers face. With heavy demands of meeting content objectives, science teachers are not likely to set aside instructional time for language instruction. In their study of university neuroscience students being unable to write effectively for their coursework, Holstein, Mickley Steinmetz, and Miles (2015) found that many students entered university with limited skills for writing in scientific genres. While professors placed a high value on writing skills for achievement in the coursework, they reported not having time to teach the language skills needed within the framework of the science course. They experimented with a solution by transforming an introductory lab course into an introduction to science writing course using science labs as a means for teaching the writing genre. Over two semesters they used quality exemplars, clear rubrics, structured peer feedback, and repeated practice as scaffolds to teaching writing in the genre of science reports with positive results. In addition to their growth in genre writing skills, the students had deeper knowledge of science. As a result of their science writing instruction, students "also learn[ed] how to create an argument, how to write using direct language, how to pay attention to detail, how to follow a specified format, and how to attach writing purpose to audience. This kind of writing fosters the development of critical thinking skills" (Holstein, et al., 2015). While it may not be practical for secondary science programs to set aside a full course for teaching the language of a lab report, this study outlines practices that can be used to achieve the overall goals of improving writing in a science lab report. Many of these practices could be embedded within the lower level science course offered in secondary education.

Strengthening Writing Skills

Sampson, et al. (2013) reported different approaches to addressing learning to write in science. While they show that teaching writing conventions and formats can help students learn better how to write, they also express concern over the likely disconnect from actual science content learning when the writing instruction is isolated from the science instruction. They hypothesize that if teachers combine realistic scientific inquiry with writing practices, provide students with good models to reference, give feedback to students about their content knowledge during the writing process, and allow students to revise their work, students will produce writing that better expresses their scientific ideas. In fact, the overall content of student writing improves significantly with these practices.

The benefits of combining writing instruction with meaningful scientific inquiry are further supported by the work of Klein and Unsworth (2014) who used SFL to study the linguistics of writing to learn. They argue that particular kinds of writing, in this case incremental construal of perceptual experience, contribute significantly to the learning process, and science is a subject area that evidences great potential for the integration of writing and learning. After conducting a pretest to measure student background knowledge of a physics topic, two different scientific demonstrations were presented on the same physics principle, a principle that had been shown in the pretest to be widely misunderstood. Following the demonstrations, the students were asked to discuss orally then in writing the similarities of the two demonstrations. The researchers were able to map the development of language structures with the development of scientific understanding which moved from generalizations in the pretest, to valid explanations in the end. In the final writing samples the students were compacting their clauses with nominalization, which mediated the development of a complex organization of ideas that clearly expressed their new scientific understanding. Thinking aloud in oral discussion and subsequent writing regarding their new understandings from the demonstrations provided a needed scaffold for increased language proficiency.

One approach to strengthening writing skills in the classroom is using writing frames. Subramaniam (2010) notes that writing science in the classroom can be an interpretive task evidencing comprehension and skills, knowledge-transforming evidencing critical thinking skills, or discursive evidencing students' negotiated meanings. When students write science lab reports, they have opportunity to engage in all these various dimensions of thinking and communicating. Since writing in science not only exposes student thinking but also contributes to their understanding of science, providing a template for students to start their sentences or begin their thinking for writing helps to give structure for their inquiry and new knowledge. For this project, the opportunity to model the language structures a significant benefit to using writing frames. The frames modeled in Subramaniam's work lead students through the scientific thinking; a deficit, however is that they do not all engage the technicality of the register that demonstrates a high level of proficiency. Nevertheless, writing frames are a flexible tool for scaffolding scientific thinking through language.

Other practical strategies are offered by Kucan and Boliha (2016) to assist students in decoding the language they find in science textbooks, specifically in the glossary. By expanding dense definitions, students can uncover the multiple layers of information that are compacted into concise explanations. For example, this dense definition is given for the term *active transport*: "the movement of particles from an area of low concentration to an area of high concentration that uses energy provided by ATP or a difference in electrical charges across a cell membrane" (Kucan & Boliha, 2016, p. 55). The teachers help students by expanding the definition to these four points :

- Active transport is the movement of particles across a cell membrane.
- The particles move from an area with a low level of concentration to an area with a high level of concentration.
- The energy that makes the movement possible is released by ATP.

- Another source of energy that makes the movement possible is electrical energy, a difference in electrical charges (positive and negative) across a cell membrane (Kucan & Boliha, 2016, p. 55).

While this process of expanding condensed text is helpful for the decoding process of reading, the task of encoding scientific thinking into writing is the reverse. In order to support more condensed student writing, science teachers can demonstrate how the volume of information given in the expanded points can be reorganized and condensed into a series of complex clauses. In order to move from simple, expanded ideas to complex, dense clauses, students need to be able to transform words between nouns, adjectives, and verbs (Kucan & Boliha, 2016). Explicitly teaching a variety of word forms for key vocabulary within a unit or science lab as well as general common affixes and their uses is an additional scaffold for students learning to write in the register of science (Kucan & Boliha, 2016). A clause-level linguistic skill needed is the use of specific connectives for the specific purposes of adding (*and, also, as well as*), contrasting (*although, however, despite*), demonstrating causality (*because, as a result, consequently*), demonstrating time and order (*first, next, finally*) (Kucan & Boliha, 2016). With the information readily at hand, science teachers could embed instruction of these writing skills within the context of their science lesson.

Synthesis

Science teachers face a number of challenges in teaching the language of science to their students. They report being underprepared in their teacher training to meet this expectation, they lack pedagogical knowledge and skill for teaching language, they are not convinced of the strong connection between the language and the content, and they are managing time restraints. A number of strategies have been shown to help science teachers teach the language of science to their students, especially when the writing instruction is embedded in science instruction. These include think-alouds and incremental writing on new learning, writing frames, modeling, expanding dense phrases and condensing others, transforming words to fulfill different grammatical structures (noun, verb, adjective, adverb), examining affixes and roots, and practicing connectives.

Summary

This chapter has reviewed literature addressing the question, What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports? The language used in the register of science was shown to be different from everyday conversational English. Authoritativeness, informational density, technicality, and nominalization are some of the key characteristics of the register of science. These characteristics not only enable students to evidence their learning in science, but they also contribute to the understanding of the science they communicate, evidencing the strong connection between language and science. The science lab report is a specific genre of writing in the register of science. It has multiple sections that function differently within the overall argument of the genre and that require specific language structures. Science teachers may find teaching the language of science difficult because they are underprepared to do so and may not prioritize it because of time restrictions or because they do not realize the deep connectedness between language and science. There are, however, some teaching practices that have been shown to increase student proficiency in writing science. The language structures and teaching pedagogy discussed here will contribute to the suggested learning activities included in the project. These findings will guide the content of the iBook project to be created.

In chapter three the iBook project is described including the goal of equipping science teachers, the rationale for choosing the format of the iBook, and the audience intended for the project. The requirements of an IB MYP Sciences lab report and the content of each chapter of the iBook is outlined.

CHAPTER THREE

METHODS

Overview

This chapter gives an overview of the project which explores this question: What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports? The chapter begins with the framework and rationale for the creation of a teaching guide for science teachers. Next is a description of the setting and science teacher colleagues who are the audience for the project. Then the rational for the iBook format is explained. Finally the chapter outlines the content of the iBook which is organized in four chapters around different sections of a science lab report: the starting question, hypothesis, method, and explanation and evaluation.

Framework

The completed project is a teaching guide for science teachers to teach language in the register of science, specifically in the genre of a science lab report. Although science teachers are expected to teach the language of their subject area (IBO, 2014), research indicates that they feel underprepared for the task (Gillespie, et al., 2013) and likely do not see the direct connection between teaching writing and teaching science

(Lerner, 2007). Studies also show, however, that the language structures in the register of science are intricately connected to knowledge of the scientific itself (Gillespie, et al., 2013; Klein & Unsworth, 2014; Sampson, et al., 2013; Seah, et al., 2014; Stoddart, et al., 2002). Little attention has been given to the science lab report as a genre of writing in the register of science (Lerner, 2007), yet it is the centerpiece for the science objectives in IB MYP Sciences (IBO, 2014).

Because science teachers are the primary providers of science education for students, they are the professionals with the greatest opportunity and responsibility to teach students how to write for scientific purposes. This project outlines key linguistic features for each of the following sections of a science lab report: starting question, hypothesis, method, and evaluation. Each chapter develops knowledge of the language features using descriptions and examples, presents various charts and lists as resources, and includes strategies for teaching the language structures within the science classroom. This project has been approached from an SFL perspective which provides a paradigm for examining the way language functions for different purposes (Derewianka, 1991; Halliday & Martin, 1993; Halliday & Matthiessen, 2004; Schleppegrell, 2001).

Audience

This project was designed to meet the needs of my science teacher colleagues in a K-12 international school in South Korea. Over the past eight years I have worked with the secondary science department to support English learners in science classes and to adapt the learning activities to match student language proficiency with the demands of the curriculum. A significant part of the IB MYP Sciences curriculum involves writing science lab reports (IBO, 2014). In professional development sessions with these colleagues they have indicated their frustration with the level of student writing, including both English learning and English proficient students. Furthermore, these science teachers have expressed their lack of knowledge about English language structures and an abundance of curriculum to teach within a limited time frame.

My colleagues, however, are not the only science teachers who can benefit from the resources provided in this project. Any teacher of IB MYP science, or of secondary science in general could make use of this tool to support writing development in science lab reports.

Format

The format for the teaching guide is an electronic book. My school, like many others, is highly engaged with digital resources. The school's 1:1 Apple laptop program ensures that all secondary students and teachers have a personal MacBook for use in the classroom and beyond. Therefore, I have chosen to create an electronic book, specifically an iBook, that can be accessed from any Apple computer or iOS device (iPhones or iPads). The iBook format is supported by the application iBooks Author on an Apple computer and has significant capacity for imbedding a variety of media. iBooks can be easily distributed from the App Store on iTunes. The simplicity of using the embedded design elements, the flexibility of the platform as an interactive tool, and easily-accessible distribution make iBooks a desirable platform for my project. iBooks can be exported as a .pdf file which allows the content to be distributed beyond those with access to Apple devices.

Project Description

The iBook is organized in four chapters around objectives from the IB MYP sciences curriculum. Each chapter begins with an explanation of one or more key language structure for a particular section of the lab report including examples. The explanations are followed by language support resources like charts and lists, suggested teaching strategies that fit with the particular language feature, and suggestions for embedding language instruction within a science lesson.

Chapter 1: Starting Question

Chapter 1 focuses on explaining the aim of the investigation or a starting question. In an IB MYP setting, science students are expected to explain scientific knowledge about a subject as a precursor to designing their experiment. Explanations in science are often lexically dense and make use of nominalization (Derewianka, 1991; Halliday & Matthiessen, 2004). Nominalization is the topic of Chapter 4: Explanation and Analysis, therefore, Chapter 1 focuses the use of technical vocabulary.

Technicality is introduced as a key feature of scientific writing. The author then lays out examples of closely-related scientific terms to make the connection between scientific terms and scientific concepts. A section entitled "Making Thinking Visible" suggests four pedagogical tools to support student learning of sets of related terms. The following section, "Prefixes, Suffixes and Roots" outlines background information for the formation of some scientific vocabulary and demonstrates how morphemes work together to adapt word meaning and word functions in written communication. Suggestions for classroom use and links to other resources are included.

Chapter 2: Hypothesis

Chapter 2 begins with an explanation of a hypothesis as a causal relationship. Several patterns of written hypotheses are examined. Two videos are embedded that discuss the general structure of the clauses, specific processes, qualifiers (qualities and measurements), logical connectors, and an introduction to nominalization. A special feature in this chapter is per unit measurement. Terms related to per unit measurement are not only necessary in communication but also in understanding the scientific ratios indicated by them. Charts including samples of logical connectors, qualities, and measurements are included. The chapter concludes with an "In the Classroom" section providing a think-aloud model for teaching students to write hypotheses, and suggestions for using student work as editing models.

Chapter 3: Method

The function of the method is to give instructions for conducting the experiment so that it will answer the starting question. A method sequences imperative statements in a time-ordered list. Most of the verbs are material processes written in the active voice (Halliday & Matthiessen, 2004). The instructions in the method need thoroughly include technical equipment and materials and precise measurements; they need to be concise and clear so that the procedure could be repeated by a different person at a later date.

Chapter 3 addresses material process verbs, the imperative mood, and temporal conjunctions. Each of these components are described and explanations are given for instructing students how to use them in science lab reports.

Chapter 4: Explaining and Analyzing

Chapter 4 addresses the features of an explanation which expresses how things work or the reasons for a phenomenon (Derewianka, 1991). The language structure focus for this chapter is nominalization and relational processes. The chapter gives an explanation of nominalization as a key element of scientific argumentation and then outlines ideas for teaching students how to use nominalization in their explanations and analysis.

Summary

Chapter three has described the framework for teaching guide for science teachers. It detailed the audience as science teachers teaching IB MYP science in an international school in South Korea and the format for the guide as an iBook. Finally, the content of each chapter of the iBook teaching guide were outlined. Chapter four will reflect on new learnings; application of the literature; limitations, liabilities, and extensions; and professional uses for the project.

CHAPTER FOUR

CONCLUSION

Introduction

This chapter will provide my conclusions of the project which explores this question: What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports? The project has been research, planning, and completion of an iBook for science teachers to support their knowledge and skills in order to teach language in the register of science from within their science classes. It began as an investigation into the language used by students in science, especially through the paradigm of SFL, and has concluded with some practical application for science teacher colleagues.

New Learning

This capstone began as a research thesis exploring the language that students use to communicate their scientific investigations in science lab reports. From the beginning I was motivated to support learning and to make some of the embedded language structures in science more visible and accessible to science teachers and their students. Along the way my emphasis changed from a text analysis of student work to the current project: an iBook to address the needs of science teachers in teaching language to students writing science lab reports. When my thesis morphed into this practical iBook project, my initial hopes for the research became much more tangible and applicable.

Learning About Research and Writing

The practice of honing a research question during the preceding Research Methods course was perhaps one of the most rigorous and enlightening aspects of the entire process. Taking a broad approach from the beginning, then looking at the ideas from different angles really enabled me to think creatively about the possibilities. I am convinced that the time and energy spent in developing a good, clear goal from the beginning is of great value. Rushing through it to get to the hard work of research and writing saves neither time nor effort in the long run. This is learning that I am applying in my work with students and teachers. The long, drawn-out process of early exploration actually gives a jump start on the hard work of research and writing.

As a teacher I have helped many elementary and secondary students do research and write research papers. It has always been an intimidating task for me as I have not been confident in the library, either physical or digital. This process has allowed me a great volume of practice in research and has strengthened my comfort level and skill in finding resources. I am still honing them but feel I have a great deal more to offer to students.

Learning to write in the genre of a capstone project paper has had a learning curve of its own. There is an imbedded redundancy to the formatting to which my concise, sometimes truncated, writing practice has had difficulty conforming. Furthermore, upon switching from a thesis to a project, this paper necessarily required major revisions and new direction that made the process rather messy. Nevertheless, I am continuing to learn and practice the art of being explicit in my writing.

Learning About Language

An early advisor suggested I look at my topic through the lens of SFL. I took his advice and jumped in with both feet. It did not take me long, however, to realize that my limited knowledge of SFL made application of it very difficult. It was very intimidating and at times overwhelming. As I have nudged my way through it, however, I believe I have made significant headway in understanding on the overarching approach of SFL and differentiating it from a more strictly grammar-focused approach.

I jumped into the project thinking that I would find some formulas for language that I could extract and offer as building blocks for science lab reports. I have encountered very few of those. Instead, I have discovered the beautiful complexity and flexibility of the English language. A field of study like science can make and remake the language to work for its communicative purposes. I doubt that scientists intend on being linguists, but their use of language to express understanding of the complex natural world has indeed carved out a genre of its own. This can be readily seen in the wide and complex use of both nominalization and technicality in the field of science. And, as I have found, unpacking that complexity is not simple. Again, the flexibility of the English language provides opportunities for creative use and development.

As a result of this new perspective I had to first release myself from a need to learn everything there is to learn about language in the register of science. That is not a capstone-project-sized venture. Neither did I need to communicate to science teachers everything there was to say about language in the register of science. Instead, I found that I had to be creative myself in applying what I have learned and understand about language, the science classroom, and a science lab report and use my judgement to communicate what I believe to be helpful, practical insight for science teachers.

Review of the Literature

This project placed me on a steep learning curve regarding SFL. Halliday's work with both Matthiessen (2004) and Martin (1993) was initially quite overwhelming to me. The work of Kazemian, et al., (2013) was very helpful for me especially in understanding the role of nominalization in scientific argumentation and understanding the role and function of processes from an SFL perspective. Fang (2004) also contributed significantly to my understanding of various key language structures in the register of science. He argues for balance in science instruction: tending to both the language and knowledge as they are "interrelated and inseparable" (p. 336).

Seah, et al. (2015) helped to shape my understanding of the link between language and knowledge in science, exemplified in the concept of *density*. Students who did not write about per unit volume in there lab reports about density did not understand the concept. While others clearly make the connections between language and knowledge (Fang, 2004; Halliday and Matthiessen, 2004; Kazemian, et al., 2013) the work of Seah and her colleagues made the connection visible for my thinking. This particular concern (per unit volume) is addressed in the iBook. I have become convinced of the connection between language and scientific knowledge, so much so that I believe that science teachers who do not attend to the language are missing out on huge opportunities to teach scientific understandings.

The work of Kiuhara, et al. (2009) is centered in the United States, nevertheless it was not a stretch to apply it to US-educated teachers working in my school. This study indicates that science teachers report a lack of preparation to teach language and advocates for increased writing education in science classrooms. This study motivated me toward the iBook project. Some of the practical examples in the iBook were inspired by the work of Klein & Unsworth (2014) who explored the process of learning to write more competently in the register of science. Using writing to learn science they demonstrated that with "explicit instruction, modeling, and practice, students can learn to write texts more similar to those found in academic disciplines" (3)

The literature reviewed for this project has influenced my understanding of the way language functions within the framework of SFL, it has convinced me of the inseparable tie between language in the register of science and knowledge of the natural world, and it has undergirded my rationale to create a teaching guide to support science teachers teaching language within the science curriculum.

Implications, Limitations, & Extensions

I hope that this research will reach beyond the professional use by my science teacher colleagues. I have teacher-coach friends who are interested in sharing it with science teachers within their sphere. I do hope that my work is both accessible and provocative enough that my colleagues will make use of it. The iBook contains both professionally developing information for science teachers as well as practical, useful tools to be used directly in the classroom. Furthermore, I hope that this work will spark an ongoing dialogue at the school and district level regarding the value of language education within the science classroom and that science teachers, teaching coaches, and curriculum leaders will devote professional development resources to support science teachers in linguistic and pedagogical development.

This is an introductory work. It addresses a handful of significant language features in the register of science in somewhat limited form. While there is enough information to spark interest and provide initial support to science teachers, there is much more information to be learned on any of the topics. For example, this project addresses the topic of technicality in a few short pages, yet there are countless resources available on the topic of vocabulary instruction in science.

There is a great deal of research on the complexity of language in science textbooks and the reading skills needed to approach them. Further research could focus on the varying tasks of student writing in science including research papers, science lab reports, and real-world application projects. Bridging the gap between the fields of linguistics and science education will require some work on both sides. On the linguistics side, ongoing work needs to be done to make knowledge about how language works more accessible to non-linguists. Coursework needs to be developed in teacher education programs to better equip science educators to understand and teach language in the register of science. Science teachers themselves need to be open to the field of linguistics and to opportunities to learn and apply new understanding to the classroom. I have attempted to contribute to these aims.

Professional Use

If my project were successful professionally, it would provoke conversation, inquiry, and deeper understanding among science teachers about the strong connection between the vehicle of language used in science and the content of the knowledge the language expresses. My hope is that science teachers will grow in their own understanding of language in the register of science so that they can make it visible to students in their classrooms. While there is certainly room for explicit language instruction in full lessons and courses, I am convinced that much of what students need to learn about putting English language to good use in their science lab reports and other scientific writing can be embedded into general science instruction. This will require science teachers to not only have knowledge about language, but also be convinced of the value of language in learning and expressing scientific ideas. I hope my project contributes positively to that end.

Regarding distribution of my project, the iBook will be available for free on the iTunes store. I will also be gifting it directly to my colleagues in the science department at my school, other science teachers I know, and IB MYP program coordinators that are my professional colleagues.

Summary

This project has asked the question, What are the language structures science teachers must teach for secondary students to be able to write successful science lab reports? In addition to personal growth in research and writing skills, this project has provided me with a much deeper understanding of language in the register of science.

The literature developed my understanding of SFL as a framework for understanding language and enabled me to identify significant language structures in the register of science. The studies also supported my understanding of the deep link between knowledge and language in the register of science. Furthermore, the work of researchers before me evidenced the need of science teachers for support in teaching writing and provided some strategies to improve student writing in science.

The iBook addresses technicality, material and relational processes, and nominalization as features of language related to writing a science lab report. It provides science teachers with examples, charts, and suggestions for embedding language instruction from within science lessons.

At the end of this project I am even more convinced that science teachers really are the best ones to teach the language of science to their students. The efforts linguists and language teachers can make in supporting science teachers in their understanding of the language are well-invested.

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