Studies in Singapore Education: Research, Innovation & Practice 4

Lay Hoon Seah · Rita Elaine Silver · Mark Charles Baildon *Editors*

The Role of Language in Content Pedagogy

A Framework for Teachers' Knowledge

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Volume 4

Changes in education and organisational structure, teacher education, school management, curriculum, and instruction and assessment over the last few decades, and more so in recent years, have contributed significantly to the rapid and systemic improvement in pedagogical quality in Singapore. While the outcomes of Singapore's success are internationally recognised, the processes, reasons and factors that contribute to pedagogical and systemic improvements have not been systematically captured in a comprehensive manner. The series aims to fill the gap by presenting a Singaporean perspective on pedagogical research and innovation, highlighting how Singapore, drawing on knowledge and research done both internationally and locally, has successfully mobilised resources and efforts to improve learning and teaching across the various subject disciplines and education sectors. The series also aims to present education research that will help propel Singapore's education system towards its goal of meeting the challenges of the coming Fourth Industrial Revolution. It includes titles that focus on de-emphasising academic performance in favour of deep and soft skills, on de-emphasising knowledge transmission and rote learning in favour of inquiry methods, applied learning and experiential learning, titles that look into tripartite relationships with students, schools and industry to develop updated experiences with apprenticeships and internships, and titles that address the socio-political blind spots in the Singapore education system in terms of gender, racial and class equity, and others. The series includes monographs that examine Singaporean pedagogies in terms of policies and practices. It also includes edited volumes that will cover, but not be limited to, the following structure: a state-of-the-art review of research and knowledge in the topics covered by and, an introduction of the purpose and the key issues covered by the volume; international and Singaporean experience in these topics, presented in a series of empirical studies or theoretical/conceptual pieces; comparison and synthesis of Singaporean pedagogical research and innovation experiences, and its applicability to other systems; and directions for future research and practice.

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Chapter 1
Introduction to the Volume: Mapping the Language-Related Knowledge Base for Content Teaching

Lay Hoon Seah, Rita Elaine Silver, and Mark Charles Baildon

1.1 Introduction

In this volume, we focus on the language-related knowledge base (LRKCT) for content teachers, i.e., those who are not teaching language as an academic focus. Taken together, the chapters in this volume build on and illuminate the LRKCT framework proposed in this chapter. The framework comprises four interacting knowledge components (plus one sub-component) which are important for content teachers to utilise. In addition to explaining the framework, this introductory chapter provides background to show the links between content and language in learning, including discussion of teacher roles in relation to language use in the classroom. After explaining the broad theoretical underpinnings of the volume, this introduction culminates with a brief description of each chapter and how each fits within the volume's broader conceptualisation and the LRKCT framework.

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1.1.1 Background: Language in Learning

Learners encounter multiple languages in the course of schooling. These can include home language(s) and foreign languages, as well as academic language and disciplinary languages. In any learning situation, consciously or otherwise, students experience the learning of and about language through a multiplicity of languages.

We take language as a semiotic ('meaning-making') tool which is the foundation of learning (Halliday, 1993). Without language and other semiotic tools, humans would not have the means of knowing, i.e., "the process by which experience **becomes** knowledge" (original emphasis, ibid., p. 94). According to this view, the process of learning is fundamentally a semiotic one involving not just "learning *through* language" but also "learning *of* language" and "learning *about* language" (p. 113). This threefold perspective (through, of, about) applies not only to learning in a language classroom but to all learning processes, contexts (including home, neighbourhood, school and workplace) and contents (e.g., science, social studies, mathematics).

The links between language and content have been recognised for decades. For example, Mohan's seminal work (1986) devoted the first chapter to explaining the role of language as a medium for learning in contrast to language as a goal of learning. Mohan posited a knowledge framework which linked types of activities (e.g., classification) with types of language (e.g., description). He referred to these as "knowledge structures" as they required not only linking types of learning activities with language structures but also with thinking skills appropriate to the activity and language. Subsequently, a number of monographs explored the role of language in content learning, but often with a view towards supporting language learners in content area classes (e.g., Brinton et al., 1989; Cantoni-Harvey, 1987; Crandall & Dale, 1987). This area of scholarship is still vibrant, especially with investigations of theory–pedagogy links such as Content and Language Integrated Learning (CLIL, e.g., Cenoz et al., 2014; de Zarobe, 2016), including CLIL and teacher education (e.g., Banegas & del Pozo Beaumud, 2020; Darvin et al., 2020; Pérez Cañado, 2016), and language immersion-based content instruction (Navejas, 2022; Ó Ceallaigh et al., 2021). This volume, in contrast, focuses on content teachers and the need for a language-related knowledge base that extends beyond student language learning status.

In education research, the importance of language in learning has been widely recognised since the emergence of the "linguistic turn" (Veel, 1993) or the "interactional turn" (Erickson, 2006). For example, Lemke (1990) proclaimed that "learning science means learning to talk science" (p. 1). This is equally true in other content areas. Wagner (2007), for example, wrote about the critical need for students to develop "voice" in mathematics. Dombek et al. (2017) stressed the link between literacy and content for building science and social studies knowledge, while Duff (2010) emphasised the role of socialisation into academic discourse communities for all learners. These statements on the importance of language in content learning assume that language differs in some ways from one discipline to another. A key consideration in this volume is the extent to which teachers are aware of such differences and how these differences might be usefully addressed to support student learning.

To meet the needs and requirements of specific content in a given context, language changes in meaningful, functional ways (Halliday & Martin, 1993). These language changes may relate to conceptual, ontological or epistemological distinctions across disciplines. For this reason, language as used in one discipline may contain features, linguistic resources, norms and conventions distinct from the features, resources, norms and conventions in another discipline even if both disciplines are being taught in the same linguistic variety (e.g., in English) (see for example, Schleppegrell, 2004). Differences between disciplinary languages can extend to differences in literacy practices such as reading (Shanahan et al., 2011). For instance, Shanahan et al. (2011) found that critique during reading by chemists, historians and mathematicians differed in nature. They asserted that these different reading practices provide "clear evidence" that the disciplinary expertise the readers brought with them could influence the ways in which readers engaged with the texts (p. 424). Disciplinary differences in reading extend beyond words or linguistic structures. They also encompass the use of multiple semiotic modes (e.g., graphs, diagrams, photographs, charts) which serve distinctive purposes and embodied unique conventions (see, e.g., Prain, this volume; Yeo & Tan, this volume). As every discipline comes with its own epistemic values and ontological requirements, further research is needed to unpack how these disciplinary differences can impact on the nature of the language and literacy practices of each discipline and teachers' language-related knowledge base.

K-12 students do not just engage in the disciplinary languages of the various subject areas they are exposed to, they also encounter multiple uses of language in everyday life. Using a science classroom as an example, Yore and Treagust (2006) introduced the "three-language problem" to encapsulate the different languages a learner encounters: home language (i.e., everyday conversational language); academic language [for our purposes, this refers to the linguistic variety used in schools and for schoolings (see Schleppegrell, 2004)]; and scientific language. In an increasingly globalised world, the home linguistic variety of the learner can and often does vary from the linguistic variety used as a medium of instruction in school. In such cases, learners grapple with learning academic language with and through a different linguistic system. Extending the three-language notion to learning in other disciplinary areas, students must learn multiple "languages" including one or more home linguistic varieties, one or more school linguistic varieties, multiple disciplinary languages and how to leverage these multiple languages in their learning.

While we acknowledge that students experience learning through, of and about language, this volume focuses on the teacher's roles, knowledge and understandings of language in school contexts to support student learning. We consider teachers' knowledge of and about language, the influence of teachers' knowledge of (their) students and teachers' pedagogical knowledge. We are particularly interested in how teachers' knowledge of language, students and content are linked as part of a larger pedagogical content knowledge which includes knowledge of the role of language in content learning.

1.1.2 Teachers' Roles

Classroom teachers take on multiple roles. In addition to the role of content teacher and teacher of disciplinary language, they must concurrently be proficient language users. To support students in learning disciplinary languages, teachers must develop a deep appreciation of the language demands and challenges involved in the learning process. This entails being an analyst of the language. These three distinct roles—language teacher, language user and language analyst (cf. Andrews & Lin, 2017)—encapsulate the demands placed on teachers and point to the knowledge base that teachers need to be equipped with to take on a "language-informed" approach to teaching, an approach to teaching that explicitly and systematically considers the role and nature of language in and for student learning (Fillmore & Snow, 2018).

Teacher language awareness (TLA), characterised by Thornbury as "the knowledge that teachers have of the underlying systems of the language that enables them to teach effectively" (1997, p. x), provides one potentially useful lens for identifying the knowledge base with which content teachers would need to take on a language-informed approach to teaching. TLA has been closely associated with knowledge of language needed for language teaching (see Andrews, 2003, 2006 for reviews and discussion in relation to second language teacher professionalism). This notion has also been implicated in second language teachers' knowledge about language and knowledge of students to support selection of language resources, design language scaffolds and deliver corrective feedback on students' language use (Andrews, 2008). In taking a language-informed approach, content teachers are expected to make pedagogical decisions similar to those of language teachers, albeit with a focus on disciplinary semiotics. Hence, the components of TLA such as knowledge of language (KL), knowledge about language (KAL) and knowledge of students (KS) offer useful constructs for unpacking the language-related knowledge base of content teachers.

Notably, Fillmore and Snow (2000) highlighted what "the average classroom teacher" (p. 13) should know for language/literacy in content teaching. Adger et al. (2018) articulated why basic language knowledge (e.g., differences between oral and written language; fundamentals of language development, linguistics and cultural diversity; what makes texts easy/difficult to read) is essential to all teachers, including content teachers. However, these early discussions did not develop a framework for understanding and investigating a language-related knowledge base (LRKCT) for content teachers.

In the next section, we articulate a framework for LRKCT based in prior scholarship and as the basis for this volume. We turn the lens away from language awareness as a broad approach and from the teaching of linguistic varieties to teaching of other content subjects.

1.2 Language-Related Knowledge Base for Content Teaching (LRKCT)

Several constructs have been proposed in recent years to capture the components of a language-related knowledge base that teachers need to support students in their learning of content. Examples are "pedagogical language knowledge" (PLK, Bunch, 2013), "language knowledge for content teaching" (LKCT, Morton, 2016) and disciplinary linguistic knowledge (DLK, Turkan et al., 2014). These constructs have been proposed in response to the challenges of teaching in contemporary classrooms that are often composed of students of varied cultural and linguistic backgrounds, students who are learning language and content concurrently. It is our contention that the language-related knowledge base proposed below is equally relevant for teaching in monolingual classrooms, albeit to a different extent from multilingual ones, since disciplinary languages are distinctive. Thus, all content teachers need a strong LRKCT.

We distinguish this knowledge base from the well-known construct pedagogical content knowledge (PCK) (Shulman, 1986, 1987). PCK links teachers' content knowledge, general pedagogical knowledge and specific pedagogical knowledge relevant for the subject content. This knowledge is seen as being unique to teachers. Similarly, we see LRKCT as a specialised body of knowledge, unique to content teachers. It serves to inform how content teachers represent content knowledge linguistically as well as supporting the learning of general academic discourse and disciplinary-specific language/literacy practices. In the following sub-sections, we outline the components constituting this knowledge base, synthesised from scholars such as Andrews and Lin (2017), Bunch (2013), Love (2009), Morton (2016), Turkan et al. (2014). These components include knowledge of language, knowledge about language, knowledge of students and pedagogical knowledge (with a sub-component knowledge of the role of language).

1.2.1 Knowledge of Language (KL)

This component (KL) refers to the linguistic competence of a teacher, including both the medium of instruction (the linguistic variety used), academic language (which, for our purposes, refers to the school-based language used for teaching that differs in many ways from conversational language) and the specific disciplinary language (Morton, 2016). KL encompasses the implicit knowledge held by teachers and manifested procedurally in practical language skills when talking, listening, reading and writing. KL represents the essentials of what teachers need to be able to communicate effectively in the medium of instruction and to represent the content of the subject in ways that are aligned with disciplinary standards and norms. Among the three teacher roles, KL would be of particular importance for a teacher as a language user when communicating the content knowledge and as a language analyst when examining student work for language errors (Morton, 2016).

1.2.2 Knowledge About Language (KAL)

In contrast to KL, which is implicit, knowledge about language (KAL) refers to the explicit, conscious (i.e., declarative) knowledge of the nature of language (Essen, 2008). This comprises the different aspects and features of academic language and disciplinary language such as structural components, use of linguistic resources and disciplinary-specific conventions and norms of language use. The declarative knowledge that constitutes KAL also includes metalingual knowledge, that is, knowledge of the metalanguage used to label and describe linguistic features, categories, functions and conventions (cf. Andrews, 2007). KAL enables teachers to "explain the linguistic forms and discourse structures they are using" (Morton, 2016, p. 278), and thus equips teachers with tools for the role of language analyst. In the classroom, KAL also provides the tools and resources for the role of language teacher when explaining to students the nature, purposes and practices distinctive to the discipline. This teacher role is especially important given calls for more explicit instruction to help students access and master disciplinary language and literacy skills (Brown & Ryoo, 2008) given their distinctiveness across subjects (Schleppegrell, 2004; Shanahan et al., 2011).

1.2.3 Knowledge of Students (KS)

Knowledge of students (KS) identifies the knowledge that teachers have of their students in order to help the students develop academic and disciplinary language. Less developed in previous scholarship than the other knowledge components, the KS component is generally taken to include the language background of individual students (Rollnick et al., 2008). Language backgrounds of students, in this case, would include the linguistic varieties used at home as well as students' proficiency in the medium of instruction. Few studies have sought to unpack KS as related to disciplinary languages. One case study that examined the KS of a science teacher uncovered five aspects of KS beyond that of students' language backgrounds. These aspects were (i) prior knowledge of and about scientific language, (ii) difficulties with scientific language and its use, (iii) differences in ability across language skills, (iv) differences in language ability across subject areas and (v) learning progress in language use over time (Seah & Chan, 2021). A teacher's KS can relate to students in general, to specific groups of students or even to individual students. KS is related to KL in that the former is generated through evaluating students' linguistic performances against the latter. KS enables a teacher to attend to the emerging and evolving language needs of students and to adjust pedagogy in a responsive and contingent manner. While KS is manifested in the teaching of the disciplinary language, it is generated when teachers take on the role of language analyst when examining students' language in reference to the disciplinary language.

1.2.4 Pedagogical Knowledge (PK)

In this framework, pedagogical knowledge (PK) includes both the declarative knowledge of the pedagogical strategies and approaches that are available for supporting instructional and disciplinary language learning as well as the instructional knowledge that is manifested when a teacher engages in teaching in the classroom. PK comprises the knowledge for engaging students in the disciplinary language, modelling and unpacking the use of the language as required in the curriculum (Turkan et al., 2014). PK may be explicit or tacit. It interacts with the other knowledge components as the teacher engages in pedagogical decision-making. PK is particularly important since it directly determines how lessons are planned and enacted as well as teacher responses during lessons.

1.2.4.1 Knowledge of the Role of Language (KRL)

Subsumed within pedagogical knowledge is knowledge of the role of language (KRL) (Love, 2009). KRL refers to knowledge about the role that oral language and written language serve in the teaching and learning of the disciplinary language. Oral and written language include whole class discourse, student-to-student interactions, textbooks and other written teaching and learning materials that function to illustrate, unpack and scaffold how disciplinary language is used in the context of the classroom. KRL encompasses the knowledge of the various functions that language as a whole serves in learning [e.g., as a cultural, cognitive and semiotic tool (Halliday, 1993; Vygotsky, 1986)] and in the discipline [e.g., as a communicative, rhetorical and epistemic tool in a science classroom (Carlsen, 2007)]. It also includes how classroom talk, whether as teacher–student or student–student interaction, reading/writing and visual representations can support and enhance learning (Love, 2009). In other words, KRL concerns language use for general instructional purposes and using language to meet the needs of all learners in classrooms. This knowledge component plays a direct role in supporting the teacher in the role of language user and teacher and even as language analyst.

While some prior scholarship has explored the knowledge constructs which are part of the LRKCT for content teaching, those studies were mainly theoretical or review studies which sought to highlight the importance of knowledge components for teacher professional learning. Among these are teacher language awareness (TLA, Andrews & Lin, 2017), Pedagogical Language Knowledge (PLK, Bunch, 2013), literacy PCK (Love, 2009), Common and Specialised Language Knowledge for Content Teaching (CLK-CT and SLK-CT, Morton, 2016) and disciplinary linguistic

Table 1.1 Knowledge components discussed in prior scholarship

Knowledge construct	KL	KAL	KS	PK
Teacher language awareness (Andrews & Lin, 2017)	Briefly	√	Briefly	√
Pedagogical language knowledge (Bunch, 2013)		√		√
Literacy PCK (Love, 2009)		√		√
Common and specialised language knowledge for content teaching (CLK-CT and SLK-CT, Morton, 2016)	√	√		√
Disciplinary linguistic knowledge (DLK, Turkan et al., 2014)		√		√

knowledge (DLK, Turkan et al., 2014). Table 1.1 highlight links between the four main constructs of LRKCT and prior scholarship.

Except for CLK-CT and SLK-CT (Morton, 2016), which elaborated and exemplified the importance of KL, other studies have mentioned KL briefly or taken it for granted. For instance, Andrews and Lin (2017) identified "knowledge of the language (i.e., language proficiency)" (p. 59) as a component of TLA, but they did not elaborate on the nature and role of this knowledge. Also, although Andrews and Lin (2017) mentioned the importance of an "awareness of students' developing interlanguage" and of the "knowledge of the learners" (pp. 58–59), for the most part, these studies did not unpack the content of KS as is done in this volume.

1.2.5 Mapping LRKCT

In our conceptualisation, LRKCT comprises four knowledge components: KL, KAL, KS and PK (with the sub-component of KRL). It is important to be clear that the distinctions between the various knowledge components are for analytical and theoretical purposes. In teaching, these knowledge components are likely to be utilised in a synthesised manner. Crucially, the knowledge components interact with one another to enable a teacher to serve the roles of a language user, language analyst and language teacher in the context of a content classroom.

Figure 1.1 shows our conceptualisation of how these knowledge components map to each other. There are three broad segments: the main components of LRKCT, the roles of teachers for enactment and the links to student learning.

The main components of LRKCT are positioned at the top of Fig. 1.1: KL, KAL, KS and PS. As mentioned above, KL includes knowledge of common and specialised language for content teaching (Morton, 2016), whereas KAL includes knowledge of academic language and disciplinary languages, and KS includes knowledge of the students' everyday languages. KS also includes the sub-component of KRL. A few specific details are included to show further mappings, e.g., common/specialised language knowledge as more detailed aspects of KL; students' everyday, instructional, disciplinary language as more specific aspects of KS.

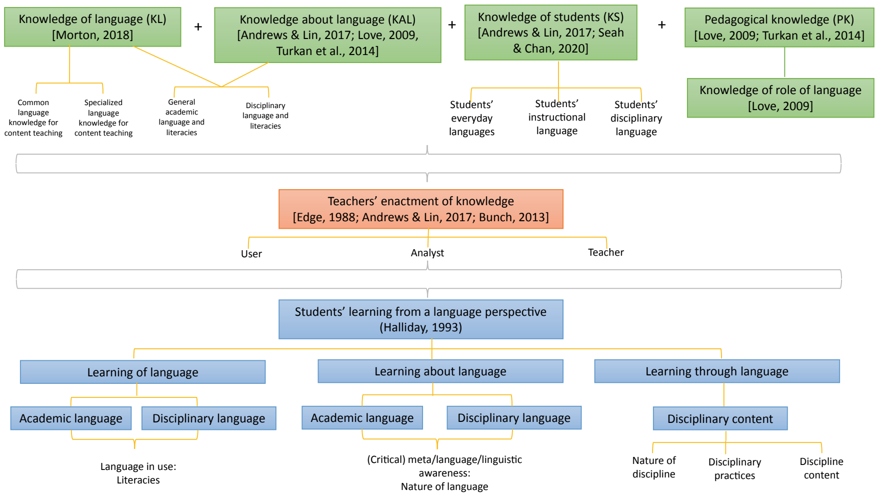

Fig. 1.1 Language-related knowledge base for content teaching (LRKCT)

The link between the main components and teacher roles as language user, language analyst and language teacher is shown in the centre of the figure. This also captures the positioning of teacher roles in classroom enactment.

Students' learning—encompassing the learning of, about and through language and linked with (general) academic language and disciplinary language—is shown at the bottom of the figure. Ultimately, language learning and learning in content instruction require language in use in the form of disciplinary literacies, while learning about language leads to awareness of the nature of language which constitutes students' (critical) meta/linguistic/language awareness depending on the extent of their KAL. Finally, learning through language refers to the learning of the disciplinary content, practices and its epistemic and ontological nature that is made possible through language. This connects to teachers' knowledge and enactment as contributors to students' learning.

The segments of the visual representation are not intended to be interpreted as hierarchical but as interactive. For example, students' learning can act as a feedback mechanism to teacher enactment and support continual teacher knowledge development.

1.2.6 LRKCT for Content Teaching and the PCK of Language Teachers

We recognise links between the LRKCT for content teaching and the PCK of a language teacher: these overlap when content teachers explicitly teach academic language as part of teaching content, with academic language serving as the conduit by which the distinctive features and conventions of the disciplinary language are manifested. Nonetheless, the scope for content teachers to prioritise the teaching of academic language is less than the scope of a language teacher.

In this volume, our focus is on content teaching and content teachers which we see as being distinct from teaching a specific linguistic variety. Depending on the curriculum, language teachers are usually not expected to teach the distinctiveness of various disciplinary languages. Exceptions might be classes emphasising Language for Specific Purposes, typically English for Specific Purposes (ESP). ESP refers to "… the teaching and learning of English as a second or foreign language where the goal of the learners is to use English in a specific domain" (Paltridge & Starfield, 2013, p. 2) (e.g., medical English, English for tourism). Thus, ESP has a strong content component but the focus is on language learning. A recognised sub-field is English for Academic Purposes (EAP) which stresses language learner needs for academic language in general. This includes both native and non-native speaker needs and encompasses needs of students (K-12 and tertiary) and academics (especially non-native English users who use English for international, scholarly communication). Though the goal of ESP is usually to address the needs of specific learners (e.g., hotel workers or research students), the research has been criticised as being overly normative, prioritising English not as *an* academic language but as *the* academic language and neglecting the social–political influences on language use and learning in academic contexts. One useful point we take away from studies of EAP is the importance of considering learner needs not simply to instil normative practices but to understand disciplinary practices as social and to consider specific socio-political–contextual concerns as they link to LRKCT. Charles (2013) provides an overview of EAP but for our purposes it is sufficient to note that while there are some overlaps of interest, EAP still tends to be focussed more on language learning than on language-related knowledge for content learning.

1.2.7 LRKCT and the PCK of Content Teachers

Among previously published studies, there exist different views on the boundary between the constructs of LRKCT and PCK. While Bunch (2013) conceived of Pedagogical Language Knowledge (PLK) as conceptually distinct from PCK, Love positioned literacy PCK as part of the PCK of content teachers. The latter viewed teachers' understanding of "the role of language and literacy in learning disciplinary content" as "a key component" of PCK (p. 541). She identified three sub-components when unpacking literacy PCK: (1) "knowledge about how spoken and written language can be best structured for effective learning"; (2) "recognition that subject areas have their own characteristic language forms and hence entail distinctive literacy practices"; and (3) "capacity to design learning and teaching strategies that account for subject-specific literacies and language practices" (p. 541). She discussed these sub-components as constituents of KAL that are essential for teachers to acquire as they progress in their professional development. The lack of clarity on boundaries may stem from a lack of consensus of what constitutes PCK. By contrast, the LRKCT framework distinguishes between the three sub-components by characterising (1) and (3) as PK and (2) as KAL, hopefully bringing more clarity to the distinctiveness of each component as well as coherence to the ways the components are interrelated.

As research on such a knowledge base is limited, it is perhaps unrealistic to draw a clear boundary between the LRKCT and PCK of content teachers, let alone comment on how the two constructs interact with each other. The intricate interrelationships between language and content (Fang, 2014) also mean that there are likely to be aspects of knowledge that involve both. Nonetheless, as noted by Morton (2016), "it is important to conceptually map out the types of knowledge in order to move towards adopting measures to facilitate their development in teachers", distinguishing the language and content dimensions in teacher knowledge base is thus "both an analytic and a practical move" (p. 278). We note that both LRKCT and PCK have sociocultural underpinnings. The teachers' knowledge base of language, pedagogy and the content they teach is always situated in the particular contexts of their teaching and professional learning. This volume is intended to conceptually map this knowledge base as an analytic and practical move and offers chapters that demonstrate how components of this knowledge base are both mobilised and developed when teachers confront the daily problems of their professional practice. While more research is needed to understand how teachers develop and can be supported to develop a language-related knowledge base for content teaching, it is our hope that this volume illuminates some of the ways the LRKCT and PCK of content teachers are interrelated and mutually reinforcing.

1.3 Overview of the Volume

1.3.1 Sociocultural Perspectives

The chapters address different academic subjects (e.g., physics, history), but there are common themes of teacher professional learning through engagement in collaborative studies, inquiry-based learning and knowledge building approaches to teaching and learning. In addition, the studies suggest ways to enhance LRKCT through pedagogical resources and implementations which incorporate classroom dialogue and talk moves, read-alouds, functional literacy and multimodality.

In addition, the chapters in this volume all locate their work within a sociocultural perspective on language and learning, broadly defined. Briefly, the work presented in this volume sees language and learning, including teacher professional learning, as socially, historically and culturally situated. Culture, in this view is seen as a system of meanings which can be linked to notions of practice (Göncü & Gauvain, 2012). This view aligns with the studies in this volume which investigate the systems of meaning and semiotic practices which are part of language-informed content teaching. Each empirical study focuses on a specific context for teacher professional learning with consideration of how the specific educational, disciplinary/content and language needs intersect. For example, Adams and Lim (Chap. 3) and Seah and Silver (Chap. 2) make use of inquiry cycles and teacher-collaborative research to carefully situate their studies in specific sociocultural contexts of teacher professional learning.

A sociocultural perspective also points to understanding language, knowledge, discourse and learning as always embedded in ideology and relations of power (Baildon & Damico, 2011). As learners encounter multiple discourse communities in their everyday lives, there is also a need to consider how these discourses, or uses of language, are legitimated, and disseminated in various communities (Segall, 2006), for example in educational or scholarly communities. Ardell and Yoder (Chap. 10) consider how culturally and linguistically responsive pedagogy links with pedagogical language knowledge to empower learners to engage with social studies texts. Accurso and Levasseur (Chap. 5), in contrast, examine how the development of disciplinary linguistic knowledge (DLK) over time empowered the case study teacher (John) to see himself not only as language user but also language analyst and teacher in the context of science teaching to English language learners. In another example, Wrenn and Stanley (Chap. 9) base their study in critical disciplinary literacy to consider power and culture in disciplinary settings, especially potential power imbalances between professor/researcher and pre-service teacher participants but also as represented in the historical texts used in the study.

Being aware of multiple forms of language use as sociocultural practices and being able to draw on different language uses for educational purposes places a number of demands on learners and teachers as evidenced in the chapters in this volume. Patrick and Yang (Chap. 4), for example, note the need to consider not only contextual factors such as school culture but also personal factors such as conceptions of science and knowledge of English grammar in terms of demands on teachers. Seow, Ho and Lin (Chap. 11) highlight how talk moves as a pedagogical strategy can work with multimodal data to engage students for the study of Geography. Prain (Chap. 7) raises questions on how the multimodal nature of learning links to "disciplinary language" as social semiotic practice. Fitzgerald, through a detailed analysis, shows how (linguistic) causal constructions go beyond everyday usage and are crucial to historical thinking.

1.3.2 Systemic Functional Linguistics

Due to the specific interest in language as social semiotic, most of the chapters make reference to Systemic Functional Linguistics (SFL) (e.g., Halliday, 1993)—a social semiotic approach to language learning and use. As Hao (2020, p. 6) explains, "SFL distinguishes itself by treating knowledge and semiotic resources as unified phenomenon". Hammond in her discussion of links between "dialogic teaching" and SFL goes further, stating "A key tenet of systemic theory is the argument that there is a systematic and mutually predictable relationship between form of language and the context in which it occurs" (2016, p. 10). Thus, SFL approaches tend to look for ways in which linguistic forms are used systematically in relation to content (e.g., as academic or disciplinary language). In addition, SFL has been used in previous scholarship to investigate pedagogy, including content pedagogy, and teacher professional learning. For example, Harman and Simmons (2014) investigated content teachers engagement with critical text analysis through an SLF lens. In another example, Sembiante et al. (2021) investigated teacher candidates (pre-service teachers) and found that the knowledge base of SFL, including understandings of “everyday” and “scientific” language, was acquired through phases.

In this volume, SFL is referenced in discussions of “functional language”, e.g., how language is used to make meanings in science (Patrick & Fang, Chap. 4) and as part of contextualised linguistic decisions (e.g., pre-service teachers learning to teach academic language, Wrenn & Stanley, Chap. 9). In three chapters, SFL plays a more prominent role. For example, Accurso and Levasseur (Chap. 5) use SFL concepts of register (language variation by situation) and genre (patterned registers which can be identified as recurrent text types) in the development of teachers' disciplinary linguistic knowledge (DLK). Fitzgerald (Chap. 8) provides some useful background on SFL and discusses teacher preparation to support analysis of causal structures (linguistic structure stating or implying causation) in historical texts as a way of highlighting the importance of teachers' DLK to support student content learning. Ardell and Yoder (Chap. 10) also discuss historical texts—in their case noting that seemingly “everyday language” can have different (metaphorical) meanings in historical registers leading to difficulties in student understandings which teacher must address through their own pedagogical language knowledge (PLK).

While readers do not need to know details of SFL analyses or theory as each chapter explains their use, it is useful to remember that this approach sits well with sociocultural perspectives on teaching and learning and has been used in numerous prior studies on content and language teaching, including studies related to teacher professional learning.

1.3.3 Building on the LRKCT Framework

Building on the LRKCT framework of this introductory chapter, ten empirical studies constitute this volume. They are broadly classified under the following themes (1) Studies in Science and TLA and (2) Studies in Social Sciences and TLA. A final commentary concludes the volume. The first six chapters under the theme of Science and TLA came from studies conducted in the USA, Australia and Singapore, while the four chapters under the second theme were conducted in the USA and Singapore. Five of the volume's chapters focus on secondary content teaching, three chapters are studies of primary classrooms, and two of the chapters examine content teaching issues in both primary and secondary classrooms. Each chapter provides information on the specific educational context and the purpose of the empirical study.

Drawing on the LRKCT framework in this introduction, Seah and Silver (Chap. 2) unpack the language-related knowledge components of science teachers.

Their chapter demonstrates how the main constructs in the framework can enable science teachers to understand the language demands of science and translate this knowledge to classroom practice. Based on an empirical study of six teachers from primary and secondary schools, the chapter demonstrates how a series of inquiry cycles focused on students' writing helped develop teachers' language awareness (specifically in KAL and KS) and how the teachers in the study were able to apply various aspects of KAL and KS in their teaching.

Inquiry cycles are also relevant in Adams and Lim's study (Chap. 3). They examine the reflections and learning of five teachers who adopted the use of a functional literacy approach in teaching science. This teaching approach, introduced to teachers through a professional learning model that emphasises inquiry and knowledge building cycles in collaboration with language experts, offers an example of how content teachers can engage in discussion with their students about language use within the discipline. The chapter foregrounds the importance of LRKCT in content teaching as the teachers reflected on the language awareness gained and their experiences in designing a communicative classroom and making learning visible. The study offers insights into how language experts could work collaboratively with content teachers to introduce instructional strategies for language-content integration in school subjects.

Science reading is the focus of the teacher professional development study by Patrick and Fang (Chap. 4). While noting that teachers in their study developed an understanding of important links between science reading and language, the researchers also noted the importance of personal factors such as conceptions of science, knowledge of English grammar, past learning experiences and of factors external to the training such as school culture and level of support from school administrators. The study demonstrates the importance of multiple factors for encouraging teachers to engage in evidence-based language and literacy practices in science education. Their findings link to the LRKCT framework by highlighting the role of KL, KAL but especially KRL as part of teacher professional development to support PCK and especially literacy PCK (cf. Love, 2009).

Accurso and Levasseur (Chap. 5) provide a four-stage account of the DLK development of a science teacher. The development trajectory of the teacher provided a backdrop to underscore the importance of the language-related knowledge that a content teacher can develop and apply in classroom instruction. The knowledge manifested in the use of functional metalanguage (adopted from the tradition of Systemic Functional Linguistics) enabled the teacher to view and experiment with classroom discourse in innovative ways. The developmental account offers readers an intimate look at the challenging but fruitful journey of this teacher as he grappled with acquiring DLK and reflected on his learning. The authors extend beyond the LRKCT framework in their consideration of how power, ideology and sustainability matter in developing DLK.

Yeo and Tan (Chap. 6) consider how a focus on semantic meanings can support meaning making through integration of multimodal resources. Their particular concern is in helping teachers address key aspects of the language of science (i.e., technicality, abstraction, information density) through an image-to-writing teaching approach which engaged students in constructing meaning through visual representations before engaging in science writing. Their chapter extends the notion of PCK in the LRKCT framework by introducing pedagogical-representational-content knowledge (PRCK).

The Representation Construction Approach (RCA) is raised in Prain's study (Chap. 7). This approach advocates the learning of science through inquiring into and constructing representations as resources for reasoning and claim-making. In this chapter, the importance of LRKCT is brought to the fore by highlighting the role of KAL (e.g., science's symbolic meaning-making processes, affordances and constraints of the various modes of representation in science), KS (e.g., prior understandings and representational resources of students) and PK (e.g., designing representational challenges, strategic questioning to guide the inquiry process) that are needed to enact the RCA approach. The two case studies in this chapter exemplify how this knowledge base was integrated in the teachers' instructional strategies. More importantly, the chapter extends beyond the LRKCT framework to highlight the multimodal nature of the knowledge base required, particularly within the science education context.

Turning to the chapters on Social Sciences, Fitzgerald (Chap. 8), like Accurso and Levasseur, draws on the lens of DLK. The study examines high-frequency causal constructions used in history textbooks and primary source documents that are used in history instruction. Since causation is a core concept in learning history and developing historical thinking skills, the chapter examines three high-frequency causal constructions important for teachers to understand—cause circumstantial, causative and causal asyndetic constructions. In doing so, Fitzgerald illustrates the importance of teachers' KAL and practical pedagogical strategies (PK) they can employ in the classroom to develop students' disciplinary language knowledge to work with different types of historical texts and to better understand the past.

Wrenn and Stanley (Chap. 9) offer an action research study that investigates the ways different groups of pre-service teachers design and implement historical read-aloud lessons in their elementary practicum classrooms. The authors highlight the role of critical disciplinary literacy as a form of KAL that provides a critical understanding of disciplinary language as well as equity-oriented PK. By introducing pre-service teachers to dialogic and critical talk moves, the chapter demonstrates how KRL can enhance teachers' language awareness in using inquiry-oriented and student-centred historical thinking read-alouds with different types of texts.

The role of PLK with emergent bilingual learners to address the use of figurative language in social studies content is addressed by Ardell and Yoder (Chap. 10). Using a PLK-noticing framework to build teacher language awareness, the authors provide a case study of an upper elementary teacher's linguistic interactions with emergent bilingual students during lessons on plate tectonics and the underground railroad. Using the noticing framework, Ardell and Yoder highlight Missed Linguistic Opportunities as a metalingual form of KAL that can support teachers as language analysts as well as help them provide more explicit instruction to support students' development of disciplinary language and literacy skills.

In a collaborative undertaking to support student engagement in geography learning, Seow, Ho and Lin (Chap. 11) worked with classroom teachers to better understand and make use of dialogic teaching, inquiry-based pedagogy and multimodal data analysis. Their study is part of a larger "Whole-School Approach to Effective Communication in English". Their analysis determines that teachers spend considerable effort in employing multimodal resources (e.g., creating, discussing, understanding graphs); however, the dialogues around the resources often lead to teachers decoding the data rather than scaffolding students in decoding the resources and integrating this process knowledge into their geographic understanding. As they engaged with the teachers over time, the teachers became more language aware in terms of how the classroom discourse helped to construct geographical knowledge. Their study highlights the interplay of the factors in the LRKCT model including the segments of Students' Learning and Teacher's Enactment of Knowledge.

The final chapter by Bunch provides a commentary on chapters in this volume, noting the central role of language and teachers' need to know about this central role. He also raises the crucial question of "What do we mean by 'language'?" and highlights how the studies are based in sometimes differing conception of language and what teachers should prioritise when trying to address language and content. The commentary ends by highlighting the importance of "knowledge of students" (as in the LRKCT framework), of valuing students' linguistic repertoires and of addressing this in teacher education. The commentary, then, serves to not only reflect on the chapters but to encourage readers to reflect as they continue in their quest to develop students' language and literacy practices in the various disciplines.

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Part I
Studies in Science and TLA

Chapter 2
Unpacking the Language-Related Knowledge Components of Science Teachers Through the Language Awareness Lens

Lay Hoon Seah and Rita Elaine Silver

Abstract Research from both science and literacy education has provided a rich repertoire of ways that the language demands of science can be addressed in classrooms. However, there has been relatively less research on knowledge required by teachers, so they can fully leverage on this repertoire. This study builds on the LRKCT framework proposed in Seah, Silver and Baildon (this volume) by identifying the main constructs in the framework within the domain of science education through empirical investigation. It focuses on unpacking teacher knowledge through the teacher language awareness (TLA) lens proposed by Andrews ((2008). While the notion of TLA has been traditionally applied to language arts education, particularly in second language acquisition, more recent attempts have sought to apply this notion in the context of content education (Andrews & Lin 2017). This study extends this line of research by illustrating how the TLA lens can be used to provide a framework for capturing the foundational knowledge base that science teachers need in order to understand the language demands of science and to translate this knowledge base to classroom teaching. The data came from a study testing the assumption that raising science teacher's language awareness improves their capacity to address the language demands in science lessons. A total of six teachers (from primary and secondary schools) took part in the project. To raise their TLA, a series of inquiry cycles based on their students' writing was conducted. In the process, language-related knowledge to support science learning and communication was invoked and shared among the researchers and teachers.

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2.1 Introduction

Like language in other disciplines, the language used in science has acquired its own unique lexicon, grammar and semantics to meet its particular disciplinary requirements (Gee, 2004). An important aspect of science learning entails mastering disciplinary-specific ways of reading scientific texts (Shanahan et al., 2011) as well as the use of unique grammatical features and text structures of science genres (e.g., Unsworth, 2001). Studies have developed and tested the efficacy of numerous teaching strategies and practices that support learners' language and literacy skills in science, providing a rich repertoire of ways for addressing these learning demands (e.g., Fazio & Gallagher, 2019; Rose & Martin, 2012). Often these strategies and practices need to be embedded in a discourse that entails teachers recognizing and explicating the features, conventions and requirements of language used in science. However, there is little research that unpacks the language knowledge required by science teachers to optimize these strategies and achieve the learning gains that these strategies have been shown to accomplish. Research on science teachers' knowledge and skills has focused mainly on teacher knowledge related to addressing the conceptual demands of science (e.g., pedagogical content knowledge, PCK) (Kind, 2009). Comparatively, studies on science teachers' knowledge required for teaching the language and literacy of science are rare.

2.2 Literature Review

2.2.1 The Importance and Role of Language-Related Knowledge in Science Teaching

Students' struggles with the language of science have been well documented (Afitska & Heaton, 2019). These struggles may be, for example, related to learning science in another language (Maerten-Rivera et al., 2010), the transitions across different discourse communities (everyday, school and science) (Yore & Treagust, 2006) and learning the disciplinary practices associated with generating scientific discourse types such as argumentation and explanation (Swanson et al., 2014). Students need to overcome these obstacles if they are to master the language of science because this mastery serves not only as a communicative tool in science classrooms but also as an epistemic and rhetorical tool (Carlsen, 2007).

More explicit instruction is advocated to overcome students' struggles in learning the language of science (Fazio & Gallagher, 2019). Despite this advocacy, some obstacles stand in the way, including limitations in teachers' knowledge (Morton, 2016) and lack of professional development opportunities (Tedick et al., 2011), as well as beliefs that language objectives are not part and parcel of science teaching (e.g., Hüttner et al., 2013). While an increasing number of studies have identified language-related knowledge that would be useful for content teachers (see Seah, Silver & Baildon, this volume), much of the knowledge was derived theoretically, often by a review of the literature, rather than empirically from the actual practices embedded within content classrooms. These studies also tended to focus on content-language integration with a particular focus on English language learners (ELLs). Research on the language knowledge required by teachers of specific content, such as science, but not necessarily for language learners, is rare. An exception is a case study done by the first author which examined the knowledge of students (KS) possessed by a science teacher who was highly articulate in the language-related challenges encountered by her students. Her KS included student's prior knowledge of and about scientific language, difficulties with scientific language and its use, differences in ability across language skills, differences in language ability across subject areas and learning progress in language use over time (Seah & Chan, 2020). However, these components of KS relate to generic language-related knowledge, hence are less illuminating of the specific features of the scientific language teachers need to know. More studies are needed to reveal the specialized language knowledge that teachers need to teach the language and literacy practices unique to science to all students and not just ELLs.

This study addresses this gap by empirically establishing the language-related knowledge base relevant to science teaching. This was accomplished by a research design that concurrently generated knowledge based on the contingent needs of the teachers and of the students involved in the study. Such an in situ study has the benefit of authenticity and ecological relevance. The research design involved enhancing the science teachers' language awareness by involving them in iterative cycles of collaborative inquiry using students' written artifacts as the object of inquiry. The teachers selected student writing samples that were of concern to them, primarily those displaying issues related more to the use of language rather than conceptual understanding. Researchers and teachers worked together to examine these artifacts to learn about the underlying challenges students likely faced. In the process, teachers were introduced to linguistic tools and knowledge that would help them examine and/or understand students' challenges. The knowledge generated through this collaborative process was the target of this study. We also examined how the teachers leveraged this knowledge in their teaching. Our analysis was thus guided by the following research questions:

1. What knowledge related to language was invoked during the inquiry sessions?
2. How was the language-related knowledge manifested in the teaching?

2.2.2 The Lens of Teacher Language Awareness

The theoretical lens of teacher language awareness (TLA) underpins this study. Used mainly in second language (L2) teaching research, TLA denotes "the knowledge that teachers have of the underlying systems of the language that enables them to teach effectively" (Thornbury, 1997, p. x). It is "essentially concerned with subject matter knowledge (specifically, knowledge of the language) and its impact upon teaching" and involves the ability to understand how the language works and to analyze it (Andrews, 2007, p. 24). Originally narrowly confined to knowledge about language (KAL), it has since evolved to encompass teachers' awareness of their students' use of language, KS, as well (Andrews, 2008). In addition, there are two dimensions to TLA: a declarative dimension which emphasizes the knowledge that a teacher needs and a procedural dimension which emphasizes the use that the teacher makes of such knowledge. The *declarative* dimension is constituted by the three components of knowledge of language (KL), knowledge about language (KAL) and knowledge of students (KS) within the LRKCT framework. The *procedural* dimension relates to the use of declarative knowledge in talking about the teachers' own knowledge, language analysis and teaching. This dimension is distinct from the notion of pedagogical knowledge within the LRKCT framework because while the former depends on the teachers' pedagogical knowledge particularly in teaching, it is the applicability of their KL, KAL and KS that is foregrounded.

TLA as required by a teacher is not exactly the same as the knowledge required of a competent user of the language. Beyond the levels of implicit and explicit knowledge of the language for effective communication, a teacher "needs to reflect upon that knowledge and ability, and upon her knowledge of the underlying systems of the language, in order to ensure that her students receive maximally useful input for learning" (Andrews, 1999, p. 163). This reflective component relates to another feature of TLA: its *metacognitive* nature, given its emphasis not only on KAL per se but also as a reflection on KAL to translate the knowledge into a form that would be useful to learners. This reflective dimension links the declarative dimension to the procedural and explains the preference for the use of the word 'awareness' over 'knowledge' in this construct (Andrews, 2007). TLA can impact teaching of and about language in a number of ways (Andrews, 2007). For example, it can shape teachers' selection of language sources as input for learners, their abilities to spot opportunities to stimulate a discussion on language issues, their provision of corrective feedback to students as well as their design and use of relevant language activities.

For the purpose of this study, we focus on the declarative knowledge invoked during the inquiry sessions and the teachers' procedural use of the newly acquired declarative knowledge in their teaching.

2.2.3 The Relevance of TLA to Science Teaching

We propose three reasons for the relevance of TLA in science teaching. First, learning science involves not only the abstract and often counterintuitive ideas that explain natural physical phenomena and scientific concepts and principles, but also the capacity "to control the unique linguistic forms and structures that construct and communicate scientific principles, knowledge, and beliefs" (Fang, 2005, p. 337). It follows that teaching science involves making the conceptual knowledge of science accessible as well as helping students make sense of and effectively engage in the practices of science through appropriate uses of language. Teaching the language of science is thus an important role of science teachers. Second, there are inherent differences between 'everyday' English and scientific English. Students need more than just basic proficiency in English in order to talk and write science (Shanahan & Shanahan, 2008). Seen in this light, learning the language of science can be compared in some ways to the learning of a 'second' language. Third, research has often emphasized the importance of explicit instruction of the language features and structures of science (e.g., Rose & Martin, 2012). To be able to provide such explicit instruction, science teachers need not only fluency with scientific language but also a certain level of awareness of scientific language.

These reasons suggest that TLA can be important to science teachers who have to equip students with the ability to learn the language of science with its distinctive features, norms and conventions (Andrew & Lin, 2017). For example, in a comparative case study of three science teachers working with classes of multilingual students, Seah and Silver (2018) showed how one exemplary teacher gave rationales for language use in relation to science rather than language learning. This was indicative of her "awareness that language is not peripheral to the study of science but embedded in it" (ibid., p. 11). Thus, TLA in science teaching focuses on form-function connections in science as a resource for meaning-making (Halliday, 2004).

In this study, the notion of TLA was used as an analytical tool to examine the knowledge required of and displayed by the participating teachers over the course of the inquiry process. The main aim was to investigate the nature of TLA that was drawn upon in the process of supporting science teachers in their quest to address the language demands of science in science instruction.

2.3 Research Design

This project adopted a case study approach (Stake, 1995) with an inquiry-based intervention to study the process undertaken by individual teachers in collaboration with researchers, as they planned and enacted their lessons with students in order to develop science writing. Since most assessments are primarily in written form, science writing provides a useful starting point to engage teachers with the issues of language use, given teachers' predominant concern with assessment (Deng & Gopinathan, 2016). Students' written artifacts are also a readily available, concrete and practical resource for inquiring into students' language use. Their writing is also generally more considered and representative of their academic language abilities compared to their oral language.

Table 2.1 Profile of participating teachers

Teacher	Grade level (science subject)	No. of years of experience	Academic major
Aaida	Grade 5 (Science)	8	Business
Hana	Grade 5 (Science)	10	Business
Yiling	Grade 7 (Science)	38	Education
Bao-fei	Grade 10 (Biology)	4	Science
Hsu-mei	Grade 10 (Biology)	8	Science
Tasha	Grade 10 (Biology)	11	Science

2.3.1 Research Context

A total of six teachers, two teaching Grade 5 (11 years old), one teaching Grade 7 (13 years old) and three teaching Grade 10 (16 years old) took part in this study. They came from two primary schools and two secondary schools in Singapore (Table 2.1). These were mainstream schools which mainly served their immediate neighborhoods and hence comprised students of a wide range of academic and language abilities. The teachers differed in their years of teaching experience, ranging from 4 to 38 years, with a median of 9 years. They also differed in their educational backgrounds with the secondary school teachers (except one) trained in science-related majors, while both the primary schools teachers majored in non-science-related fields. Only one of the teachers had formal studies or in-service training specifically in the area of language use and demands in science prior to participating in this research.

In Singapore, students begin science education from Grade 3 and use English as their language of instruction throughout their 10 years of compulsory education (i.e., Grades 1–10), except for their Mother Tongue (typically Mandarin Chinese, Malay or Tamil) classes.

2.3.2 Inquiry Cycle

Participating teachers engaged in iterative inquiry cycles of TLA in relation to science teaching and learning. In each cycle, teachers examined students' written artifacts with the researchers in a pre-lesson inquiry session, planned and enacted lessons and finally reflected on the lessons enacted with the support of the researchers in a post-lesson inquiry session (Fig. 2.1).

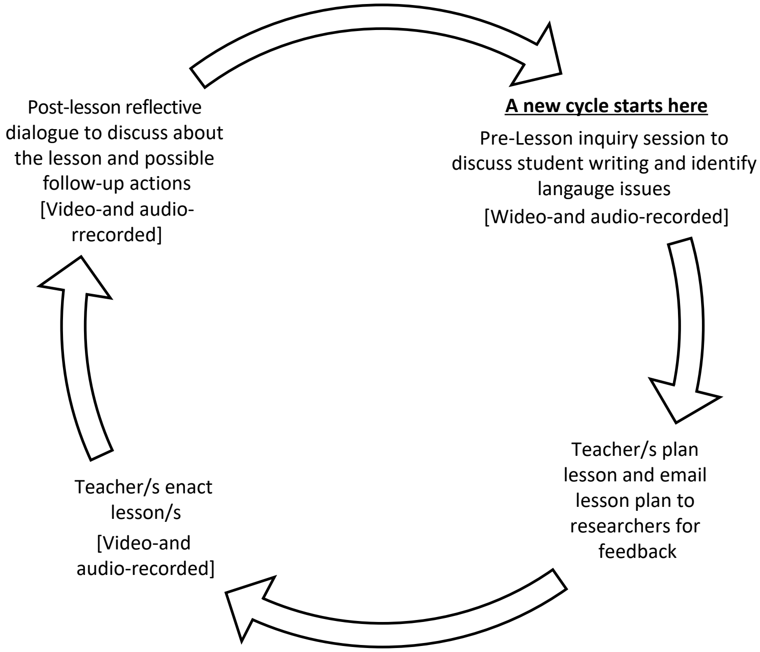

Fig. 2.1 Process involved in each inquiry cycle

Timperley, et al. (2007) found that engagement in evidence-informed inquiry is essential for teacher professional learning and development. In addition, they found that having external experts work with teachers in iterative ways, such as involving discussion and the development of meaning in classrooms, is more successful than having external experts expect teachers to implement specific, preferred practices. In this study, external experts served to introduce new perspectives and assist in challenging the current practices in place, to present teachers with new possibilities and to keep the focus on student learning (Timperley, 2008). The researchers mainly adopted a functional language perspective (Fang, 2005) in discussing with teachers the language challenges reflected in student writing. For example, instead of focusing on traditional grammar rules, the researchers only attended to language features that affected the representation of scientific meanings.

During the pre-lesson inquiry sessions, which were video- and audio-recorded, the research team provided support in the forms of thinking prompts to facilitate analysis of the artifacts and lessons, metalanguage to talk about various aspects of language and the issues that warranted instructional attention and possible resources, and instructional strategies to address surfaced issues. The teachers were given the autonomy to develop their own lesson plans to address the issues which surfaced during the pre-lesson inquiry sessions. Whenever possible, the lesson plans and teaching materials were shared with the researchers prior to lesson enactment for feedback. Lessons were enacted, observed and video- and audio-recorded. Subsequently, the researchers engaged in post-lesson dialogs with the teachers to further reflect on the extent to which the lessons addressed the targeted language objectives as well as the improvements that could be made for future lessons. This provided the foundation for embarking on deeper inquiry in subsequent cycles. Each teacher went through three to five inquiry cycles. As each cycle took place over a month or more, the student writing examined during the various pre-lesson inquiry sessions was often of different topics. Except for the inquiry sessions with the Grade 10 teachers, all the inquiry sessions were conducted with individual teachers. Researchers worked with the Grade 10 teachers in a combination of individual and group sessions depending on the needs of the teachers.

2.3.3 Data Sources

Videos collected from the pre- and post-lesson inquiry sessions as well as the lessons were transcribed verbatim. The transcripts captured the interactions that the teacher had with the whole class as well as with individuals or groups of students. Contextual cues that aided the interpretation of the content of the whole-class instruction were also added to the transcripts. These transcripts (24 from pre-lesson inquiry sessions, 42 from lessons, 24 from post-lesson inquiry sessions) served as the main data source for analysis. Other relevant data included the student writing samples discussed during the inquiry sessions as well as the teaching materials and student artifacts from the lessons.

2.3.4 Analysis

An interpretive stance was taken toward the data by viewing the meaning of language as contingent on its use at a particular moment in time and space in the flow of a social situation (Bloome & Clark, 2006). Analyses of the data were first conducted at the individual level where the focus was on illuminating the knowledge that was invoked during the inquiry with each teacher. The findings were subsequently examined at a collective level and coded along the declarative and procedural dimensions. Analysis of the declarative dimension of TLA (dTLA) was intended to address RQ1, while analysis of the procedural dimension of TLA (pTLA) was intended to address RQ2. Figure 2.2 summarizes the data sources and the main analytical steps undertaken to unpack the various components of TLA.

2.3.5 Declarative TLA (dTLA)

The transcripts from the pre- and post-lesson inquiry sessions were particularly useful for identifying dTLA as it was during these sessions that the relevant knowledge was

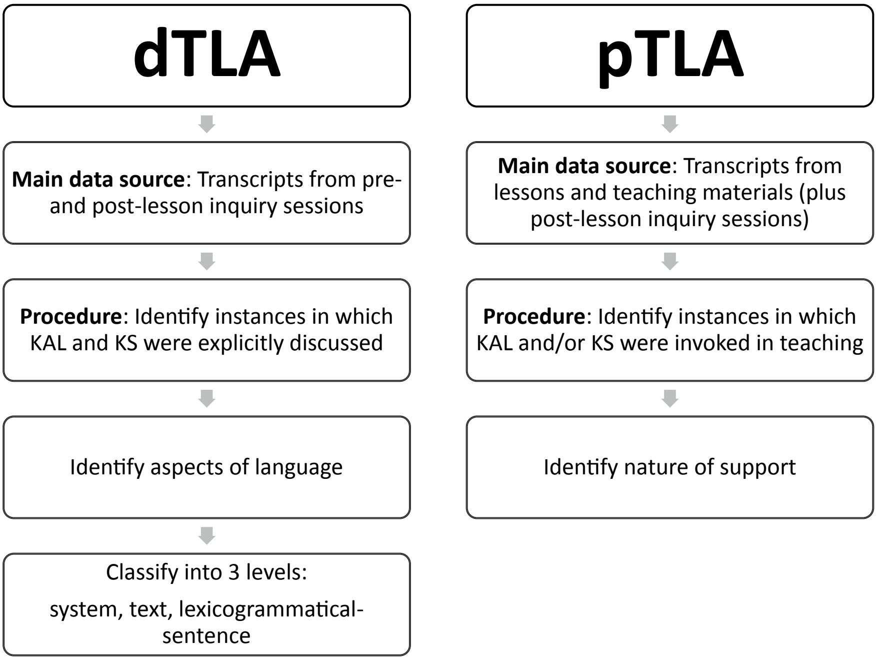

Fig. 2.2 Data sources and main steps of analysis for dTLA and pTLA

made explicit, mainly elicited by the student writing that was the focus of inquiry. Within dTLA, there are three components: KL, KAL and KS (Andrews, 2008). For the purpose of this study, we focused mainly on unpacking KAL and KS.

In this study, KAL denotes the conscious and explicit knowledge of the nature and features of scientific language that was drawn upon either during the inquiry cycles or the classroom lessons conducted. Given its nature, KAL was inferred primarily from the content of talk (either between teacher/s and researcher/s or during class). For example, in Excerpt 1, the researcher (R) and the teacher were discussing one difference between oral and written languages: the use of pronouns such as ‘it’.

Excerpt 1

R: One of the issues we’ve highlighted so far, in this case the use of ‘it’. They can be traced back to ways we use spoken language. We tend to use ‘it’ very liberally because in spoken language we’ve gestures, we’ve our videos, we’ve our powerpoint slides. So we use ‘it’ and by just pointing, everybody will understand what we’re referring to. But in written language you can’t because the [referent of] ‘it’ and ‘they’ have to be contained in the sentence itself. So that’s one of the differences between written and spoken language.

Differences between oral language and written language were thus among the KAL components identified. Discussion of these components could be initiated by the teachers or the researchers and subsequently became part of the knowledge base applied by the teachers in their analysis of student writing, their oral interactions or design of lessons.

KS is closely related to KAL as some KS components indicate specific challenges related to various KAL components that students face. For example, one teacher commented on the difficulties that students displayed in their writing in terms of lack of or inappropriate use of linguistic resources: "Of the most common ones i.e., errors, I see that for myself, and also that's my impression, that non-specific and irrelevant words keep coming up".

The various KAL and KS components were further classified into three levels: system, text and lexicogrammatical (LG)-sentence levels.

- System-level KAL components refer to the broad understanding inquirers have of the scientific language as a system rather than of particular texts.
- Text-level KAL components refer to the knowledge about particular text types.
- LG-sentence-level KAL components cover the spectrum of knowledge that relates to meaning, feature and function of individual words (both lexicons/vocabulary and grammatical resources such as pronouns and prepositions) to their use in sentence making.

Though the focus of KS in this study is from the language perspective, the 'inextricably intertwined' relationships between content and language (Fang & Coatoam, 2013, p. 628) means that the aspects of KS identified here are related as much to students' conceptual understanding as their use of language.

2.3.6 Procedural TLA (pTLA)

The broad ways in which teachers make use of their KAL and KS constitute pTLA. Hence, the lesson videos as well as the teaching materials used during the lessons were the main source of data for addressing RQ2. Another data source was the post-lesson dialogs in which the teachers reflected on how language awareness gained during the pre-lesson inquiry sessions impacted their teaching. To detect pTLA components, we identified instances in which the teachers provided support for student writing during the lessons and when the teachers described such instances during the post-lesson dialogs. In Extract 2, the teacher read out a sentence from a student's written work and then commented on the sentence.

Extract 2

> T: "Gradually affect organisms in the wild". Ah what word is this? [referring to the word 'affect'] Action word right? This action is non-specific. 'Affect' can happen in so many ways. Can you please give some examples right? ... So if you are writing non-specific verbs, think about it, think again okay.

In Extract 2, the teacher was explicit about the nature of the language that was expected of students in science writing—the use of specific action words.

The researchers also identified features in the teaching materials that supported students in understanding the language conventions and requirements in science. These instances were classified based on the nature of the support into various pTLA aspects, with each of them denoting the way in which the teachers provided the support. For example, Extract 2 was classified as use of metalanguage (underlined words in Extract 2).

2.4 Findings

The findings for RQ1 are presented in tables below. Table 2.2 highlights KAL components at system, text and LG-sentence level invoked by both researchers and teachers in inquiry sessions with explanations. Table 2.3 highlights KS components at all three levels, also from the inquiry sessions. The last section, which addresses RQ2, highlights how KAL and KS were manifested by the teachers in their teaching (i.e., their dTLA).

2.4.1 Knowledge About (Scientific) Language (KAL)

Twelve KAL components were identified in the analysis (Table 2.2). Many of these components were drawn from cumulative and related episodes across transcripts and teachers rather than isolated instances in individual transcripts.

2.4.2 Knowledge About Students' Language (KS)

A total of seven KS components were identified and classified into the same three levels as KAL (Table 2.3). More components were identified at the LG-sentence level than the other two. This was particularly prominent in the primary science classes given that the students at these grade levels were learning basic and disciplinary literacies concurrently. These seven KAS components constitute the knowledge base about students' language that was co-constructed as student writing was analyzed and a better understanding of student language challenges students was sought.

2.4.3 Procedural Dimension of TLA (pTLA)

pTLA denotes how teachers apply the various aspects of KAL and KS in their teaching, which addresses RQ2. The teachers' various KAL and KS components were manifested in six distinct ways through: (1) use of metalanguage, (2) activity design, (3) task scaffolds, (4) use of student writing as resources for teaching and learning, (5) use of visual aids to facilitate learning about language and (6) feedback for students.

Table 2.2 KAL components

Level	KAL component	Comments
System	(1) Differences between everyday and scientific languages	Usually invoked when researchers and the teachers discussed the language demands unique to science, such as how everyday conversational English does not entail the level of precision as required in science nor are certain terms in everyday life used the same way in scientific contexts
	(2) Knowledge required to construct scientific texts	Refers to knowledge required by students when formulating scientific texts such as explanations, for example (a) content knowledge related to the conceptual understanding students need to construct texts that align with the scientific perspective and (b) representational knowledge that relates to the language abilities to represent the meaning as intended by students
	(3) Differences between oral language and written language (e.g., use of pronouns, active vs. passive voice)	Invoked when the researchers and the teachers discussed the differences between oral language and written language. Examples include student writing that entails (a) the use of pronouns (e.g., 'it') and (b) conversion of active voice to passive voice, given that these two features of language often distinguish between speech and writing
Text	(4) Differences between text types (e.g., description vs. explanation, description of features vs. description of function)	Refers to knowledge that allows one to distinguish between text types in terms of their structure and grammatical features. For example, a description typically contains observable attributes and involves the use of descriptors and additive connectives, whereas an explanation usually contains the cause (often invisible) and the effect and entails the use of causal connectives. (See also Patrick & Fang, this volume.)
	(5) Textual components required of various text types (e.g., explanations, relational statements, definitions, data-based description and explanation)	Involves knowledge of the distinctive components that make up a particular text type. For example, the text type 'definition' typically encompasses two components: the nature of the concept being defined and its critical attributes and the use of a defining verb such as 'is' Components 4 and 5 thus allow the teachers to discuss with students the differences in requirements when constructing different text types and particular texts. For example, in our data, the teachers made explicit the differences between description and explanation when responding to data-based questions and identified the typical components of a relational description in their lessons

(continued)

Table 2.2 (continued)

Level	KAL component	Comments
	(6) Ordering/sequencing of text components (e.g., when making comparisons, when describing and explaining data)	Invoked when teachers discuss with students how to present their ideas in a systematic and coherent manner in their texts. For example, one teacher was explicit about how students needed to compare two entities with the same characteristics when making a comparison and the possible ways of sequencing the differences between these entities when writing about them
LG-sentence	(7) Morphemes: parts of words: prefixes, roots, suffixes	Morphemes are the smallest meaningful units of a language. In this study, this aspect of language was invoked when the discussion turned to reading. Though reading was not the focus of this project, the importance of reading was a frequent topic of discussion given the interdependent relationships between reading and writing. As many scientific words have root words that come with a prefix or suffix (morphemes), teacher knowledge of the meaning of common prefixes/suffixes can help to support students in interpreting unfamiliar words containing similar morphemes. For example, one teacher highlighted to her students how enzymes can be recognized by 'ase' that appears at the end of their name (e.g., amylase, protease)
	(8) Role of grammatical resources (e.g., preposition, noun, verb, adjective)	Refers to knowledge about the functions of various types of grammatical resources such as pronouns, comparatives and superlatives (e.g., 'cooler' and 'coolest') and connectors (e.g., 'but', 'therefore). For example, connectors play the important role of signaling logical relations between ideas. Knowing the functions of grammatical resources thus helped the teachers to move away from their narrow focus on 'keywords', or technical terms, toward a more holistic view of language resources
	(9) Role and nature of nominalizations (function of grammatical metaphors)	Less frequently invoked but nonetheless discussed during the inquiry. Although nominalizations[a] are extensively found in science, science teachers do not always pay much attention to them as a distinct form of language resources. This KAL was thus important in establishing the role of nominalization in generating new technical terms and the challenges likely encountered by students in interpreting and using such terms

(continued)

Table 2.2 (continued)

Level	KAL component	Comments
	(10) Expectations of command word (e.g., describe, explain) as in assessment questions	Teachers were also concerned with the role and expectations of command words (e.g., describe, outline, explain) as used in question stems. A better understanding of this KAL component in their instruction can better support teachers not just in terms of their teaching but also in setting appropriate assessment tasks that are fit for purpose
	(11) Condition/context of use of technical terms	Recognition that there exist particular contexts, circumstances or conditions in which particular technical terms can be used (Seah et al., 2013). Conscious awareness of the condition-of-use of a particular technical term allows teachers to better understand when and why the term can be used in some situations but not in others
	(12) Sentence construction	Involves an understanding of the typical components of a sentence and how these can be strung together to make a coherent meaning unit. For example, metalanguage adapted from a functional grammar language perspective (Fang, 2005) such as 'participant', 'descriptor', 'circumstance' were introduced to the teachers to identify the various sentence components and understand the function a particular component serves in construing the scientific meaning. Such metalinguistic terms were useful in recognizing the particular issues students have with their written sentences

[a] Nominalizations are grammatical metaphors in which processes more commonly represented as verbs are represented in the form of nouns (e.g., 'expansion, 'condensation'). Such grammatical conversion is one of the established ways by which scientists generate new technical terms

Table 2.3 KS components

Level	KS	Comments
System	(1) Students' language can indicate misconception or misrepresentation	Invoked when science teachers paid attention to how students may misrepresent their intended meaning and not just the misconceptions the students have (as teachers tend to do) Misrepresentation suggests that even if students have the conceptual understanding, they may lack the necessary knowledge of and about language to be able to construct a scientifically sound explanation. An awareness of this aspect enables teachers to be more open to the possibilities of challenges faced by students
	(2) Challenges in comprehending questions and the requirements	Students face challenges in understanding question stems and recognizing the requirements that are expected. This KS component is related to the KAL component involving differences between everyday language and scientific language The explanations one provides in everyday life can be quite distinct from those given in science, in terms of not only the content (intuitive vs. scientific understanding) but also in terms of the language values of the scientific community such as 'precision, clarity and brevity' (O' Toole, 1996, p. 117). Other differences include the scope and epistemic nature of the explanations (Seah, 2015)
Text	(3) Confusing the various types of texts (e.g., explanatory, comparative, descriptive, relational) and knowing the structural components and sequencing	Related to the difficulties students encountered in recognizing and differentiating text types, for example, between description and explanation and between definition and description. Students tended to provide one text type instead of another as a consequence
	(4) Missing structural components	Incomplete students' responses would typically come under this fourth component. This is in turn related to the second KS component in that missing out on certain structural components of an expected response may indicate that students might not know the content sufficiently or what is expected of them in a question (Component 2)

(continued)

Table 2.3 (continued)

Level	KS	Comments
LG-sentence	(5) Excessive lengthy sentences that lacked coherence and clarity (e.g., using too many ‘and’)	Invoked when student writing appeared incoherent, often attributable to stringing multiple clauses together with the connector ‘and’. This sometimes resulted in the use of verbs that did not match with the first subject that appeaeds in the sentence and/or inappropriate connectors to represent the logical relations. An example is, “The water is collected by evaporating and it condenses into tiny water droplets and slide down the mirror”, where the verb ‘condenses’ was matched with ‘water’ as represented by ‘it’ rather than with the intended but unwritten ‘water vapor’
	(6) Converting active voice to passive voice (reversing the actor and the entity being acted upon)	Relates to students’ attempts to convert the active voice to the passive voice. Take this sentence as an example, “When the water evaporates, the water will go to the mirror and go downward and will collect water”. Instead of ‘will be collected as’ water, the student wrote ‘will collect water’ instead. This led to the teacher circling the word ‘will’ and writing on his script ‘what will collect water’ The use of the passive voice is particularly prominent in scientific language to convey authority and objectivity. However, for pedagogic purposes, science textbooks and teachers prefer the active voice, which is more easily understood by students since this form of sentence construction is more congruent to everyday usage. This disconnect may make it difficult for students when converting what they learn orally into writing. This last component often overlaps with the other KS components
	(7) Conventions: (ir)relevance, (in)accuracy, (non-) specificity and (in)appropriateness of particular vocabulary and grammatical resources	Invoked when the researchers and teachers discussed the specific linguistic components (e.g., pronoun, preposition, comparative, technical term, prepositional phrase) used by students, which could be either irrelevant or missing, inaccurate (non-alignment with scientific use of words), unspecific (not precise in identifying the referents) or inappropriate (words used not appropriate to the context although their meaning may overlap with those that are appropriate) Knowing the possible ways in which students’ use of language can differ from what is expected from a disciplinary language perspective can help teachers to better pinpoint more specific language challenges faced by students and provide more targeted interventions

1. **Use of metalanguage**

One feature of the teachers' oral interactions is the extensive use of metalanguage. In this study, metalanguage refers to the second level of language used to analyze and describe the language of school science (cf. Shanahan, 2012). Research has shown that "metalanguage supports elaboration and enactment of meaning and exploration of patterns in language" in language arts classrooms (Moore & Schleppegrell, 2014, p. 92).

Among the lessons we observed, metalanguage was found to enable the teachers to unpack question demands for students, illuminate the conventions and norms of scientific writing for students, support the use of language in science, critique the use of language by students and stimulate deeper thinking into content with students. The teachers' KAL and KS empowered them with the metalanguage that enabled them to talk about the language with their students.

Without the various aspects of KAL and KS identified above (e.g., Components 4, 5, 8 and 10 of KAL (Table 2.2) and Components 4 and 7 of KS (Table 2.3), teachers would be less likely to pay attention to or possess the vocabulary to talk about the language explicitly during science lessons. The more KAL and KS teachers had, the more metalanguage the science teachers were likely to acquire, apply and adapt in their oral interactions with students.

2. **Activity design**

Innovative learning activities were designed by the teachers to foreground the role of language. An instance was an activity designed by Aaida who wanted her students to be aware of the role of pronouns in writing. This activity was prompted by her students' indiscriminate use of pronouns resulting in a lack of specificity in the referent being referred to. It involved the students working in groups to discuss several sentences (answers to some questions) containing indiscriminate use of pronouns that students needed to replace with the appropriate referents for the meaning of the sentences to be clear.

This activity opened up the opportunity for students to discuss with their peers the use of pronouns and how the unclear pronouns used in the sentences could be replaced. This process activated their language knowledge and was also contingent upon their conceptual understanding since students would not know what words to replace the 'it' with if they did not understand the contexts for which the sentences were intended. This activity is related particularly to Component 8 of KAL (Table 2.2) and Component 7 of KS (Table 2.3).

3. **Task scaffolds**

The teachers designed and employed a range of scaffolds for students to support their completion of a task (i.e., task scaffolds). Examples of such scaffolds included sentence starters, helping words and sentence/text construction tables, to more elaborate support such as rubrics for students to practice peer evaluation and a glossary list with the terms organized into categories that reflected the key ideas in the topic.

These scaffolds reflected an awareness the teachers had toward the potential challenges that their students might have faced in completing the task and the teachers' abilities to integrate their pedagogical knowledge with their KAL (e.g., Components 6 and 12, Table 2.2).

4. **Use of student writing as resource for teaching and learning**

This aspect of pTLA involved the ability of the science teachers to leverage student writing as a resource to highlight, illustrate, critique and model how language was used and ought to be used by students. Through the use of student writing, the teachers were able to make explicit the language-content connections by relating the language features and resources employed to the meaning realized. The teachers made use of writing as a resource in multiple ways: as board notes for discussion (when students wrote their answers on the board), as a group activity for peer discussion (when the teacher collated student writing as resources for students to discuss and critique) and as an individual activity for self and peer evaluation (when students were expected to critique their peers' explanations with the rubrics given).

The KS (e.g., Components 3, 4, 5 and 7, Table 2.3) of the teachers were especially relevant here as the use of the student writing could be optimized if the teachers had a clear understanding of the challenges that their students exhibited in their writing and how these challenges could be leveraged to help students be aware of and overcome them.

5. **Use of visual aids to facilitate learning about language**

Visual aids were also employed to support students in their acquisition of the language skills needed to construct scientific texts. A particularly vivid example was when Hana used laminated magnetic colored cards containing words representing the various states of water (e.g., water, water vapor), processes of change of state (e.g., evaporate, condense) and other associated words of the water cycle (e.g., sea, cloud). These cards were color coded according to whether they were nouns or verbs and could be shifted around on the whiteboard easily. As students often mismatch the noun (the various states of water) and the associated verbs (the processes involving changes of state), it is crucial to make students aware of the need to match the right noun with the right verb (Component 7 of KS, Table 2.3).

Apart from deepening students' understanding of the meaning of the terms, the teacher was able to make use of the cards to demonstrate the importance of these matchings. Unlike PowerPoint slides which tend to have a fleeting presence and contain limited information per slide, using the cards on the broad canvas of the whiteboard allowed the students to have a sustained visual of these words as well as the interrelationships between them through the arrows and links that the teacher drew to connect the words together. The cards also enabled the teacher to facilitate an extended debate as the students argued with one another about the position of the card containing the word 'condense' in the water cycle. The completed water cycle on the board scaffolded the extended writing that the teacher requested of the students as a formative task at the end of the lesson, as the cards at their respective positions provided the students with the helping words to construct the writing.

6. **Feedback for students**

Teachers also applied their KAL and KS to provide more specific and elaborated feedback to students. Feedback included both oral and written form. The oral feedback overlapped with the first and fourth aspects of pTLA, as the feedback often entailed the use of metalanguage and was usually given in the context of whole-class teaching when the teachers made use of student writing as resources. The written feedback was given when the teachers marked the assessment tasks given to students. Such feedback given by the teachers is important as students are more likely to know how to improve on their writing if they know the specific areas that are problematic beyond not using the 'right keywords' or that their answers are 'vague'.

2.5 Discussion

Teachers' knowledge related to language, i.e., KAL and KS as part of dTLA as identified in this study was generated mainly in the inquiry sessions when the researchers and teachers worked together to inquire about the language challenges encountered by the students. As these knowledge components were based on actual students' challenges, they had the value of ecological validity in the context of the classrooms studied. These knowledge components were also related to learning demands that the students needed to overcome in order to use language productively in science. Thus, teachers' awareness of these knowledge components could enhance the teaching in these classrooms. This is evident in the six aspects of pTLA, which reflected the multiple ways in which the teachers were able to leverage on their dTLA to adjust their teaching accordingly to address the language challenges encountered by their students.

Many, if not all, of the KAL and KS components could have been predicted or derived from our existing understanding of the features of academic language in general and scientific language in particular. One contribution of this study lies in verifying the relevance of such knowledge for understanding a) the language challenges encountered by students and b) their utility in informing and enhancing science teaching. These knowledge components are organized differently from existing frameworks such as the conceptual framework for academic English proposed by Scarcella (2003). The latter identified five components of academic English: phonological, lexical, grammatical, sociolinguistic and discoursive. However, in our analysis, both KAL and KS components are organized into the three levels of system, text and LG-sentence. This simplified organization mirrors more closely the concerns that science teachers have in relation to the language demands of science. As science teachers, their primary concerns are and will always be on the conceptual demands and the ways in which students can display their conceptual understandings. Though language plays an integral role, science teachers are more likely to perceive language aspects as secondary or subservient to the conceptual demands. The KAL and KS that science teachers are most likely to find relevant and usable are thus those that have direct implications on the classroom practices that are circumscribed by the curriculum (e.g., learning objectives, pedagogy, assessments) and what teachers value as important in science. The three levels of system, text and LG-sentence capture and reflect the concerns that the teachers have in the context of their classrooms.

However, the ecological validity can also be a limitation of the study as not all KAL and KS components identified in this study may be relevant to other science classrooms. We expect that those components directly related to conceptual understanding (e.g., KAL Components 1 and 11, KS Component 1)—versus those more related to text production—would be more universally applicable. Neither are the identified components exhaustive as classrooms with a different set of learning objectives and instructional focus may also generate additional KAL and KS components. Moreover, the scope of the identified components is also contingent on the selection of artifacts by the teachers and limited by the number of inquiry sessions that the teachers' schedules allowed for.

The KS components identified in this study differ from the KS components identified in another study previously conducted (Seah & Chan, 2020). One observable distinction between the two sets of KS is that the former study identified more system-level KS compared, whereas this study was able to capture more of the KS at the text and word-sentence level. This can be explained by the different research designs and data sources from which the KS components were identified. The former study's use of teacher interviews was able to capture broad teacher understanding of students, while the current study's use of student writing that spanned multiple science topics is better able to generate more specific and fine-grained understanding of the students' language challenges at the text and LG-sentence level. Nonetheless, the combination of these two studies provides us with a more extensive view of the KS that science teachers may find useful in informing their teaching, particularly in providing the necessary support that students would need to overcome their language-related struggles in learning science.

Although this study is based on the TLA generated from a limited number of inquiry cycles from six teachers, the identified TLA components can provide a useful starting point and resource for developing professional learning programs for other science teachers. In particular, the six pTLA aspects provide empirically tested ways in which science teachers can support students in learning the language of science. Instances that illustrate these components can be made available to other teachers to illustrate the value of KAL and KS in informing their teaching and how explicit instruction of language use in science can be enacted (cf. Fazio & Gallagher, 2019). Though the KAL and KS components are not exhaustive, they provide a starting point for other science teachers to explore and inquire about their own students' work. Although not all the KAL and KS components are manifested through the pTLA components, the fact that they were derived from actual student writing means that they have relevance to the students' needs and can therefore be leveraged to design science lessons that can better address these needs. Finally, this study has demonstrated that iterative cycles of inquiry using student writing as objects of inquiry can be productive in generating dTLA of science teachers and the role of TLA in enhancing science teaching.

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Chapter 3
Raising Science Teachers' Language Awareness: A Functional Literacy Approach to Teaching Science

Jonathon Adams and Fei Victor Lim

Abstract Learning science involves learning how to use specific, conceptual language in talking, reading and writing for reasoning and problem solving (Lemke, 1990). However, research has argued that language is a major barrier to students learning science (Wellington Osborne 2001). In response, this chapter reports on a project in a Singapore secondary school, where researchers worked with five science teachers at different stages over two years to trial a functional literacy approach to the teaching of lower secondary science. The functional literacy approach was informed by systemic functional theory and drew on the work of (Rose Martin, 2012) and (Rose, 2015) for language learning in the science context. This chapter focuses on the shifts in language awareness for teaching science from the teacher reflections collected during the process of implementing ideas from the functional literacy approach to address students' needs. The reflections indicated a shift from initial reservations to an eventual recognition of the value of how awareness and attention to language can support students' learning of scientific concepts, develop communicative classrooms and make the knowledge process visible.

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3.1 Introduction

Learning science involves learning how to use specific conceptual language in talking, reading and writing for reasoning and problem solving (Lemke, 1990; Norris & Phillips, 2009). However, language can be a major barrier to students learning science (Wellington & Osborne, 2001). In the Singapore science curriculum, the need to build concurrently both students' competence in English and their understanding of science is well-documented (Tobin, 2014). Research in science education in Singapore has also surfaced the didactic, traditional and rote reproductive character of pedagogy (Chin & Poon, 2014) with few opportunities for students to work together (Tan & Tan, 2014). This description of science education is in opposition to the Singapore Ministry of Education's call for "a more student-centric active learning environment" (Chin & Poon, 2014, p. 34).

A functional literacy (FL) approach to teaching science addresses the need to develop the language of science and to engage learners in collaborative learning. The FL approach was developed from Halliday's (2004) functional model of language, which initially served to enable non-mainstream groups in schools to access the genres required for success in school which they might otherwise have struggled to do so (Derewianka, 2015). This study builds on a previous study trialling an FL approach in two lower secondary school classrooms in Singapore. The earlier study examined two science teachers as they undertook professional learning on an FL approach to teaching secondary school science with the authors of this chapter (Adams & Lim, 2020). That analysis showed how the teachers were able to use the FL approach to support student learning through joint construction activities. In this chapter, we report on a scaled-up implementation of the FL approach from two to five teachers across the science subjects and student levels in the follow-up study. We collected teacher reflections through recorded conversations and email exchanges over a two-year period. The teacher reflections are used as the main data to understand their professional learning. In particular, we examined the teacher reflections to document the changes from their initial reservations to an eventual recognition of how awareness and attention to language can support students' learning of scientific concepts, develop communicative classrooms, and make the learning process visible. The research question guiding the study was "What is the evidence of teachers' professional learning and language awareness from implementing an FL approach to teaching science?"

3.2 Literature Review

Prior research has described classroom talk in school science as teacher-dominated with few opportunities for students to voice their ideas (Mercer et al., 2009; Tytler & Aranda, 2015). In the Singapore context, recent research has examined the role of teacher talk moves to unpack the meanings in visual representations to learn science, which highlighted the potential of teacher talk to deepen science learning (Adams et al., 2020). The teacher's role is unique, having influence over the design of the learning experience and having the authority to control content, procedures and participation (Lim, 2021; Walsh, 2011). Studies have also reported successes in literacy-based approaches to science teaching with the role of the teacher central to such successes (Lara-Alecio et al., 2012; Lee et al., 2016; Wallace & Hand, 2007).

3.2.1 A Functional Literacy Approach to Literacy

With the focus on specific school genres, a functional literacy (FL) approach is "concerned not only with what the students were learning, but also how they were taught" (Derewianka, 2015, p. 71). In the Singapore context, Halliday's (2004) functional model of language has been used to examine the need for students to learn specific science literacy practices (Tang & Moje, 2010), the infusion of literacy into science teaching (Tang & Putra, 2018) and the assessment of students' conceptual understanding through multimodal representations in science notebooks (Ho & Lim, 2020). At the lexical level, Seah (2015a, 2015b) has analysed the challenges primary students faced in writing scientific explanations and elementary teachers' perceptions of language issues, respectively.

A well-established example of an FL approach for learning English language is the teaching and learning cycle, initially developed by the Sydney School for primary teachers (Hammond, 2001). The aim was to make the "language of learning visible and accessible to all students" (Derewianka, 2015, p. 72). The teaching and learning cycle draws on Vygotsky's (1962) sociocultural theory and Bruner's (1986) scaffolded instruction (Burns & Joyce, 2007). An interpretation of this cycle has been adopted extensively in a variety of school science contexts by Polias (2016) and Forey and Polias (2017).

The key stages of the cycle are:

1. Building the field: The teacher guides students in developing their understanding of the topic at hand and its associated language (vocabulary and grammatical patterns) in its context.
2. Deconstruction of genre/modelling of text: The teacher uses a model text to show how the text is structured and how its language features are used to achieve the purpose of the genre.
3. Joint construction: The teachers and students jointly construct a text in the target genre with the teacher guiding the students.
4. Independent construction: When the students are ready, they construct a similar text in the same genre, but with different content.

The teaching and learning cycle has also been applied in the Reading to Learn genre-based pedagogy. Reading to Learn is designed "not only to be teachable in the classroom but [also] learnable in teacher education" (Rose, 2015, p. 7). The joint construction activity from the cycle used in the Reading to Learn approach has been detailed as part of a professional learning package for teachers, with many applications across a wide range of contexts including science. With extensive resources designed to train teachers in carrying out joint construction, the FL approach developed by Rose and Martin (2012) was introduced to the teachers to guide them in the design of joint construction activities in this study.

3.2.2 Teacher Reflections

To examine the learning of the teachers from the study, reflections from the teachers as they carried out their trials were collected and analysed. Approximately, four reflections were collected from each teacher during their trial with the researchers. Dewey (1933) defined reflection as an active process aimed at resolving a problematic situation and in that process learning deeper insights continuously and cumulatively. Schön (1983) has been widely cited as making the distinction between two types of teacher reflection: reflection-in-action, which is carried out spontaneously with action in class, and reflection-on-action, which is done after the action has been carried out (Burns, 2010).

Mann and Walsh (2017) argued that professional learning requires dialogue and reflection to create opportunities for learning and the appropriation of new knowledge, a position we also subscribe to. It is through such dialogue that teachers' existing understandings can be aligned with new knowledge, which can then be integrated into their current practices. This leads to an approach that is data-led, drawing on evidence from the classroom to engage teachers in improving their learners' outcomes through reflection-in-action and reflection-on-action. This type of reflection, which is carried out through discussion with another person, is termed by Mann and Walsh (2017) as dialogic reflection.

One of the ways to promote teacher reflections is through the use of Timperley et al. (2008) teacher inquiry and knowledge building cycle to guide the teachers. Essential to this cycle is the notion that teachers are critical agents rather than passive players simply implementing change. They treat their classrooms as sites for investigation to challenge their assumptions and identify potential problems and salient issues in their practices to be examined. A key feature of the inquiry cycle is the use of evidence, such as student artefacts, to inform teaching and learning. This takes the position that evidence of student learning is not seen as a reflection of students' abilities but used to guide effective teaching (Timperley, 2010).

In our study, the dialogic reflections were carried out with the teachers and researchers in the form of reflective discussions after the lesson trials. This enabled the researchers to probe for potentially rich articulation and analysis of the teachers' thoughts on a focus on language with the FL approach, uncovering insights that may not have been uncovered through solitary written reflections. By engaging the teachers in a variety of reflective tasks in this study, the teachers were encouraged to think more deeply about their actions with the FL activity they were using.

3.3 Methodology

Following the success reported in the earlier study (Adams & Lim, 2020), the school was keen to continue the collaboration with the researchers and to involve more teachers. The school identified potential teachers; the researchers then contacted the potential teachers to gauge their interest and invite them to participate.

Participating teachers were supported by the researchers in the FL trials through teacher inquiry and knowledge building cycles. Teacher reflections were captured at the end of each cycle. In this section, we explain that process as well as our process for analysing the teacher reflections. First, we provide the context of the study.

3.3.1 Context of Study

The publicly funded, co-ed secondary school took in students of mostly average academic ability as determined by national assessments. The school offered three courses of study, with the "Express course" for higher ability students who are expected to complete their Singapore-Cambridge General Certificate of Education Ordinary-Level (GCE O-level) certification in four years. "Normal Academic" classes are undertaken by students who are expected to either complete their four-year Singapore-Cambridge GCE Normal (Academic) Level (GCE N (A)-Level) course and continue to study vocational courses or continue for a fifth year to complete their O-Levels. "Normal Technical" classes are for students who are expected to complete a Normal (Technical) four-year course, then progress to either the fourth year of the GCE N (A)-Level course or study vocational courses offered by the Institute of Technical Education. The participating teachers had mentioned that students undertaking Normal Technical classes tended to have more English language challenges, so there was interest to trial the functional literacy (FL) approach at both the Normal Technical level as well as the Express level. Characteristic of Singapore, the students came from three main ethnic groups: Chinese, Malay and Indian. The respective three mother tongue languages (Mandarin Chinese, Malay and Tamil) are taught in the school. However, Singapore is a multilingual society, with many students using more than one language, and students may or may not use English as the home language (Ministry of Education, 2020). The General Household Survey conducted in 2015 by the Singapore Government identified the following languages spoken at home as reported by residents aged five years and over in Singapore: 48.3% English, 29.9% Mandarin, 8.7% Chinese dialects, 9.2% Malay, 2.5% Tamil and 1.4% "others" (Singapore Department of Statistics, 2020).

Over a two-year period, a total of five teachers from the school participated in the study (Table 3.1).

Table 3.1 Overview of teacher participants

Teacher	Teaching experience (years)	Engagement in project	Subject taught	Class taught
1	2	Four months	Physics	Sec 3 (Express)
2	7	Six months	Chemistry	Sec 1 (Normal Technical) Sec 1 (Express)
3	10	Three months	Biology	Sec 1 (Express)
4	6	Worked together as a pair supporting each other (and initially with Teacher 3) for 9 months	Biology	Sec 1 (Express)
5	15		Biology	Sec 1 (Normal Technical)

3.3.2 Teacher Inquiry and Knowledge Building Cycles

Participating teachers were encouraged to adopt an inquiry stance in their engagement with the researchers, as such a stance is understood as being fundamental to sustainable professional learning. We used the teacher inquiry and knowledge building cycle (Timperley et al., 2008). Timperley (2010) proposed the use of these cycles based on earlier successful research using classroom evidence for the improvement of classroom teaching. Each teacher engaged in the inquiry cycles individually at different times of the year.

Stage 1. Identify the learner needs

The teachers discussed with the researchers and reflected on their students' language and learning needs. From this discussion and with reference to student artefacts as evidence, they identified the building of students' speaking, reading and writing skills in science as the focus area for inquiry. Solutions to the learner needs as identified by the teachers were then be addressed in Stage 2 by introducing the FL approach, which encompassed the knowledge and skills the teachers needed.

Stage 2. Identify and deepen teachers' knowledge and skills to meet the learner needs

The researchers introduced the teachers to the teaching and learning cycle for students, described above. The teachers identified the joint construction stage as being of particular value to addressing the learner needs identified in the discussion with the researchers in Stage 1. The teachers recognised joint construction as a way to develop their students' speaking, reading and writing skills by guiding them in the negotiation and joint construction of scientific knowledge taught in class. The teachers also felt joint construction would support conceptual understanding and engage their students in more active discussion to learn science. It was agreed that these activities gave their students opportunities to interact with each other while co-constructing texts with teacher guidance at the front of the class on a whiteboard. All teachers expressed that joint construction was an approach that would meet their department and school needs: to build the scientific communicative skills of students so that teachers could gauge their levels of understanding and build more communicative classrooms where students could have a voice and be more engaged. The joint construction stage was also an opportunity to engage students actively in learning where more authoritative teacher-centric approaches may not be as effective (Polias, 2016).

To meet the learners' needs identified by the teachers, the researchers drew on their knowledge of FL to propose appropriate resources and instructional strategies for teachers to carry out joint construction activities with their students.

The following activities were carried out as part of stage two of the teacher inquiry and knowledge building cycle:

- Discussing and sharing an overview of the FL approach to surface beliefs and congruence with current teaching practices.
- Reviewing the teacher's current practices by creating a table featuring a column with a description of the teaching actions employed for an observed lesson segment and adding a hypothetical sequence of the same segment if it had been done from an FL perspective involving joint construction in another column. The current and hypothetical activity sequences were compared and unpacked in discussion.
- Walking through examples of joint construction activities created by the researchers with science content and discussing how the teachers would adapt, modify and use such activities to suit their teaching context.
- Modelling of the approach with the researchers carrying out demonstrations to show how the joint construction activities could be enacted and discussing how the teachers would situate such pedagogical activities in their context.

Stage 3. Engage learners in new learning experiences

With the new knowledge gained by the teachers, each teacher planned and conducted an FL activity for a lesson, which was audio recorded by the researchers. The lesson segment featuring the FL activity was subsequently transcribed by the researchers. These transcripts captured the teacher talk and teacher actions, which were valuable artefacts to mediate the reflective discussion from the teachers. The sequences of teacher-student exchanges where an FL-informed activity was being enacted were identified as crucial to understanding teacher learning in this study. In this chapter, the main data are the teachers' reflections, and the data from the lesson observations are used to support the findings from the main data, where appropriate.

Stage 4. Examine the impact of the changed actions

After the application of new learning experiences, the teachers monitored the effectiveness of their actions in the enactment of their FL activity in terms of the impact on their students. This involved asking the students about the lesson, examining student artefacts and reflecting on student activity during the lesson. Insights from the examination of the lesson then informed the next stage of action in terms of students' needs for the next iteration of the cycle. Where outcomes had not been met, the teacher might then adjust the goals, plan their actions in the next iteration of the cycle starting at student needs. Reflections were undertaken as the teachers monitored the effectiveness of the actions they had taken to improve student outcomes. These reflections were collected and analysed, as explained below.

3.3.3 Analysis of Teacher Reflections

The teacher reflections were collected through recorded conversations and email exchanges with the researchers over a two-year period. These reflections were done after the teachers had trialled their FL activity to evaluate the student learning experiences and at the end of the project. The type of reflection was driven by the teacher's availability after their lesson trials. If the teacher did not have time to meet the researchers after the lesson trial for a reflective discussion drawing on their experiences of that lesson, the teachers would carry out a written reflection that day and email it to the researchers or meet at a later date to have a discussion with the use of a transcript of that particular lesson. The teachers' email reflections included a date, commentary on what happened during the lesson and thoughts on that commentary. The teachers also sent email reflections at the end of the project. At the end of the project, the teachers also provided written reflections based on follow-up discussions which drew on evidence captured in the lesson transcripts created and sent to the teacher to help recall a particular lesson, including teaching actions, spoken language and resources used, examination of student artefacts and other resources. Written reflections provided an accessible record of the teachers' thoughts, which could be shared easily with others (Mann & Walsh, 2017). Written reflections also offered the teachers flexibility to compose, review and structure their thoughts (Farrell, 2013). However, dialogic reflections, as described above, enabled probing for potentially richer articulation and analysis (Mann & Walsh, 2017). By engaging teachers in a variety of tasks (written reflections on a class, reflective dialogues after lesson recordings, discussions in email and face-to-face on lesson plans and preparations for lesson trials and reflections at the end of the project), the teachers were encouraged to think more deeply about their actions. The teachers' reflections documented challenges, successes and directions for improvement.

In addition to the reflections as described above, Teachers 4 and 5 engaged in collaborative reflections (Mann & Walsh, 2017). The collaborative reflections involved the two teachers participating in the reflective discussions together with the researchers. The decision for collaborative discussions was made due to Teacher 5 acting as a mentoring role for Teacher 4; Teacher 4 expressed the desire to carry out the reflections as a pair for his own personal growth. With both teachers carrying out the study at the same time with the same lesson content, these were the only teachers in the study to have collaborative reflections. The collaborative reflections resulted in the teachers learning from each other's practices in trialling their FL approach and building a community of practice within the science department.

A thematic analysis of the written and spoken reflections was carried out to organise the teacher reflections into themes and examine how the teachers articulated language awareness for teaching science through implementing the functional literacy (FL) approach. The analysis took an inductive approach to coding data as the research question sought to understand changes in language awareness, if any, of the teachers for teaching science with the FL approach. One researcher carried out the first analysis of the written reflections and transcriptions of the dialogic reflections for all teachers, identifying broad themes, such as their perceived value of scientific language for developing student understandings of science and their reported changes to their teaching practices involving language for teaching science. This initial set of coding was then examined by the second researcher to check that the codes were congruent with the text excerpts of the teacher reflections and consistent across all five teachers' sets of reflections to ensure consistency in the coding. Following this, the researchers reviewed all text excerpts of the reflections together to check for congruence with their allocated code, and any incongruence in the codes was discussed and resolved as a measure to ensure the accuracy of the reflection coding.

3.4 Findings

In this section, the findings are discussed in relation to the research question. The analysis indicated evidence of teacher learning through a shift in their epistemic beliefs towards developing language awareness in science teaching, as well as learning ways of designing a communicative classroom and making the knowledge process visible for students.

3.4.1 Developing Language Awareness in Science Teaching

The growth of the teachers' language awareness was evident in their reflections on how they were able to guide their students' scientific language use. Teacher 1 shared that he supported his students in co-constructing sentences as well as guiding the students in the elicitation of keywords. Similarly, Teacher 5 reflected that her students were able to express their answers using the target scientific language confidently. She credited this in part to having established routines and expectations earlier in the year so the students were enculturated to the FL approach.

Teacher 4 shared that he had become more aware of the science terms he used in class. He also reported that he "made [the students] highlight the important terms as opposed to [not doing so] last time." His reflection showed an increased awareness of language use and a shift in teaching practices with a greater focus on language. Teacher 4 also stated that he "was very mindful of the words [he used], the words that the students were using… [and] wrote [them] down on the whiteboard for the students to actually see for themselves, and from there, change it to become more scientific." He also got students to pronounce several words so that they would be accustomed to the pronunciation of the words as "this would help students to remember them more effectively instead of through the normal passive learning." Teacher 4 revealed that at the start of his study, he had found the use of the FL activity quite daunting as he was not "a language person." At the end of the study, however, Teacher 4 reflected that he had grown in his appreciation of how language is important in science teaching. He aptly summarised his growth in the following excerpt from his written reflection:

> In a nutshell, using the FL approach in lessons has made me aware of the terms I used in classroom. This certainly has an impact on the students' learning as well. Most importantly, it is the process of scaffolding the students' learning to get to the answers.

3.4.2 Designing a Communicative Classroom

The teachers reflected that they felt the focus on the joint construction activities had resulted in a more communicative classroom for the learning of science. Teacher 1 shared that the FL activity was student-centred because "it is the kids that generate the answers rather than the teachers just giving [it to] them." He reported becoming more aware of the need to involve the students in the process of learning and found that the FL activity allowed for more student participation than his usual teaching style. Teacher 4 also highlighted the value of communication between students. He reflected that "I always tell the students… share with your partners instead of… doing it alone, so, it's something which I have been doing inside the class as well."

The teachers also felt that the FL activities raised their awareness of how they could design for more opportunities for students to talk. For example, Teacher 2 reported that through the FL approach, her students carried out discussions and interacted a lot more than compared to her usual classes. Teacher 4 also emphasised that the FL approach offered "a safe environment for the students. By getting them to share in pairs first [it] is well-suited, especially for a class with mixed abilities/readiness." This was an indication of his recognition that the FL activity was appropriate for encouraging different students to communicate.

Likewise, Teacher 5, the most experienced teacher amongst them, reflected that "joint construction is useful… to allow students to share their answers and build upon one another's points," further stressing the communicative aspect of the FL activity. She noted that the students "who [were] usually quiet in class, raised their hands more than once… a positive sign that they are engaged and learning." Teacher 5 also added that she enjoyed the "lively interaction… with the class. [The] students love to provide answers and that day [of a classroom recording being discussed] they were more actively engaged and involved."

3.4.3 *Making the Learning Process Visible*

The teachers also reflected that the FL activities enabled them to make the learning process visible. For example, they felt that the joint construction activity facilitated the representation of students' ideas through writing on the whiteboard. Teacher 4 shared how the use of the whiteboard to show the students' responses had allowed him to "check on their visible thinking process as well as to check on the quality of their drawings of the cells and the correct labelling of the structures." He reflected that he was intentional in using the whiteboard, and wrote key phrases "on the board for all to see." A similar point was also made by Teacher 5, who said that as a takeaway from the study, the department now needed to place a "greater emphasis on encouraging students to share their thoughts and answers in class," and added that "this also forms the essence of a "visible thinking" process." Teacher 5 emphasised that "there must be a platform where the students can see their input and to act on a selected set of answers." This could be achieved with traditional tools, such as whiteboard, as well as with digital tools, such as the use of PCs with the *Answer Garden* software by Teacher 3 and iPads with an online forum by Teacher 4.

Polias (2016) has highlighted the sustained nature of assessment throughout the stages of the teaching and learning cycle. Specifically, the interactive nature of joint construction offered assessment data by making the learning process visible for the teachers. Being able to hear and see students' responses is valuable and as Teacher 4 reflected, would enable him to "gauge the level of learning as well, how fast [he] can pace the lesson." Likewise, Teacher 5 reflected that "the process of steering students' thinking process is much more important than the final product (i.e. students' answers)." She also added that the FL approach encouraged "students to adopt the growth mindset instead of fixed mindset" with students being "continually challenged to improve on their answers and solutions." This was because the FL activity offered opportunities for teachers to make the knowledge process visible to the students.

3.5 Discussion

The teachers' participation in this study has contributed to their professional learning as evident from their reflections. In particular, they reported developing a language awareness in science teaching, as well as learning ways to design a communicative classroom and to make the learning process visible for the students. The teachers that were introduced and guided in the adoption of an FL approach for the teaching of science experienced growth resulting in changes to their science teaching practices and beliefs towards the value of language for teaching science. This is consistent with the findings from the use of an FL approach across other subjects, such as Derewianka (2015), Rose (2015) and Rose and Martin (2012). The five teachers demonstrated an increased awareness of the value of language for teaching science.

This increased awareness was supported by reflections detailing positive impressions of the FL approach trials in the classrooms and the teachers stating the value of a focus on language for teaching science during and following the trials. The findings suggest that there was a shift in the teachers' epistemic beliefs. This claim is evidenced in the teachers' reflections on the essential role language had in the teaching and learning of science, and how an FL approach was understood as beneficial to developing their students' knowledge of science. The more student-centred FL activity helped students to build knowledge, recognise the structuring of knowledge and patterns of language, and apply them in collaborative meaning-making. In this, we advance the arguments made by Tang and Moje (2010) and Tang and Putra (2018) that the teacher's knowledge of language for specific subject content and the directing of attention to the language can contribute to shaping students' understanding and learning of the subject.

Our study highlights how the variety of spoken and written reflections recorded by the teachers helped them examine their thoughts and practices to improve teaching science with a focus on language embodied in an FL approach, affirming the position made by Mann and Walsh (2017) on the role of reflections in teacher professional learning. Discussion in teams of teachers and with the researchers enabled the teachers to evaluate their actions in the trials and provide a point of reference upon which to improve their teaching for the next iteration of the trial of their FL activities in the following cycle. By exposing the teachers to an extended period of documenting their thoughts in a variety of reflections, the teachers could develop their own reflective practices for sustained professional learning after the study had ended.

Our findings could also inform future studies on how language experts could work together with content specialists in developing instructional strategies for integrating the learning of language and content of school subjects. For example, the success of pairing Teachers 4 and 5 seemed to be beneficial in terms of peer support to share and consolidate understandings. The peer support was valuable as they also shared their lesson experiences with each other. In addition, the engagement with researchers seemed to be beneficial for both teachers' professional learning. The approach of observing and recording a lesson segment, followed by proposing how the same sequence could look from an FL lens as a hypothetical transcript was also well-received by all teachers. This resource helped mediate discussions on not just what an FL approach looked like, but how such an approach could be crafted based on the initial actions of the teachers earlier lessons. When combined with other resources such as summaries of readings and theory-based discussions, the lesson segment proposal could be used in other contexts as a resource to support professional learning.

Notwithstanding the value expressed by the teachers, they also highlighted challenges. The most frequently reported challenge was the tension between a more interactive approach to teaching with a focus on language and the time taken to carry out an FL approach. Despite all teachers reporting the value in the FL activity they had carried out, there was still a consensus that this approach would be challenging for many teachers due to the time taken in the light of the high curriculum load. Professional learning was also highlighted as a critical success factor. Teacher 5 expressed that while she could share her lesson resources with other teachers wishing to adopt an FL approach, there was still a need to guide the teachers so that the FL activity could be carried out well. This indicates that more support was needed from the researchers to grow the professional capabilities of teachers to implement an FL approach.

With the exception of Teacher 3, who withdrew after two weeks of his trial for personal reasons, all teachers stated that they had continued with their use of an FL approach even after the study with the researchers had ended. The continued application of an FL approach to teaching and learning science demonstrates not only successful buy-in from the teachers, but also an impact beyond the duration of the study. For example, Teacher 1 shared that he had been trying out strategies in his other classes to practise what he has learnt from the study. Teachers 4 and 5 also revealed that they had been trying out the joint construction activity in other classes and had found the approach helpful for students from different academic courses. Teacher 4 contended that "because if you try [the FL] activity every other week, in a few weeks [time] it will become a lot easier."

As one of the leaders of the department, Teacher 5 organised professional learning sessions for the science teachers in her department on the FL approach and reflected that the joint construction activity was "used many times as we discussed the development of lesson plans." She also expressed a commitment to scale up an FL approach to science teaching in the school. She expressed that she would look through the curriculum plans in lower secondary science and identify challenging topics which could be best taught through the FL approach. She planned to surface 10 such lesson topics within the secondary 1 curriculum for implementation in the following year.

3.6 Conclusion

Being literate in a school subject requires more than understanding the content knowledge of that subject. It includes the ability to read, write, think and reason in that discipline (Fang, 2014). Although reading and writing can be used as tools to support the construction of conceptual understanding and problem solving in science (Fang et al., 2010), science teachers need support to be able to identify students' linguistic challenges when learning with science texts (Unsworth, 1998; 2001). The FL trials reported in this paper have shown how teachers can develop such awareness and use it to meet their students' learning needs.

Our exploratory work reported in this chapter has led to an awareness of language for teaching science amongst the participating teachers. This language awareness has led them to integrate elements of a functional literacy approach into their pedagogical strategies in the teaching of science in their classrooms. The use of the joint construction activity of drawing attention to the linguistic and semiotic features of scientific representations and then co-constructing meanings in group and whole class activities was the main activity employed to shape students' learning and engagement in learning the subject. We argue that an FL approach places language in a central role for teaching and learning science, and the heightened language awareness that teachers need to carry out such activities from an FL approach enables teachers to guide students as they learn collaboratively through discussion and various resources in groups and whole class activities.

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Chapter 4
High School Science Teachers Learning to Teach Science Reading Through a Functional Focus on Language: Toward a Grounded Theory of Teacher Learning

Jennifer Drake Patrick and Zhihui Fang

Abstract Reading is fundamental to the conception of science and the practice of scientists. Understanding the language used to create, discuss, and disseminate scientific knowledge is central to science teaching and learning. This chapter describes the experience of seven high school science teachers in a professional development (PD) program aimed at developing their expertise in teaching science reading through a functional focus on language. Data sources included interviews with participants, audiotaped PD sessions, and field notes from classroom observations. These data were analyzed using multi-tiered coding and constant comparison. Results indicated that the teachers developed a basic understanding about the relevance of language to science, the unique challenges of science reading, the special features of science language, and strategies for teaching science reading through a functional focus on these features. They demonstrated a willingness to try out what they were learning in their own classrooms and experienced varied degrees of success and satisfaction in their endeavors depending on their levels of familiarity and comfort with particular language features. Their learning and implementation were impacted by personal factors (e.g., conception of science, knowledge about English grammar, prior training, past learning experience, motivation to learn and try out new ideas), as well as contextual factors (e.g., school culture, classroom realities, opportunities to learn/share/reflect, level of support from experts/peers/administrators). These findings have important implications for science educators interested in using evidence-based language and literacy practices in service of science teaching and learning.

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4.1 Introduction

Science requires "both material and semiotic practices" (Halliday, 1998, p. 228). It involves conjecture, rhetoric, and argument, as well as the empirical work of observation and experiment in natural and laboratory settings. Contrary to popular misconceptions, the empirical work is not the bedrock upon which science is built, but rather a subsidiary activity used to support the discursive practice of generating and justifying knowledge claims about how the universe works (Osborne, 2002). Because of the centrality of language and literacy to science, science educators have been exhorted to "give prominence to the means and modes of representing scientific ideas, and explicitly to the teaching of *how to read*, *how to write* and *how to talk science*" (emphasis original, Wellington & Osborne, 2001, p. 138). National standards in the USA, such as the Next Generation Science Standards (www.nextgenscience.org) and the Common Core State Standards (www.corestandards.org), recognize the importance of language and literacy to science education, calling on science teachers to promote language use and support literacy development in service of science inquiry, learning, and sense making (National Research Council, 2012). Empirical research has consistently demonstrated that reading/writing is a powerful vehicle for engaging students' minds, fostering the construction of conceptual understanding, supporting inquiry and learning, building disciplinary knowledge, and cultivating scientific habits of mind (e.g., Cervetti et al., 2012; Chen et al., 2013; Fang & Wei, 2010). Without the ability to read/write science texts, or the fundamental sense of science literacy (Norris & Phillips, 2003), students are severely limited in the depth and breadth of science knowledge they can attain.

4.2 Science Language and Science Teaching/Learning

For schools to effectively develop students' ability to read/write science, the study of science language is essential (Fang, 2006; Seah & Silver, 2020; Yore et al., 2003). *Science language* refers to the linguistic register that is typically used by scientists to construe and communicate scientific knowledge, principles, understanding, and worldviews. This language differs from other varieties of language (e.g., everyday language) in that it is more technical, abstract, dense, and hierarchically structured (Fang, 2005). Science language is technical in part because it uses specialist terminology (e.g., *electromagnetic wave, penumbra*) and everyday words with technical meanings (e.g., *fault*, *matter*). It is abstract in part because it uses nominalizations (e.g., *polarization*, *frequency*), i.e., words that derive from concrete happenings (*polarize*) or qualities (*frequent*). It is dense in part because it uses long noun phrases that pack a heavy load of information (e.g., *Humidity is a measure of water vapor in atmospheric air*). It is hierarchically structured because it construes complex ideas and their relationships through expository genres such as report, explanation, and argumentation. The degree of technicality, abstraction, density, and hierarchy increases from elementary science through secondary science to professional science, presenting an ongoing challenge to science teaching and learning.

To support the development of science literacy, science teachers must demonstrate a solid understanding of science language and at the same time be equipped with strategies to help students make sense of and use this language (Fang, 2006; Patterson et al., 2018; Seah & Silver, 2020). Many science teachers are, however, ill prepared for this important work. Although most states in the USA now require a content area literacy course in secondary educator preparation programs to help teachers address the literacy demands of disciplinary learning (Romine et al., 1996), the course typically focuses on generalized reading strategies such as note taking, graphic organizer, and summarizing, with marginal attention to language (except for vocabulary). Professional development programs for in-service teachers, likewise, focus on essentially the same set of generalized reading skills and strategies, with teachers expected to integrate them into their teaching practices after limited exposure in workshops. Consequently, many secondary science teachers lack expertise and confidence to help their students tackle the unique challenges of science reading—they lack knowledge about different genres and registers of science texts and strategies for teaching students to comprehend and critique these texts. This contributes to their resistance to reading instruction; in fact, many science teachers view the teaching of reading/literacy as an optional extra that can wait until they have covered a curriculum that is already packed with content (Fang et al., 2008).

For these reasons, scholars (e.g., Fang, 2014; Patterson et al., 2018; Seah, 2016) have reiterated the imperative for science teachers to develop a foundational understanding about language and reading as part of their professional knowledge and skill. In this chapter, we report on a seven-month professional development (PD) program designed to support high school science teachers in learning how to teach reading in science through a functional focus on language. Two specific questions guided our study: (a) What understandings about science language did the science teachers develop through the PD experience? and (b) how did the science teachers integrate what they were learning into their teaching practices?

4.3 Methods

4.3.1 Setting

Our research took place in a large suburban Florida (USA) high school serving grades 9 through 12. The student population in the school totaled nearly 3000, with an ethnic makeup of approximately 60% White, 26% Black, 10% Hispanic, and 4% Asian/other. Twenty-two percent of the students were from low-income households, as evidenced in their being on the school's free or reduced-price lunch program.

The school administration encouraged teachers to learn about reading in content areas. It supported an after-school study group where teachers met regularly to discuss pertinent topics in education. Several texts that addressed generic content area reading strategies were used in this context, including Allen (1999), Beers (2002), and Tovani (2000). In addition, a reading specialist was on staff to provide support for teachers across all content areas. She regularly conducted workshops for faculty, addressing topics in fluency, vocabulary, and generic reading strategies.

4.3.2 Participants

Participants for the study were recruited through an institutionally sanctioned informed consent process. Their selection was based primarily on practical considerations such as willingness and access (Strauss & Corbin, 1998). Specifically, the high school principal reviewed a brief description of our research project and convened a meeting with the 28 teachers in the science department, where we presented information about our study (e.g., purpose, structure, time commitment) and offered incentives (a $300 stipend and two books on science and literacy) to encourage participation in the study. Seven science teachers—six females and one male—agreed to participate in the study. They represented various areas of science, including biology, anatomy and physiology, physical science, and marine science. Their teaching experience ranged from 5 to 34 years and covered grades 9–12. Individual profiles of the teachers are presented in Table 4.1.

4.3.3 Professional Development Program

The seven teachers participated in a professional development (PD) program that we, two university-based language and literacy researchers, designed to further their understanding of science language and science reading. In designing this program, we followed the guidelines teacher researchers (e.g., Borko, 2004; Desimone & Garet, 2015; Lee & Buxton, 2013) found effective in facilitating teacher learning and promoting change in beliefs and practices. Specifically, our PD program was content focused (i.e., science language/reading) and used a research-based model (Fang, 2013; Watson & Manning, 2008) that integrates learning, practice, and reflection. It lasted an extended period of time (7 months), which is sufficiently long to promote learning and bring about change. It encouraged peer collaboration, thoughtful conversation, and critical reflection, allowing teachers to examine whether/how their beliefs aligned with what was being studied. It also offered a safe place for teachers to try out new ideas, receive feedback, and build confidence.

The goal of our PD program was to help the teachers develop a foundational understanding of the language demands of science reading and the strategies needed

Table 4.1 Profiles of teacher participants

Name	Degree	Route to teaching	Years in teaching	Grades taught	Subject taught
Bette	Bachelor in biology with a minor in chemistry and Spanish	Alternative teacher certification program	5 years	9th and 10th grades	Honors biology
Casey	Bachelor in health education	Traditional four-year teacher preparation program	15 years	10th and 11th grades	Anatomy and physiology
Lisa	Bachelor in secondary education with a concentration in biology and a minor in chemistry	Traditional four-year teacher preparation program	34 years	11th and 12th grades	Marine science
Mona	Bachelor in science education	Traditional four-year teacher preparation program	17 years	9th grade	Physical science
Billie	Bachelor in chemistry	Alternative teacher certification program	6 years	9th grade	Physical science
Brad	Bachelor in biology with a minor in education	Alternative teacher certification program	8 years	10th grade	Biology
Patsy	Bachelor in psychobiology	Alternative teacher certification program	12 years	10th and 11th grades	Honors biology and advanced placement (AP) biology

to cope with these reading challenges. Toward this end, we designed and delivered five learning modules as follows:

- Module 1: Overview of the challenges of science reading in secondary schooling
- Module 2: The *technicality* of science language and coping strategies
- Module 3: The *abstraction* of science language and coping strategies
- Module 4: The *density* of science language and coping strategies
- Module 5: The *genres* of science and coping strategies.

Each module included examination of relevant journal articles (e.g., Fang, 2005, 2006, 2008; Fang & Schleppegrell, 2010; Osborne, 2002) and chapters (e.g., Fang, 2010; Fang & Schleppegrell, 2008; Halliday, 2006; Saul, 2004; Wellington & Osborne, 2001). In addition, the teachers brought science textbooks and other classroom reading materials to each PD session so that they could analyze language use in these texts, discuss the challenges science language presented to their students, and consider strategies for tackling these language demands.

These modules were delivered over eight meetings, with a 3–4-week interval between the meetings. Each meeting included a 2-h formal session, broken down into an hour of expert study and an hour of practice-based discussion (Watson & Manning, 2008). The first hour of expert study included discussion of professional readings and modeling of strategies. During this hour, the teachers were encouraged to analyze, weigh, and question the information presented in the readings against their own experiences. During the second hour, the teachers discussed the usefulness of the concepts covered and the strategies demonstrated in relation to their own practice. They then used their own materials to plan for classroom implementation and reflect on the feasibility of using the information from the first hour in their own classrooms. Additionally, topic-relevant questions were posed at the beginning and end of the meeting to stimulate thinking and conversation. In between the eight meetings, we visited the teachers' classrooms on a weekly basis, offering support through informal observations and follow-up conversations. This ongoing cycle of meeting, trying out new ideas, and discussing the challenges and successes of classroom implementation encouraged the teachers to actively reflect on how their understanding of science language/reading helped shape their teaching practices (Fang, 2013).

4.3.4 Data Collection

To answer the two research questions, we collected several types of data. The primary data sources were transcripts of PD sessions and individual teacher interviews. Secondary data sources included classroom observations, informal conversations with the teachers, email communications between us and the teachers, and the concept maps the teachers constructed to demonstrate their understanding of the topics discussed. Data consisted of approximately 25 h of audio recordings of eight PD sessions, 7 h of interviews, 2 h of informal conversations, and 22 h of classroom observations. These resulted in nearly 500 pages of transcription and over 70 pages of field notes. More details about the interviews, informal conversations, and classroom observations are provided in Table 4.2.

Table 4.2 Details about select data sources

Data sources	Details
Interviews	Each teacher participated in two semi-structured interviews, each lasting between 20 and 30 min. Each interview was recorded with a digital-voice recorder and then transcribed. A mid-term interview was conducted to assess the teachers' understanding and views of the PD content. A final (or exit) interview further assessed what the teachers had learned from the PD experience and probed for how they would continue to develop and implement their learning about science language and science reading. These interviews provided valuable perspectives on what influenced the learning process of individual teachers
Informal conversations	Informal conversations with individual teachers were carried out throughout the duration of the study. Field notes about the content of these conversations were recorded in a research log. These conversations focused on the teachers' understanding of science language/reading and their experience teaching it. They provided additional insights into the successes and challenges that the teachers experienced as they attempted to integrate the newly acquired ideas or strategies into their daily teaching routines
Classroom observations	We conducted observations of the teachers in action to determine (a) the degree of consistency between what the teachers said in the PD sessions about their classroom practices and what was actually occurring and (b) if/how the teachers were implementing any of the strategies discussed in the PD meetings. The observations took place on a weekly basis contingent upon a mutually agreed upon time between us and each teacher. Each observation lasted 30–50 min Detailed field notes were recorded during the classroom observations. The observation protocol included both a descriptive column and a reflective column. In the descriptive column, we recorded information about observed classroom activities that involved reading or attended directly to a concept or strategy discussed in the PD sessions. In the reflective column, we recorded wonderings and thoughts about what was happening in the classroom as it pertained to our study. After each observation, we held a debriefing conference with the teacher to discuss these two questions: (a) What do you think went well with your lesson? and (b) what would you do differently if you try this lesson again?

4.3.5 Data Analysis

Data were analyzed using methods characteristic of grounded theory studies, including repeated reading, multi-tiered coding, and constant comparisons (Creswell, 2007; Strauss & Corbin, 1998). Specifically, we read and coded data in several stages in an attempt to discover categories, relate categories, and finally organize the categories to create a theory of what facilitated or inhibited the teachers' learning about science language/reading. In stage one, we engaged in open coding by examining the interviews and PD transcripts line by line, aiming to generate preliminary categories and themes (e.g., barriers, struggles, concerns, issues, resistance, excitement, insights, successes) that explained how the teachers made sense of the information presented in the PD. We also used 'memoing'—i.e., the process of jotting down notes about an evolving theory—to record our reflections on what we were learning from the data. This helped us keep track of our own thoughts, questions, and changes in ideas as the research progressed.

In the second stage, we engaged in axial coding, seeking to discover relationships and connections among categories as we worked to put the data back together in a new way. We looked for links among categories that might aid in conceptualizing the factors that contributed to or hindered a teacher embracing and implementing a concept or a strategy presented about science language/reading. At this point, initial codes were collapsed into larger categories, and analysis of data continued until evidence of support for axial codes was found. This process enabled us to build a theory by creating categories around the conditions, actions, and consequences that were significant to the phenomenon being studied.

The last stage of coding was selective coding, which involved identifying a central category and an explanation for how the sub-categories fit together within that category. Memos and all data analysis up to this point contributed to the identification of selective codes.

In our study, data were analyzed both within and across cases. Findings from within-case analysis identified the experiences of each teacher. Cross-case analysis was then used to examine data along the lines of technicality, abstraction, density, and genres. This analysis procedure contributed to the formulation of a theory about how the teachers conceptualized and interpreted science language/reading and related it to their own teaching practice. The analysis was ongoing and iterative throughout the data collection period. This systematic coding process allowed the identification of themes and categories, helping build a theory about how the teachers learned about science language/reading and integrated it into their teaching practice.

4.4 Findings

During the PD experience, the seven science teachers were excited to learn about science language/reading and ways of integrating it into their classrooms. They developed a foundational understanding of the relevance of language to science, the unique challenges of science reading, the special features of science language, and strategies for teaching science reading through a functional focus on these features. They demonstrated a willingness to try out what they were learning in their own classrooms and experienced successes and satisfaction, as well as barriers, misgivings, and frustration, in their implementation. These findings are presented in detail below.

4.4.1 Embracing a New Perspective on Science Language/Reading

Prior to the PD, the teachers viewed science language as consisting primarily of vocabulary. They did not consider issues of abstraction, density, or genre when thinking about how to teach reading in science. Nor did they consider how science language was functional in presenting ideas and developing arguments in science. During the PD experience, they began to think differently about language in science.

For example, Patsy noted in her final interview that looking at how language functions in science was a new perspective to her. Although she knew that science language was filled with technical words, she had not considered how technicality contributed to the complexity of science language, nor had she ever learned about the concepts of abstraction, density, or genre. She contrasted her prior knowledge about science teaching with her new awareness about the role of language in science:

> We always are taught hands on, hands on – they've drummed it into us. And as scientists and science studiers of the process, we jump right on that. But there is more involved, and I never stopped to think about it's not just the labs, it's not just the hands on, it's the language approach too. (Final Interview)

With the new understanding about science language, the teachers gained fresh insights into why their students found science texts challenging. Prior to this PD, the teachers identified issues with student behavior, technology, student interest, and poor preparation from early grades as reasons that students would not or could not read science well now and in later grades. After the PD, the teachers had a better understanding of why science is difficult for students to read. They realized that unfamiliarity with science language could contribute to students' lack of proficiency or interest in reading science texts. According to Bette, it was the expository nature of science writing that made science texts less entertaining and more difficult to read than stories. Billie attributed her students' struggles with science texts to their lack of experience with these texts, noting

> The kids struggle because of the differences between what they're used to reading in the younger grades, per se, and what they have to read now [in secondary science] -- it is so much more complicated and dense. (Mid-Term Interview)

Understanding reading challenges through a language lens also impacted how the science teachers viewed their own responsibilities in teaching reading. Casey admitted she used to think that her students avoided or struggled with reading because they were lazy/disinterested or because textbooks were poorly written. She described how her thinking evolved during the PD below:

> I had become so accustomed to reading science materials that I didn't really realize that the students would have difficulty with it and why. Now, I'm more aware. In the past, I just became frustrated that they don't read their books, or I would be frustrated with the writers of the books because like, why can't they make a book that the students can read and understand? Whereas, now, I understand that what we have going on here is the fact that the students are more familiar with narrative and other types of writing. They're going to have

> to eventually be able to read science texts, so we're in that kind of transition where we have to get them to do something that they don't feel comfortable with. I have this awareness now that, okay, it's not just that the students don't want to read, it's not that they can't write a text that the students can read. Now, I do see my role more clearly as having to give them some strategies that can help them to be able to get more comfortable with science reading since they're going to need to be able to do it in the future. (Final Interview)

With a keen sense of responsibility for teaching reading, the science teachers were excited about and grateful for the new instructional strategies that they had been learning during the PD. They believed these strategies would enable them to engage their students in science learning in new, powerful ways. As Lisa said,

> And this [PD] gave us a whole box full of tools that are eminently useable. We know how to do them. You took us under the hood of the car and showed us this one will loosen this nut and bolt – it's like oh, light goes on. I feel much more – and I really love this word – empowered. I really feel more empowered to help the students deal with all these aspects. (Final Interview)

4.4.2 Learning About Science Language

Through the PD experience, the science teachers developed a basic understanding of the specialized features of science language (i.e., technicality, abstraction, density, genre), albeit not without struggles. They most easily embraced technicality and genre, yet wrestled mightily with abstraction and density. These understandings, or declarative knowledge about science language, contributed to their levels of comfort and success in teaching the four linguistic concepts, or procedural knowledge about science language, as will be shown in the next section.

4.4.2.1 Technicality

The science teachers rated technicality as the feature with which they were most familiar and comfortable. In the initial PD meeting, they understood that science language is technical due to its use of specialist terminology such as *lithosphere* and *plate tectonics.* They recognized that technical vocabulary presented a challenge to their students and were able to address it in science lessons. According to Casey, for example,

> I had the most background knowledge there [technicality] to begin with and then, of course, built upon that. I feel very comfortable with analyzing the word parts. That's something that I had actually done before. Not in such a systematic way as we learned how to do, but I feel very comfortable with that. (Final Interview)

The teachers' understanding of technicality deepened over the course of the PD. They were able to elaborate on technicality and became more aware of the need to attend to it in their teaching. In the mid-term interview, Patsy was able to identify different types of technical words—such as naming words (e.g., *trachea*), process words (e.g., *photosynthesis*), concept words (e.g., *force*), and mathematical words (e.g., *statistical*)—in a way that was consistent with how the topic had been presented during the PD and voiced a commitment to directly teach the meanings of these types of science words in her classroom.

Although the teachers were initially aware of specialist terminology (e.g., *mitosis*), they had not considered how everyday words such as *medium*, *library*, and *matter* could also contribute to the technicality of science language. In fact, they expressed surprise in thinking about technicality from this perspective. Bette indicated that it had not occurred to her that students might be confused by this type of technical words. She recalled science lessons in which her students mistook *sponge* (a sea creature) as "a cleaning tool" and *fault* (a crack in the earth) as "something that's wrong". She now recognized the need to explicitly draw students' attention to these commonsense words that are used in a scientific sense. Similar sentiments were shared by Brad and Lisa, who developed a heightened awareness of words that can have a different meaning when used in a different context.

4.4.2.2 Abstraction

Unlike technicality, abstraction sounded foreign to the science teachers. They had a difficult time grasping what abstraction in science language means. Prior to the PD, they had not thought about the possibility of science language being abstract. They associated abstraction in science language with an abstract science concept or idea that cannot be easily seen or touch (e.g., *cells*, *DNA*). Casey discussed how her understanding of abstraction evolved:

> I started out with a misconception that abstractness had to do with the fact that many of the concepts in science are not something that the student can see or touch. That was my idea of abstractness. I had thought about science as dealing with abstraction, but just more in that a lot of it is not concrete, visible. They can't touch it because we might be talking about something microscopic, you know, something that we only have theories about how it works. We don't even really know because nobody can see it, touch it, feel it kind of thing. So that was my idea of abstraction in science prior to this. I had just never thought that a word could be abstract because it has so much information in it. (Mid-Term Interview)

As the teachers were introduced to the concept of nominalization, they seemed to gravitate toward the process of changing an adjective or a verb into a noun (e.g., *discover* → *discovery*, *significant* → *significance*), but paid little attention to the functions of nominalization, such as distilling information, creating technical taxonomy, and facilitating discursive flow. They recognized that when a verb or an adjective is turned into a noun, it makes a text more challenging for students to understand. This nascent understanding can be seen in Billie's comments during one of the PD sessions.

> … it's more natural to say, "The storm made a *significant* impact on the community." That's report – that's how you might hear in reporting. But you might write about it. You want to be more assertive in your writing as a scientist because you want people to believe you and so a lot of scientists will take – instead of saying, "That storm was – that was a *significant*

> storm." They might then talk about, "The *significance* of the storm." Now you've taken that adjective – you've switched it into a noun. Well, in our narrative writing the nouns of our sentences, the *who*'s and the *what*'s are primarily peoples' names, places and, you know, *I, he, she*, *your* pronouns. In science, they're abstract: *the discovery*, *the significance.* (PD Session #5)

To help the teachers better understand the importance and functions of nominalization, we designed a sentence completion task (Fang, 2010), where they were to use an abstract noun (e.g., *the journey*) to summarize the information presented in a previous sentence (e.g., *head north for cold water of the Artic*) and make it be the subject of the ensuing sentence, as the example below illustrates:

> During the winter, humpback whales head north for cold water of the Arctic. is long and dangerous. [Answer: The journey]

This task was designed to help the teachers see how nominalization synthesizes information in a prior sentence for subsequent discussion and, in so doing, facilitates the information flow from one sentence to the next.

We also had the teachers bring their textbooks to the PD sessions, working in pairs to identify nominalizations and discussing the roles these nominalizations serve in the development of text and argument. In the following example generated by the teachers, we discussed how the nominalization "*these conditions"* condenses the information in the preceding sentences to become the subject of the last sentence and at the same time develops a line of reasoning that contributes to the cohesiveness of the text.

> Sometimes a population grows more rapidly than the available resources can handle. Resources that are needed for life, such as food and water, become scarce or contaminated. The amount of waste produced by a population becomes difficult to dispose of properly. *These conditions* can lead to stress on current resources and contribute to the spread of diseases that affect the stability of human populations both now and to come.

Despite our efforts, the teachers' struggles continued. Some teachers (e.g., Casey and Patsy) seemed to be making more progress than others (e.g., Brad and Lisa) in understanding abstraction. Toward the end of the PD, most teachers realized that abstraction was a major challenge they took for granted before and vowed to pay more attention to it in their work with students. However, two-thirds of the teachers still did not seem to substantially expand their initial understanding of the concept of abstraction; they continued to associate it only with the idea of not being tangible or to focus on the form but neglect the functions of nominalization.

4.4.2.3 Density

Like abstraction, the concept of density also presented a formidable challenge to the science teachers. They described density in terms of how much information is presented in a science text rather than how long noun phrases are used to pack dense information into a single clause. They were apprehensive about having to break down complex noun phrases because of their own lack of knowledge about the language structures. During the first PD module, the teachers were introduced to the concept of density by reading Fang (2008). They agreed that science texts were too dense and that density was a problem for their students.

When the teachers were subsequently directed to find examples of density in their science textbooks, they had a hard time finding noun phrases. Instead, they identified an entire sentence, such as "The innermost sensory tunic of the eye is the delicate white retina which extends anteriorly only to the ciliary body.", thinking that the more unfamiliar or technical words there were in a sentence, the higher the informational density. While they were able to identify simple nouns (e.g., *the eye*, *the white retina*) and verb (e.g., *is*), they had trouble recognizing larger chunks of the sentence, including complex noun phrases such as "the innermost sensory tunic of the eye" and "the delicate white retina which extends anteriorly only to the ciliary body". Billie expressed her unease with talking to her students about grammatical structures, remarking

> Well, English could be very helpful now that I am learning about this stuff. And it's so funny because I tease my students. You don't realize, oh, I'll never do this again. And then somewhere down the road you're like, if I only had paid attention to English. (Informal Conversation)

We led the teachers in completing several exercises involving deconstructing and building complex noun phrases (Fang, 2010) so that they could understand how information is packed into a long noun phrase. For example, we showed the teachers that "the innermost sensory tunic of the eye" contains a head (*tunic*), which is premodified by a determiner (*the*), an epithet (*innermost*), and a classifier (*sensory*), and postmodified by a prepositional phrase (*of the eye*).

Despite our efforts, the teachers' lack of confidence in unpacking noun phrases persisted. They noted that while density was "not necessarily a difficult topic", breaking sentences and phrases down into their constituents "has been the hardest thing". As Casey confessed,

> I think one of the challenges that I faced had to do with, again, not feeling as comfortable with the English component of it. For example, when we were doing the sentence combining or we actually did it the other way, too, where they actually wrote the sentences down and there were just some of the terms for the different parts of a sentence, the clause and such that I might not have remembered. I think that was one of the challenges. (Final Interview)

Like Casey, other teachers also expressed their concerns about having enough grammatical knowledge to effectively teach students to tackle density in science language. Toward the end of the PD experience, Brad and Billie felt that deconstructing dense sentences and phrases was, although important, "completely out of my comfort range".

4.4.2.4 Genres

There are six major genres, or text types, in school science: procedure, procedural recount, explanation, report, exposition, and discussion (Fang, 2010). Each of these genres has its own organizational structures and linguistic features that realize the purpose of the genre. Compared to abstraction and density, genre was a relatively easier concept to grasp for the science teachers. During the initial introduction to the topic, the teachers reviewed a matrix from Fang (2010, pp. 106–107) that listed different science genres and their structural and linguistic features. In subsequent PD sessions, the teachers were asked to analyze sample science texts to determine their genres and provide justifications based on their structural and linguistic features. They were able to identify and justify the genres of procedure, recount, report, and explanation, but felt unsure about how to differentiate between discussion and exposition. They drew primarily on their prior knowledge (e.g., purpose of text) and familiarity with text structure to justify their determination of genre types, but rarely mentioned grammatical features specific to each genre. (See also Seah & Silver, this volume).

Overall, the teachers found the work on genre important and useful and were comfortable learning about the concept. They indicated they were willing to try to incorporate it in their teaching. Brad commented:

> I really like genres. … it's important to teach kids what something is saying or the type of writing that it is and the different styles that you see. And they should be able to – you know, if they can identify it, it would probably help them understand it a lot better. (Final Interview)

Patsy also indicated that she found the information about genre useful for working with her biology students, especially when they were working on their science fair projects. In her own words,

> When I started looking at the genres, I thought, 'This has science fair all over it.' And the fact that I could help my students' understanding by having a better concept and better grasp of genres became apparent to me once I saw how many were used. (Final Interview).

4.4.3 Teaching Science Language

Throughout the PD, the science teachers expressed a strong desire to try out the four concepts discussed—technicality, abstraction, density, and genre. Because their understanding and comfort level varied with each of the concepts, they experienced different degrees of success and satisfaction in their endeavors. As a whole, the teachers seemed to experience more success and satisfaction when teaching concepts they knew relatively well and were comfortable with, but more anxiety/frustration and less success when teaching concepts with which they were less familiar and that required stronger grammatical knowledge.

4.4.3.1 Technicality

Of the four concepts, technicality was the most familiar to the teachers. They cited level of comfort, proximity to the strategies they had already been using, and prior knowledge about the importance of technical vocabulary to comprehension as reasons they would use strategies that addressed technicality in science reading. For example, Bette commented, "I knew that vocabulary was huge in science, so that's just something I used to always work with my students on just because I know it's so important from my medical terminology class and just experience before, as a student" (Mid-Term Interview).

Because of the familiarity, the teachers had little trouble envisioning how the strategies discussed in the PD could be a part of their teaching routines. Brad shared how he planned on addressing technicality in his teaching: "I like breaking down the word and doing the suffixes, the roots, and the prefixes; and I think in my journals next year, everyday is going to include breaking down a word from the chapter to help kids understand the vocabulary" (MT-MB-5).

Evidence from observations and interviews showed that the teachers used three of the strategies they had learned from the PD to address technicality in their classrooms: morphemic analysis, concept maps, and vocabulary think charts (Fang, 2010, pp. 52–59). For example, Patsy used the vocabulary think chart to introduce *vestigial organ* to her biology class. She began by putting a copy of the think chart on the overhead and reviewing the process of using the strategy. She then asked students to choose a word for analysis from their reading. One student picked the term *vestigial organ*. Patsy wrote it on board as the target vocabulary and engaged the class in analysis by reading through each probing question on the think chart.

Students started by identifying the word *organ*, noting that it means a collection of similar tissues within the body. Then, they examined *vestigial*. They identified *–ial* to be the morpheme that changed a root word into an adjective; so they assumed the root word must be close to *vest* or *vestige*. One student opened a dictionary and found that the word *vestige* means "a small amount".

Next, students brainstormed words that came to mind when they looked at the word parts in *vestigial organ*. They generated the following list: *footprints*, *imprints*, *organ donor*, and *carbon footprint*. While talking about these words, students connected real-life stories to their ideas, discussing people they knew who had organ transplants or why they thought the idea of a carbon footprint was connected to the concept of *a small amount*, which relates to *vestige*.

Subsequently, students examined the term in context. One student read, "The organs of many animals are so reduced in size that they are just vestiges, or traces, of homologous organs in other species. These <u>vestigial organs</u> may resemble miniature legs, tails, or other structures". Patsy then led the students to paraphrase a definition, writing on the think chart "the mark of something that once existed".

Finally, students used the term *vestigial organ* in a sentence from science. One student remarked, "A theory exists that whale's legs have become vestigial organs.". Another student shouted, "*Animals can exist without vestigial organs.*". A third student said, "The appendix is a vestigial organ because we do not need it to live.".

In closing, Pasty asked students to relate the term to a larger scientific concept, and they responded with this list: *evolution*, *Darwin*, *adaptation*, *survival of the fittest*, *natural selection*, and *modifications.*

4.4.3.2 Abstraction

The teachers believed it was important to address abstraction in science reading, despite their struggle with the concept. Brad, for example, shared in a PD session how he talked about abstraction with his students, saying,

> You know when they [authors] say *cutting down trees* and *deforestation*, they mean the same thing. Now I notice that and I can call it to students' attention when we are reading. I can ask them how they can say a word like *deforestation* or *journey* in another way. (PD Session #5)

Despite this belief, most teachers struggled in their attempts to design and deliver reading lessons that address abstraction. They focused on the lexical structure of a nominalization (e.g., changing a verb or an adjective to a noun) rather than the discursive functions of nominalization (e.g., condensing information, establishing technical taxonomy, creating discursive flow). Moreover, they designed sentence completion exercises without fully understanding the purpose of these exercises. As a result, their exercises resembled traditional cloze tasks or fill-in-the-blank items, failing to address the challenge of abstraction.

For example, Lisa developed a lesson requiring students to change abstract nouns into their verb/adjective forms, or vice versa. She wrote this brief passage on the overhead—*The shark consumes the food. This consumption of the shark involves eating seals and other marine animals.*—and asked students to locate words that were morphologically related. After students identified *consume* and *consumption*, she commented on how scientists change 'action' words into 'thing' words. She called attention to the word endings, explaining how adding *-tion* to *consume* changes the word from a verb to a noun. Next, she gave students a list of words (e.g., *absorb, reflect*, *discover*) and directed them to change these words into nouns. Students completed the worksheet in pairs.

Bette appeared to demonstrate a stronger understanding of how abstraction was used in science writing. When her biology class was studying population growth, she read a passage from the textbook (below) and called students' attention to *the relationship*, asking them to identify what the phrase refers to and what it does to the development of ideas in the text.

> Sea otters are important members of the kelp forest community of America's Pacific Northwest coast. This "forest" is made up of algae called giant kelp, with stalks up to 30 meters long, and smaller types of kelp. The kelp forest provides a habitat for a variety of animals. Sea otters need a lot of energy to stay warm in the cold water, so they eat large quantities of their favorite food: sea urchins. Sea urchins in turn feed on kelp. <u>The relationship</u> along this food chain set the stage for a classic tale of population growth and decline.

4.4.3.3 Density

The teachers likewise struggled to integrate the concept of density in their teaching. They had a difficult time identifying long, complex noun phrases in their textbooks. They relied primarily on our support in planning and delivering lessons that addressed density in science texts. For example, Billie felt that many of the sentences in her textbook were simplified. She met with us to go over some sample passages and determined that she needed to use another textbook to look for better examples of sentences with complex noun phrases. Mona had a similar feeling about her physical science textbook. She was concerned that the textbook writers did not use enough 'real' science language in their attempts to make text easier for students to read. She gave the following sentence from a textbook as an example:

> How many different ways have you used energy today? Today, Coral and Buster used a hair dryer or a toaster. If you did, you used energy. Furnaces and stoves use thermal energy to heat buildings and cook.

One solution for the teachers who perceived that their textbooks did not have enough examples of dense sentences was to locate alternative reading materials (e.g., trade books, magazine articles). Because Mona and Billie both taught the same physical science course, they agreed to work together to find some examples to supplement their textbooks.

Another solution we recommended was to look for definitions in the text, as definitions in science (e.g., *Fossil fuels are <u>the energy-rich substances formed from the remains of once-living organisms</u>.*) typically contain long noun phrases that pack dense information (Fang, 2021). However, even with definitions, the teachers continued to struggle with identifying complex noun phrases, especially when these phrases were placed in the object (as opposed to the subject) position of a sentence. They were able to pick out simple nouns (e.g., *substances*, *the remains*, *organisms*), but often did not see how these were strung together to form an expanded noun phrase that contains a head with a series of pre- and post-modifiers. As a result, we ended up co-planning and co-teaching many lessons on density with the teachers, helping them search for complex noun phrases, deconstruct these noun phrases, and model coping strategies.

The teachers seemed to consider paraphrasing and sentence combining (Fang, 2010) as useful strategies for addressing density. In paraphrasing, students repackaged the information presented in complex noun phrases and dense sentences in a way that is easier for others to understand. In sentence combining, students integrate two or more simple sentences into one sentence featuring complex noun phrases. They saw these strategies as ways to help students reword dense sentences for better understanding and to write dense sentences that sound more scientific or academic. The teachers reported active student engagement with the sentence combining task, noting that a similar task was also being used in some English Language Arts classes.

Despite our modeling and their willingness to try, most teachers were still not confident in their ability to teach density on their own. Brad and Bette, for example, reported that they tried out several lessons, but did not feel it was making an impact on their students. They hoped to be able to address density next year after more practice.

4.4.3.4 Genre

During the PD sessions, the teachers were introduced to the genre teaching–learning cycle (Derewianka, 1990; Fang, 2010), a heuristic for teaching writing/reading that consists of four phases: preparation, modeling, joint construction, and independent construction. During the preparation phase, the teacher selects appropriate materials related to the focal concept(s) in the curriculum and immerses students in reading these materials. In the modeling phase, the teacher introduces a text model of the target genre and engages students in explicit discussion of the genre in terms of its social purpose, schematic structure, and lexico-grammatical features. In the joint construction phase, the teacher engages students in writing the target genre through collaboration with peers. In the final phase, students write the target genre independently.

In implementing the genre teaching–learning cycle, one key concern shared by the teachers was time. They worried about the amount of time it would take to teach students to write each genre. They also worried about their expertise in genre instruction because they did not see themselves as literacy teachers. As Lisa put it,

> … and back to what you were discussing with modeling, I hadn't heard of this, not being a reading teacher and so getting into modeling in the classroom with the reading strategies to help them – I'm very happy with this, but I'm gonna have to stretch my muscles a good bit to work on some strategies that will work in marine science to do this kind of thing. We're doing teaching reading and we're teaching science and you can still do both, but it requires a huge, greater amount of effort in one sense to go back and learn all the modeling strategies 'cause we're not English teachers. (PD Session #7)

Even though they were concerned about time and their own expertise, they still tried to think of ways they could bring the notion of genre into their classrooms because they saw value in engaging students in learning the genres of science. Bette summarized her feelings about the genre work this way:

> I think that again, this teaching cycle of, you know, the immersion in the different types of genres and the attention to talking about the different, you know, text structures and social purposes and then allowing them to kind of jointly and then independently construct is a powerful model. I think it would take some dedication and some thought, but I think that it's – I think there's a lot of potential there. (Final Interview)

Another issue the teachers raised in their implementation of the genre teaching–learning cycle was whether to introduce one genre at a time or all of the science genres at once. Casey and Lisa indicated they would do one genre at a time to ensure mastery before moving on to the next genre. They focused on the procedure genre because their students were doing a lot of laboratory work in class then and needed to follow procedures. Brad, Mona, and Bette, on the other hand, preferred to introduce all six genres at once because they felt students would do better to see all of the genres and to recognize them across the readings that were used in the classroom. Mona, for example, introduced the genre teaching–learning cycle by telling students "I want to prepare you to read all kinds of science.". She found 25 different articles from various sources and had each student read and analyze one of the articles for its structural and grammatical features.

4.5 Discussion

During the seven-month PD experience, the science teachers developed a basic sense of the specialized features of science language, though they felt more comfortable with technicality and genre than with abstraction and density. They also became more aware of how/why science language poses a challenge to students and felt better prepared to support their students in science reading. Because of the differences in their prior knowledge, experiences, beliefs, motivations, and teaching goals, the teachers demonstrated different degrees of understanding about science language and of success and satisfaction in integrating it into their teaching.

These findings are largely consistent with what previous research has suggested about the challenges of helping teachers develop linguistic expertise for disciplinary literacy instruction (e.g., Fang et al., 2008, 2014). Science teachers were interested in but apprehensive about learning to teach language/literacy in their classrooms; and with support, they were capable of implementing, to varying degrees of success, language/literacy strategies to advance their disciplinary goals. Their success in integrating language/literacy with science depends on not only personal factors (e.g., conception of science, grammatical knowledge, prior training, past learning experience, motivation) but also contextual factors (e.g., school culture, classroom realities, opportunities to learn/share/reflect, level of support from experts/peers/administrators).

With respect to our study, a multitude of factors influenced the ways the seven science teachers learned about science language/reading and applied what they were learning to classroom teaching. We theorize the complexity of their learning in Fig. 4.1. This grounded theory model of how secondary science teachers learned to teach science language/reading consists of three systems of influencing factors, each represented in a big circle—the school culture, the individual, and professional development. The elements within and across the three systems interacted in complex ways to determine the degree of success and satisfaction each teacher experienced during the learning process. At the intersections of these three systems is the *opportunity to talk*, which emerged as the core factor that appeared to account for the greatest influence on the degree to which the teachers experienced success and satisfaction in learning to teach science reading through a functional focus on language. Each system of influencing factors can exist independently or in interaction with the others; therefore, the circles are represented both independently and intertwined. However, it is through the interaction of the systems that the *opportunity to talk*—that is, time for candid discussion, sharing, and reflection among members of a teaching–learning community—is created and in turn the process of learning is impacted. We unpack key factors that impact our teachers' learning below.

One factor that made a positive contribution to the teachers' learning and engagement was their willingness to learn. All seven teachers believed in the importance of language/literacy to science and were motivated to learn about science language in order to better help their students read/write science texts. While they continued to see themselves as science teachers, they recognized the need to engage with language/reading and were willing to take up a task traditionally thought to be English

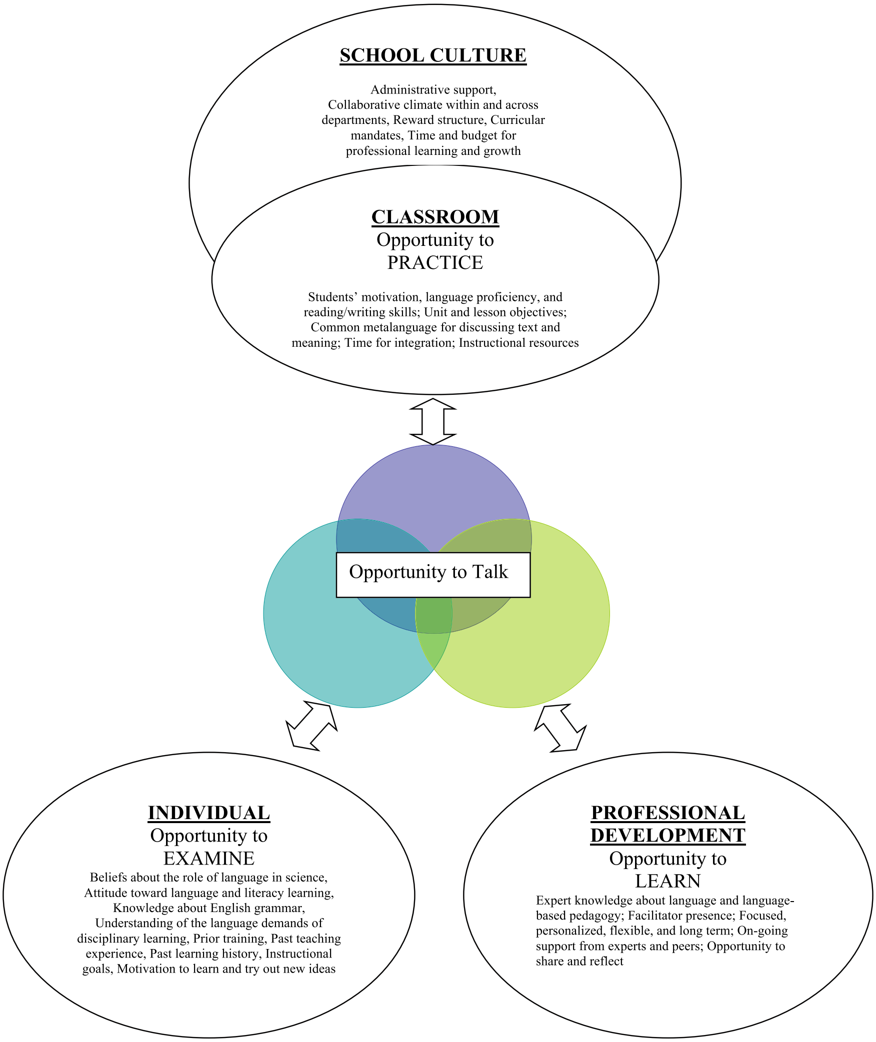

Fig. 4.1 Grounded theory model of teacher learning about science language/reading

teachers' responsibility. They were eager to learn new information and implement new ideas in their classrooms. Even when the PD was over, they expressed a desire to continue learning, sharing, and trying out new ideas and strategies. They were also interested in exploring ways of collaborating with other members in their department so that they could disseminate the knowledge they had gained through the PD. This finding suggests that the science teachers were keen to understand how to address the language and literacy needs of their students. It challenges popular depictions of content area teachers as disinterested in or even resistant to literacy learning (c.f., Moje, 2008) and support the recommendation that teacher educators reframe how they view the willingness of secondary teachers to learn about disciplinary literacy practices (Siebert & Draper, 2008).

Another factor that likely facilitated the teachers' language/literacy learning is the support they received through the PD experience. Our PD fostered a learning community in which peer collaboration and candid conversation were encouraged. The teachers seemed to be particularly appreciative of the opportunity to talk about their learning and their practice during the PD meetings. They valued the time to listen to one another sharing ideas and reflecting on what they were learning and practicing. They enjoyed the time they spent together to plan lessons and to tell stories about their implementation of new ideas and strategies. The opportunity to talk with and listen to peers also built the teachers' confidence, making them less fearful of failure and more willing to take risks. This contributed to their feeling comfortable experimenting with new ideas, which in turn increased their confidence to practice what they were learning in their own classrooms. It showed the benefits of creating learning spaces where teachers felt safe to talk about and try out new practices.

In addition to the support during the PD meetings, we also provided support to the teachers when they were in 'the trenches'. On a regular basis, we observed the teachers in their classrooms and sometimes assisted with teaching, providing feedback and encouragement. We were flexible with our role as facilitator in their classrooms. For example, whereas Brad and Bette liked us to come and do demonstration lessons in their classrooms, Lisa preferred that we observed her in a more traditional manner. Patsy, on the other hand, liked to consult with us during the lesson. She would lead the lesson, with us sitting in the back of the classroom watching. She would often ask us to elaborate on or demonstrate how to use a particular strategy when she felt stuck. In short, the teachers had individual responses to the level of support they required or wanted when attempting to integrate new ideas or strategies into their teaching.

Another accommodation we made in our role as facilitator was to allow each teacher to decide what to integrate and how to integrate based on what they were learning from the PD. The teachers sometimes struggled to find ways to integrate what they were learning with the curriculum they were using. Even though they were learning about science language/reading during the PD, thinking about how to use the newly acquired knowledge in their classroom teaching presented a new set of challenges. To address the implementation challenges, we met with the teachers individually to help them find connections between what they were learning in the

PD and what they were teaching in their curriculum and suggested ideas for making the integration. These one-on-one meetings eased the teachers' anxiety and made the task of integration less intimidating.

Two other aspects of our PD program likely helped increase the teachers' buy-in and sustain their interest and engagement. One has to do with the PD content. The teachers valued the discipline-specific information we provided, noting the benefits of being able to focus on just science language/reading rather than content area literacy more broadly. They reported that having access to expert knowledge and flexible scaffolding helped them see the important roles language plays in shaping knowledge and influenced their buy-in to the ideas presented in the PD sessions (cf. Fang et al., 2008). The second aspect about our PD program is that the teachers were all from the same content area working in the same school. This helped create a close-knit community where learning and application co-occurred and that promoted the concurrent construction of what Cochran-Smith and Lytle (1999) referred to as three essential and interrelated dimensions of professional knowledge about teaching and learning—that is, knowledge-for-practice (e.g., knowledge imparted by instructor and textbook), knowledge-in-practice (e.g., knowledge gained through reflection about and critique of one's own experience in the field), and knowledge-of-practice (e.g., knowledge gained through deliberate inquiry).

The school climate also had an impact on the teachers' commitment to learning. The seven science teachers were part of a school where continuous professional development was valued and actively promoted, as evidenced in the various department-wide study groups that had already been established prior to our project. In addition, the school principal showed her support for our project by visiting the science teachers' department meeting and encouraging them to participate in our PD project.

Besides the school climate, the classroom environment played an important role in the teachers' learning. The science teachers' commitment to the PD resulted in part from the needs they saw in their students to improve science reading. They were concerned about their students' lack of motivation and/or proficiency to read science. The teachers' commitment to the PD was likely also influenced by their perception of the PD's impact on student learning (c.f., Guskey, 2002). They reported that when their students were engaged and successful with a new strategy they introduced, it helped them see how a focus on language in science could support their students' science reading, writing, and learning. This, in turn, reinforced their dedication to the PD project.

Despite their motivation and willingness to participate in our PD, the science teachers did face some significant challenges in their learning about science language/reading and in applying what they were learning to their teaching practice. Chief among these challenges is the teachers' scant knowledge about the English grammar—its systems, forms, and functions—and the resulting lack of a linguistic metalanguage that is essential for engaging students in productive talks about language/text and meaning. Although the teachers were aware that language is a barrier to science reading, their understanding of the challenge was initially confined to scientific terminology. They had considerable difficulty identifying language patterns beyond the word level, struggling in particular with learning to teach abstraction and density, two concepts that involve understanding of language at the phrase and discourse levels. They also tended to focus on linguistic forms but neglect their discursive functions when teaching language in science.

Another factor that inhibited the teachers' learning was time. They found it challenging to add language/literacy instruction to their already packed curriculum. They felt that more time would have helped them feel more successful in their planning and implementation. They said they needed more structured time to plan lessons with the support of their fellow teachers and the facilitator to make appropriate connections between the new ideas and their existing curricula. They wanted more time to talk and share with their peers during the PD about what they were learning and how they were applying their new knowledge in their classrooms. They expressed a willingness/eagerness to stay for at least an extra hour during each PD session. They also wanted more time for feedback and support during their classroom implementation, noting that more time to practice in the classroom and receive feedback from peers would have helped them to continue using what they were learning in their teaching.

4.6 Conclusion

Science is "a unique mix of inquiry and argument" (Yore et al., 2004, p. 347). Language plays an essential role in construing and shaping science knowledge and argument. An understanding of science language is, thus, critical to supporting students in developing science literacy. Science teachers are best positioned to undertake this work because of their content expertise (Fang, 2014). However, they need considerable support in developing the linguistic expertise—i.e., knowledge about the forms, structures, logic, functions, and meanings of lexico-grammatical choices and familiarity with a linguistic metalanguage for engaging students in productive conversations about text (Fang, 2020)—that will help them better understand what it is that makes science texts challenging to read for students and explicate to students how language choices make meaning in science. Such support can be provided through professional development programs. To be effective, these programs need to be long term, discipline specific, focused, and flexible. They also need to provide ample opportunities for discussion and sharing and for connecting learning with teaching. Furthermore, they need to recognize and respond to the many individual and contextual variables that facilitate or inhibit the development of knowledge for, in, and of practice. Only until then can we truly empower teachers to make positive changes and improve student learning.

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Chapter 5
Building Science Teacher Disciplinary Linguistic Knowledge with SFL

Kathryn Accurso and John Levasseur

Abstract This chapter analyzes one high school science teacher's development of disciplinary linguistic knowledge (DLK) for the purpose of meeting the civil rights of multilingual students in his English-dominant classroom. First, the chapter offers a brief description of the theoretical underpinnings of DLK and our conception of teachers' professional knowledge development. Second, we outline our ethnographic methods for tracing the focal teacher's DLK development. Third, drawing on six years of data, we present findings which suggest four stages of DLK development: (1) learning functional metalanguage to "see" classroom discourse in new ways; (2) applying functional metalanguage to develop conscious knowledge of official literacy practices in high-school science; (3) applying functional metalanguage to develop conscious knowledge of multilingual students' literacy practices in science class; and (4) experimenting with language-focused curriculum design and implementation for unique contexts. Finally, we discuss what changes to practice emerged from this process and had staying power over time, as well as the implications of our findings for the practice of science teacher education and professional development.

Keywords Secondary teacher education · Professional development · Science education · Disciplinary literacy · Systemic functional linguistics · Critical language awareness

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5.1 Introduction

> We've got English learners at an all-time high but no ESL teachers who can pass the [content-area licensure exam] in science. And on the other hand, we've got science teachers who don't have the language piece—that's me. But we've got to give all students access to the content, so I need to understand the language of science, and I need to understand it fast.
>
> —John Levasseur, chemistry teacher at 'River City High School'

The work of secondary science teachers in the USA has changed rapidly over the last 20 years as forces of globalization and related school reforms place new demands on teachers and their students regarding the teaching and learning of disciplinary literacies. At the same time, science teachers have faced increasing calls to grapple with the ways colonialism and systemic racism have influenced science teaching, learning, and literacy practices (e.g., Mutegi, 2011; Sheth, 2019). And this is not even to mention the more recent moment-by-moment changes science teachers have contended with as a result of COVID-19. At the confluence of these factors, science teachers today are tasked with designing and implementing curriculum and instruction that aims to correct documented inequities in the discipline while also responding to the rise of new technologies and a knowledge-based economy, the widespread adoption of new content standards, and standardized accountability systems that measure teachers' and students' performance relative to those standards (e.g., Darling-Hammond, 2004).

As high school science teacher and co-author of this chapter, John Levasseur observes in the quote above, these demands and their implications for the knowledge base of teaching are felt acutely by teachers living and working in communities whose schools serve large numbers of students designated as English learners, the fastest growing student population comprised primarily of students of color (Mitchell, 2013).[1] Yet these multilingual students' civil right to a high-quality public education often goes unmet in schooling systems designed with white monolingual learners in mind. For teachers like John, responding to these issues can be daunting because many secondary teacher education programs do not include coursework in disciplinary literacies, language teaching, or literacy instruction that is racially conscious or decolonial. And even programs that do touch on these topics may only offer a single course meant to cover all aspects of teaching multilingual students in content classrooms.

Yet the Common Core literacy standards and Next Generation Science Standards (NGSS) call for science teaching that ensures *all* students develop content knowledge and knowledge of scientific meaning-making norms and conventions (CCSSO, 2010; NGSS Lead States, 2013). These disciplinary practices include making and assessing oral and written arguments; synthesizing complex information, including

[1] We prefer "multilingual students" for its asset-orientation, whereas "English language learners" or "ELLs" centers ideologies of standard and a perceived deficit in students bearing the designation (e.g., Rosa & Flores, 2015). In this chapter, we generally use the former; however, where you see the latter, it is from a direct quote or used ethnographically to report official designations used in the local school district as justification to assign particular students to particular science classes.

data that convey information and illustrate scientific concepts; and following detailed procedures and explanations. In other words, to meet the demands of new standards, students must demonstrate scientific content knowledge and critical thinking skills through their ability to comprehend and produce complex multimodal texts for a wide variety of audiences. Thus, as a matter of meeting students' civil right to equitable educational opportunity, science teachers must develop an ability to notice and build on the communicative resources that already exist in their classrooms with the goal of apprenticing all students to using talk, print, and visual modes of communication such as equations, graphs, tables, diagrams, as well as digital tools purposefully, yet flexibly, to construct and communicate content knowledge (Rymes et al., 2016). Moreover, as John's opening quote suggests, equitably teaching "all students" means centering students who have been marginalized and taking more explicit responsibility for their science education experience.

However, this emphasis on equity and literacy is new for many science teachers, who tend to view their primary responsibility as content delivery, with relatively little attention to language (e.g., Tan, 2011). When combined with the historic lack of attention to language and literacy in science teacher education programs, many educational researchers are concerned that all students are not being well-supported to meet the demands of Common Core and NGSS, particularly multilingual students (e.g., Lee et al., 2013). Moreover, they are concerned that meeting the demands of these standards is consciously and unconsciously presented to students as something they must set aside their home language practices to do (e.g., Flores, 2020). Research demonstrates that content teachers' unawareness of language and inability to support multilingual students' disciplinary literacy development in culturally sustaining ways can have long-lasting effects on these students' social, academic, and economic futures (e.g., Harman, 2018; Schissel, 2019).

In response, language education scholars have suggested that to engage in linguistic equity work, K-12 teachers must develop *disciplinary linguistic knowledge* (DLK; Turkan et al., 2014). DLK is a specialized knowledge base articulated as "the linguistic knowledge base that *all* teachers of ELLs need to facilitate students' *understanding* of oral and written discourse within a discipline and their *use* of language in ways that allow them to actively participate in the disciplinary discourse" (p. 9; emphasis original). DLK is conceptualized in two parts: (1) knowledge to identify meaning-making choices in disciplinary discourses; and (2) knowledge for modeling these choices to students. In conjunction, these knowledges are understood as foundational for teachers to design curriculum and instruction that apprentices multilingual students to disciplinary literacy practices at the same time as students are developing the content knowledge constructed through these practices. However, few studies have explored secondary science teachers' development and use of DLK. Therefore, in this chapter, we ask:

RQ1: What were key stages in John's development of disciplinary linguistic knowledge?

RQ2: How did John attempt to use DLK to meet the civil rights of multilingual students in his English-dominant high-school science classroom?

In addressing these questions, we first offer a brief description of the theoretical underpinnings of DLK and our conception of teachers' professional development. Second, we outline our methods for tracing John's DLK development. Third, we present our findings, demonstrating John's movement through four stages of DLK development: (1) learning functional metalanguage to "see" classroom discourse in new ways; (2) applying functional metalanguage to develop conscious knowledge of official literacy practices in high-school chemistry; (3) applying functional metalanguage to develop conscious knowledge of multilingual students' literacy practices in chemistry; and (4) experimenting with language-focused curriculum design and implementation for his unique context. Finally, we discuss what changes to John's practice emerged from this process and had staying power over time, as well as the implications of our findings for the practice of science teacher education and professional development.

5.2 Theoretical Framework

5.2.1 Disciplinary Linguistic Knowledge

Turkan and her colleagues' (2014) proposal of DLK built on the work of academic language scholars (e.g., Bailey & Butler, 2003; Cummins, 1980; Scarcella, 2003; Wong-Fillmore & Snow, 2000) and systemic functional linguistic theorists (e.g., Halliday & Hasan, 1989). They credited the former for defining the phenomenon of "academic language" and how it differs from "everyday language," beginning with Cummins' conceptualization of Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP). They situated this understanding of academic language within the semiotic theory offered by systemic functional linguistics, or SFL, which "sees language as a social process that contributes to the realization of different social contexts" (Schleppegrell, 2004, p. 45). In addition, they drew on SFL's rich metalanguage for talking about language choices made in different contexts to achieve particular social purposes. Based on these literatures, Turkan and colleagues defined DLK as teachers' knowledge of disciplinary discourse, specifically their knowledge for "(a) identifying linguistic features of the disciplinary discourse and (b) modeling for ELLs how to communicate meaning in the discipline and engaging them in using the language of the discipline orally or in writing" (2014, p. 9).

However, critical language education scholars have heavily critiqued academic language scholarship, including some classroom interpretations of SFL, for its binary and disembodied framing of linguistic practices (i.e., academic versus non-academic); positioning of academic language as both idealized and yet ideologically neutral; and failure to address the harmful ways academic language as a construct has been wielded against racialized students and multilingual students of color to portray them as linguistically deficient and justify low or assimilationist expectations and supports (e.g., Accurso & Mizell, 2020; Flores, 2020; Flores & Rosa, 2015). We align with these critiques of academic language scholarship and reject the idea that there is an objective or fixed set of "appropriate," "proper," or "correct" language practices that content teachers must convey or students must first master to engage in teaching and learning in a particular discipline.

Accordingly, in this chapter, we do not describe DLK or John's development of it relative to *the* language of science as if that were a fixed discourse. Rather, we understand DLK as a knowledge base for exploring and teaching a wide range of language practices in disciplinary contexts, including (a) knowledge for identifying meaning-making choices in the discourses already being used in a given class, and (b) modeling choices to students and intentionally engaging them in the production of disciplinary meanings themselves. In other words, for us, DLK is the knowledge base a content teacher needs to be a language analyst and a language teacher, as opposed to just a specialized language user (Andrews & Lin, 2017; Edge, 1988). This perspective is consistent with the dynamic non-binary view of language articulated in systemic functional linguistic theory.

5.2.2 Systemic Functional Linguistics (SFL)

SFL is a social semiotic theory that sees language as a functional meaning-making system that is flexible, adaptive, and context-sensitive (Halliday & Hasan, 1989). Other meaning-making systems include gestures, symbols, and images (Bezemer & Kress, 2016). Applied to science education, SFL would suggest these semiotic systems are dynamic sets of resources for thinking scientifically, participating in scientific discourse with others, and making scientific meanings coherent when constructing extended oral, written, and multimodal texts in different situations (Harman et al., 2020). Moreover, people draw differently on these semiotic systems as they come to know the natural world and "do" science in different contexts and from different cultural perspectives (e.g., Western, Indigenous, etc.; Medin & Bang, 2014). Thus, from an SFL perspective, the language of science is not a static construct. It is not fixed sets of vocabulary words or decontextualized rules students should memorize and follow in order to use language "properly" (e.g., never use *I* or an exclamation point in a laboratory report), views subtly promoted in many Western science classrooms (Richardson Bruna et al., 2007). The language of science is a vibrant multimodal and often multilingual system that people continually build and learn to use to accomplish a wide variety of goals associated with the discipline—cognitive, social, academic, and political goals—both in and out of school.

Register: Language variation by situation. SFL theory suggests that in any situation people make communicative choices based on three factors of context: the ideas or experiences they are construing (the *field* of communication), the social roles they are taking up (*tenor*), and the *mode* through which they are communicating. The choices people make to construct these aspects of a situation constitute the *register* of communication (Halliday & Hasan, 1989). Register choices happen at different levels of language and different levels of consciousness. When people use language, they consciously and unconsciously choose certain ways of pronouncing or graphically rendering words, making grammatical constructions, and creating coherence across extended discourse. In doing so, they simultaneously construct a topic, construct or maintain relationships with others, reflect a culture and set of ideologies, and coherently connect related topics to move through a situation (see Schleppegrell, 2004, p. 47 for more on register dimensions). The science classroom is no exception. For example, as Fig. 5.1 illustrates, many written meanings in Western science classrooms are constructed through technical words and phrases packed into dense nominal groups and relational clauses. Additionally, science classroom texts often incorporate graphs, tables, and diagrams. These register choices function to condense information, construct scientific theories, and explicate processes in a neutral or "authoritative" or "objective" voice (Schleppegrell, 2004, p. 118). Of course, these register choices are not the only way science linguistically happens. Defining, condensing, theorizing, and explicating are social functions most students already do with language—or multiple languages—in their lives outside the science classroom. If science teachers understand field, tenor, and mode choices being made in the classroom context, they may be better able to acknowledge and value the multiple social and linguistic worlds to which multilingual students already belong and support them in participating in and creating possible future worlds by expanding the meaning-making resources available to them in disciplinary spaces (Harman et al., 2020).

Genre: Recurring patterns across situations. Broad cultural goals coordinate register choices into recurrent text types, or *genres*, across situations (Martin, 1992). Within Western science classrooms, these goals are often expository or analytical and may include recounting the procedure for a science experiment, reporting on a phenomenon through description and classification, or explaining how or why a phenomenon occurs. Texts that aim to accomplish similar goals in similar cultural contexts tend to unfold across similar genre stages. For example, written explanations in Western science classrooms often have two recognizable stages in the way they are

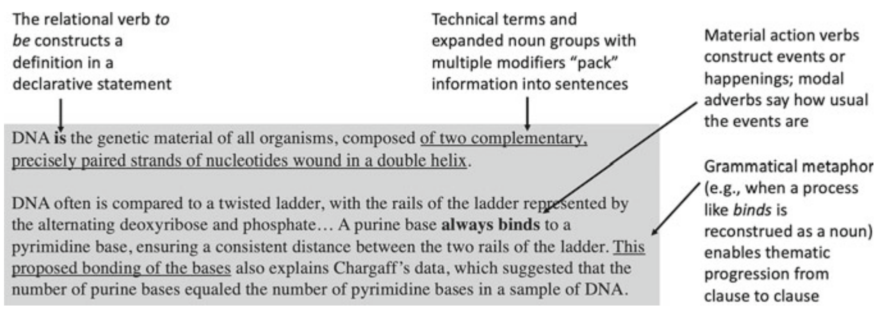


Fig. 5.1 Register choices in a sample of western science classroom discourse

structured: an identification or description of the phenomenon to be explained, and an explanatory sequence that details how or why that phenomenon occurs (Derewianka, 1990).

5.2.3 SFL and Teacher's Professional Knowledge Development

We also draw on SFL as a language-based theory of learning (Halliday, 1993) to conceptualize teachers' DLK development as having begun in their experiences as students themselves. For example, by the time most secondary science teachers enter the profession, they have had substantial experience learning to mean in science classrooms over the course of their K-12 and post-secondary education. They also have, to varying degrees, developed scientific concepts and semiotic resources with which to construct these concepts through their routine interaction with more knowledgeable others and the ways those others use particular genres and registers in school and other contexts (Wells, 1994). However, this linguistic knowledge tends to be tacit and therefore difficult to teach in any systematic and functional way to students who are unfamiliar with tasks, audiences, and language practices articulated in new science standards. To build on this tacit linguistic knowledge and support teachers in moving toward disciplinary linguistic knowledge, SFL-informed scholars argue for an explicit, critical, and sustained apprenticeship in which teachers gain a more conscious awareness of how language and other semiotic resources are being used in their disciplines as part of the new knowledge base of teaching (e.g., Gebhard, 2019).

In what follows, we present a case study of John's DLK development and how he attempted to make use of that knowledge in teaching science to multilingual students.

5.3 Methods and Context

This case study unites ethnography and action research in what we call the "ACCELA methodology" (Gebhard, 2019). ACCELA stands for "Access to Critical Content and English Language Acquisition" and is the name of a professional development alliance forged between the University of Massachusetts, Amherst and two urban school districts to develop critical knowledge for supporting multilingual students. The alliance supported the professional learning of paraprofessionals, teachers, principals, doctoral students, teacher educators, and literacy researchers by bringing them together around classroom-based action research projects and supporting their inquiries through professional development courses. When this study began in 2012, we (John and Kathryn, the co-authors of this chapter) had both just joined ACCELA and were taking a course that introduced us to SFL and positioned us as co-researchers of literacy practices related to science teaching and learning. At the time, John had been a high school science teacher at River City High School (a pseudonym) for 12 years, but was transitioning from being a so-called mainstream science teacher to teaching dedicated ELL science classes. He had just taken over his first ELL chemistry class. Kathryn was a doctoral student in teacher education with a background in linguistics and teaching K-12 multilingual students. John graduated from ACCELA with a master's degree and ELL licensure in 2016, but our inquiry continued through 2018 when John left River City High to teach at a middle school in the district and Kathryn moved out of state.

5.3.1 School Context

River City High is a large urban high school. In 2012, it was the highest achieving public high school in the city according to state standardized test scores and this was a reputation administrators wanted to protect. Yet the school was in a state of flux, as John observed in the quote that opened this chapter. The student population had shifted dramatically over the previous decade in terms of its racial, socioeconomic, and linguistic diversities. In 2012, a majority of students identified as Hispanic (46%), whereas ten years prior the majority were white (43%). In 2012, 79% of students were experiencing poverty, a proportion that had more than doubled since 2002. And in 2012, nearly a quarter of the student body spoke a language other than English at home (23%), whereas in 2002 ELLs accounted for only 3% of the student body. In the same span, while students' racial and linguistic diversity shifted, faculty diversity did not.

School administrators were keenly aware of students' race, class, and language backgrounds as factors that influenced their performance on standardized tests. For example, they noted that only 3% of ELLs who took the mandated state science test the previous year were rated as proficient. Rather than considering the suitability of a performance measure designed for and normed on a different student population, the state began to label all ELL and low-income students—categories largely comprised of students of color—as "high needs." As a result, in 2012, the first year this label was applied, 82% of students at the city's highest performing public high school were considered "high needs."

The state's solution to designated ELL students' "high need" was to provide content courses taught by teachers who were licensed in a subject area but also had some preparation for teaching English as an additional language. As enacted in River City, this policy had the effect of keeping designated ELLs in a silo; they were grouped into content courses separate from those taken by non-ELLs and their learning spaces were, for the most part, physically separated into an "ELL wing" of the building. Moreover, all their content learning was governed by a single ELL department that was often not in conversation with other disciplinary departments (e.g., Science, Math, Language Arts, and Social Studies). John's ELL chemistry class was an exception. Because John's teaching assignment still included several

Table 5.1 Demographics of John's 2012–2013 ELL chemistry class ($n = 23$)

Gender	Grade	Race/ethnicity (self-identified)	Home language	English proficiency level (WIDA)	Years in River City district
10 female 13 male	3 grade 10 19 grade 11 1 grade 12	13 Hispanic 4 Asian 2 African American 4 Prefer not to say	16 Spanish 3 Nepali 2 Arabic 1 Urdu 1 Vietnamese	2 Emerging (level 1) 6 Beginning (level 2) 7 Developing (level 3) 7 Expanding (level 4) 1 Bridging (level 5)	2–3 years: 11 students 4–6 years: 5 students 7–9 years: 3 students Unknown: 4 students

mainstream chemistry classes held in the science wing of the school, his ELL students came there. As Table 5.1 shows, John's first class of ELL chemistry students were mostly 11th graders who came from a range of ethnic and linguistic backgrounds. They had differing levels of English proficiency. Some were relatively new to the River City public schools, while others had been in the district for as many as nine years. Naturally, student demographics in John's ELL science classes shifted from class to class and year to year, but across the time of this study, each class could be characterized by a similar range of diversities.

5.3.2 *Data Collection and Analysis*

The first year of our collaboration (2012–2013) was focused on understanding how John and his first class of ELL chemistry students used and made sense of language as they engaged in science teaching and learning. During that year, we collected ethnographic data across two sites: (1) John's ELL chemistry classroom at River City High and (2) the ACCELA course where we met weekly to learn SFL and practice using it to analyze the language practices in that chemistry class. Kathryn was the main data collector and she collected multiple domains of data, including field notes; transcripts of audio and/or video recordings of ACCELA and ELL chemistry class sessions; chemistry class artifacts such as textbooks, curricular materials, and ELL student writing samples; photos of River City High to document John and his students' semiotic context; and ACCELA artifacts such as our recurring reflections on SFL and language use in science education. Subsequent years (2013–2018) were focused on curriculum design, implementation, evaluation, and refinement. During these years, John collected data and Kathryn served as a critical partner for feedback, analysis, and interpretation (Young, 1999). John collected curricular materials from approximately one ELL science unit of instruction per academic year, samples of student work during the unit, video recordings of his instruction, and written reflections on his design of materials and multilingual students' interaction with them.

We analyzed these data qualitatively drawing on principles from grounded theory (Charmaz, 2006) and a coding process following Saldaña (2016). First, we reviewed all hard copy data for general impressions; memory refreshment; data reduction; and to pre-code, or mark any moments, passages, or quotes that stood out to us. Then, we began initial coding manually, followed by focused coding using categories connected with John's language-related development, such as his feelings about linguistic theory, use of metalanguage, understanding of SFL concepts, being a language analyst, adoption of a linguistic concept into teaching practice, explicit language teaching, and so on. Then, we wrote a series of analytic memos regarding important moments in John's language-related knowledge development and the activities or events that contributed to his learning. Finally, we revisited the memos and our previous rounds of coding with the constituents of DLK specifically in mind to identify key stages in his development and use of this specialized knowledge base. This research process incorporated important validity strategies, such as prolonged time in the field, triangulation across multiple types and sources of data, and member checks from Kathryn to John (Creswell, 2014).

5.4 Findings: Four Stages in Developing Disciplinary Linguistic Knowledge

Our analysis revealed four key stages in John's development of disciplinary linguistic knowledge as he moved from simply being a language of science user to being a language analyst and language teacher, as well: (1) learning functional metalanguage to "see" classroom discourse in new ways; (2) applying functional metalanguage to develop conscious knowledge of official literacy practices in high-school chemistry; (3) applying functional metalanguage to develop conscious knowledge of multilingual students' literacy practices in chemistry; and (4) experimenting with language-focused curriculum design and implementation for his unique context. The first three of these stages are pertinent to RQ1 and John's development of knowledge for identifying disciplinary meaning-making choices. The fourth stage relates to RQ1, RQ2, and John's development and use of knowledge for effectively modeling new options for disciplinary talk, writing, and meaning production.

5.4.1 Stage 1: Learning Functional Metalanguage to "See" Classroom Discourse in New Ways

John was introduced to functional metalanguage in September 2012 through Mary Schleppegrell's (2004) book *The Language of Schooling*. Over two weeks, John read about the SFL concepts and metalanguage of *genre*, *register*, *field*, *tenor*, and *mode*. He also read articles in which other teachers recounted their use of this metalanguage to understand their classroom practice and students' language use (e.g., Gebhard et al., 2007). Though John was quite open to these readings and had a desire to learn more about language, he was initially resistant to functional metalanguage, describing it as excessive jargon. "I do think language is important," he said during an ACCELA class discussion following these readings, "but I'm not into edu-babble," which he defined as "non-productive thoughts and theories" (9/27/12). This view persisted for several weeks as John was introduced to more SFL metalanguage for analyzing specific dimensions of register (e.g., *participants*, *processes*, *mood*, *modality*, *zigzag, theme/rheme*). As this metalanguage built up, John struggled to integrate the concepts and metalanguage into his existing, more traditional understanding of grammar, saying "it is **all** slippery to me" (10/18/12).

Over time, however, functional metalanguage became more than slippery, irrelevant edu-babble to John; it became a way of understanding the connection between specific language choices and the scientific purposes they accomplished. The breakthrough moment for John came in an ACCELA class meeting where we were asked to use the metalanguage of *theme* and *rheme* to notice how information built up in a text (*theme* is the starting point of a clause, *rheme* is the rest of the clause where the theme is developed; see Schleppegrell, 2004, pp. 67–68).

At the time, John was teaching his ELL Chemistry class a unit on gas laws and had assigned some reading from the textbook (pictured in Appendix A). Taking this text as a starting point, we tried to identify themes in one of the passages by looking at each clause and identifying the theme, as italicized in the following excerpt:

1. *In 1702, Guillaume Amontons* demonstrated that
2. *a change in temperature* caused a change in gas volume.
3. *He* realized that
4. *heating a gas* caused it to expand.
5. *An increase in temperature* caused an increase in volume. (Hsu et al., 2010, p. 454)

John quickly noticed a pattern. Most of the themes related to the scientist or temperature, the phenomenon under study. And the themes did more than repeat; throughout the passage, these theme choices kept the text on topic while also moving toward more precise and generalizable information—a driving goal of Western science. "I just got theme and rheme!" John exclaimed (10/25/12). With this realization that functional metalanguage can be used to "see" how classroom discourse functions within a cultural context, John was no longer strictly a language of science user. He had become a language of science analyst.

5.4.2 Stage 2: Applying Functional Metalanguage to Develop Conscious Knowledge of Official Literacy Practices in High-School Chemistry

Once John experienced the shift toward being a language analyst, he was eager to continue. Even as our ACCELA class meeting continued with a short lecture, he passed a note that read, “I just want to get back to analyzing text” (10/25/12). Over the next two weeks, we completed thorough genre and register analyses of the textbook passage John was teaching in his gas laws unit (Appendix A). Though John already had a deep knowledge of the content presented in this textbook passage, the practice of SFL discourse analysis was critical for his development of more conscious DLK for identifying how the content was constructed linguistically. Some of the grammatical features he identified that functioned to explain gas laws included the use of goal-oriented text structure choices, condensed and abstract participants, and zigzag patterning.

Identifying goal-oriented text structure choices. Based on Schleppegrell (2004, p. 85), John identified the purpose of the textbook passage he had assigned his ELL Chemistry students as to “explain and interpret a phenomenon.” Another book assigned in the ACCELA course, *Exploring How Texts Work* (Derewianka, 1990), indicated that explanations often have two recognizable stages in the way they are structured: an identification or description of the phenomenon to be explained, and an explanatory sequence that details how or why that phenomenon occurs. John identified this pattern at two levels in his textbook. As Fig. 5.2 illustrates, a heading identified the phenomenon to be explained and then paragraphs below that heading provided explanatory information about the phenomenon. This pattern was also repeated within individual paragraphs, where a topic sentence re-identified the phenomenon and subsequent sentences provided explanatory details. Explanations of small components or secondary phenomena were nested inside the larger explanation. John felt this pattern in text structure aligned with something he knew about the Western scientific community: that scientists do not just make observations and list them for others to make sense of; scientists arrange their observations purposefully in order to explain. In the textbook, it is one thing (communicated in one heading) to understand that there is a relationship between the volume and temperature of gas molecules. It is yet another thing to understand the proportional nature of the relationship, and another thing still to understand how pressure caused by molecular movement drives this relationship. Through genre analysis, John became more conscious of how a series of micro-explanations built toward an explanation of the larger phenomenon. Next, we describe more fine-grained identifications John made using the SFL concepts of field and mode.

Identifying how information is constructed and condensed through field choices. Field choices include words and phrases that construct what field of knowledge a text is talking about (Gebhard, 2019). In John’s textbook, we focused primarily on noun phrases and verbs as they present the *participants* and *processes* in a clause. Our

Textbook passage	Genre stages
Charles's law: volume versus temperature	Identification of phenomenon
If the Kelvin temperature scale is used, the volume versus temperature relationship is simplified so that doubling the Kelvin temperature of gas causes a doubling of its volume. This means that volume is directly proportional to temperature, and it can be expressed as V/T = some constant. The "constant" could change from one experiment to another if the pressure or amount of initial gas used was different, but as long as the pressure and moles of gas remain the same (and the temperature is measured in kelvins), the V/T = constant relationship will be true.	Repetition of phenomenon How the phenomenon works (*explanatory sequence*)
From a molecular standpoint, the direct relationship between pressure and volume makes sense. If the temperature of the gas is increased, then there will be more frequent and harder impacts on the walls of the container. This will cause the gas to expand until the molecules are spread far enough apart so that the pressure inside and outside of the container are now equal again.	Repetition of phenomenon Why the phenomenon works (*explanatory sequence*)

Fig. 5.2 Genre stages that function to explain in a high school chemistry textbook (Hsu et al., 2010, p. 455)

goal was to identify patterns in how authors constructed *who* was doing *what* in each clause. We noticed that participants in the textbook were both humans (scientists) and nonhumans (scientific concepts, symbols, or relationships), such as those italicized in the clauses below:

- *Charles* used a sealed container. (Hsu et al., 2010, p. 454)
- *A change in temperature* caused a change in gas volume. (p. 454)
- *The direct relationship between the temperature of a gas and the kinetic energy of its molecules.* means that two gases that are at the same temperature must have molecules with the same kinetic energy. (p. 458)

Generally, clauses with human participants were more straightforward, telling who did what in that order, as in the first example above. But John noticed that this information was harder to track in clauses with nonhuman participants, which often involved abstracted action and condensed information, as in the second and third sentences above. For example, in the second sentence, the action of "change" has been turned into an abstract noun and nonhuman participant (*a change in temperature*). This abstraction may present a challenge for multilingual students in beginning stages of reading extended English texts, who are often taught to find action primarily in verbs (Gebhard, 2019). In addition, John identified the way textbook authors packed participant structures to condense information. For example, 16 words form the italicized subject of the third sentence above, which is a lot of language to wade through before readers get to the verb *means*. John reported that field analysis made him aware of how even reading assignments that are just a few pages long require students to do more than a little linguistic processing to understand precisely who or what is involved.

Identifying how information builds through mode choices. After identifying how the textbook authors constructed information, we conducted a mode analysis to identify how they connected information to create a logical flow. A predominant strategy these authors used was *zigzag patterning* (Eggins, 1994; see Fig. 5.3). In a zigzag pattern, a theme is presented at the beginning of a clause and that theme is expanded in the rheme, or remainder of the clause. A piece of the rheme then gets taken up in the theme of the next clause, creating a flow that allows for logical accumulation of information.

As John inhabited the role of language analyst and developed the ability to identify how language was working in the texts he assigned his ELL Chemistry students, he began to realize the potential implications for his teaching. He imagined that the same SFL concepts that unlocked new understandings for him would also be quite powerful in the hands of students:

> We aren't giving these students the basics to talk about language. I teach this well and those kids will have a whole new set of power tools. The textbook is just the beginning…teach them the pattern and it will be easy to analyze, easy to write. (11/1/12)

Yet eager as John was to model language features and SFL concepts for his students, he was also facing significant time pressures in the ELL Chemistry class. A district pacing guide dictated how quickly he needed to cover the chemistry curriculum, and while it had some wiggle room, weeks of mandatory standardized

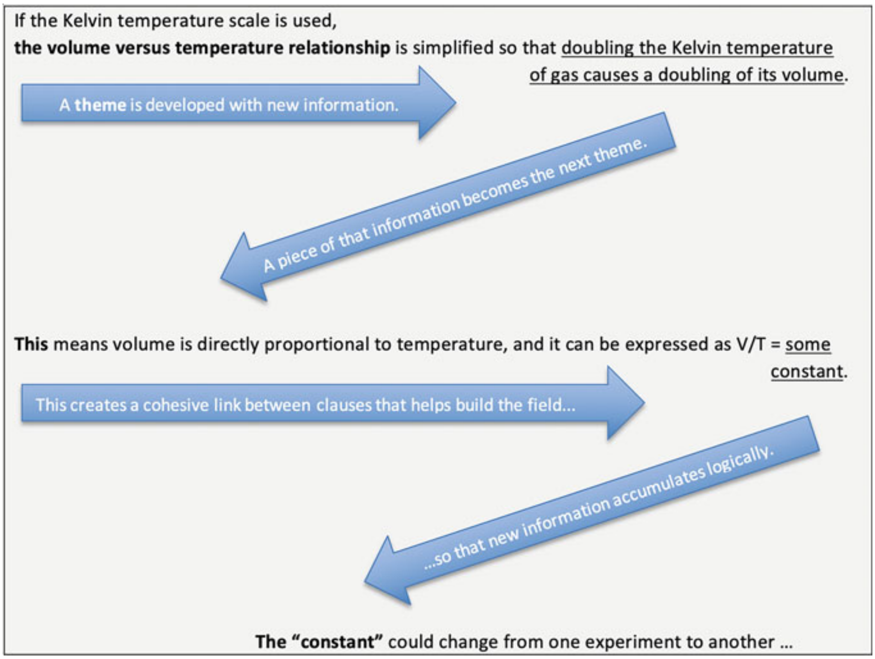


Fig. 5.3 Zigzag pattern in a high school chemistry passage (Hsu et al., 2010, p. 455)

testing rendered it basically inflexible. What's more, after-school tutoring work and ACCELA classes meant he had little time to rework the curriculum he had already developed. As a result, John determined he would have to start slow and prioritize by identifying what literacy practices his multilingual students were already using.

5.4.3 Stage 3: Applying Functional Metalanguage to Develop Conscious Knowledge of Multilingual Students' Literacy Practices in Chemistry

As John's focus shifted from the textbook to student writing, he was also moving on from teaching gas laws to a curricular unit on the periodic table. Therefore, we set out to identify students' literacy practices by looking at their writing during the periodic table unit. Most of the writing we collected was short answer responses on worksheets, such as those shown in Appendix B. These writing samples were quite short. Nevertheless, John's students were making choices to construct scientific explanations even in these short texts, and we collected samples from worksheets completed by all 23 of his ELL Chemistry students. Here, we share an example from just one focal student, Ly, (a pseudonym) to illustrate how identifying students' existing meaning-making choices was an important stage in John's DLK development. This stage was critical in developing knowledge for modeling language features in ways that responded to classroom affordances (e.g., students' existing literacy practices, John's emergent DLK) and constraints (e.g., time pressures, John's emergent DLK).

In 2012, Ly was a 19-year-old 12th grader. She had emigrated with her family from Vietnam in late 2010 and had been in the River City school system for nearly two years since midway through 10th grade. Ly's academic English proficiency was considered to be "developing" including simple sentence structures and some grade-level disciplinary vocabulary (WIDA, 2012). Using his emerging DLK, John was able to identify some linguistic resources Ly was using to make scientific meanings in her worksheet responses and compare those to the choices made by the textbook authors. For example, John identified how Ly constructed scientific information through her *field* choices. Having already learned some metalanguage and practiced applying it to the textbook, John could now see that Ly selected nonhuman participants more often than human ones in her chemistry writing, and that these participants engaged in both relational and material processes, as in the textbook. However, Ly used participant structures that were much less dense than those in the textbook at an average of 1–2 words (e.g., *metal*, *other elements*, *some stardust*) and her participants were more often engaged in material processes (i.e., concrete actions), than relational processes which often do the work of theorizing or defining (see Fig. 5.1).

Developing conscious knowledge of multilingual students' existing literacy practices was critical for John in two regards. First, as Table 5.2 illustrates, this knowledge was key for prioritizing what language features to model and generating ideas around how to model them while building on students' existing literacy practices. Second, it

Table 5.2 DLK application: language feature identification and modeling opportunities in high school science

Language features identified	Text book	Ly's writing	Language modeling ideas
Text structure			
Identification + explanatory sequence	✓	✓	Make extended writing a routine class expectation; conduct group genre analysis of texts to identify expected stages; have students check one another's writing for these stages; draft explanation outlines as a pre-writing activity
Field: constructing and condensing information			
More nonhuman participants than human ones	✓	✓	Track human and nonhuman participants with different colors in reading passages and during self-evaluation of writing
Dense/abstract participant structures (4 + words per participant, nominalizations)	✓		Practice "packing" and "unpacking" nonhuman participants
Verbs that construct relationships of cause/effect, description, or identification	✓	✓	Explicitly teach process types; identify words that mark relationships; practice paraphrasing relationships; encourage students to quantify relationships, give examples, or draw representative pictures
Mode: building and connecting information			
Zigzag patterning	✓		Teach zigzag patterns using a worksheet on theme development in a model text; practice writing meaningful responses to questions with purposeful theme/rheme construction
Lexical chaining	✓	✓	Use a model text to practice identifying lexical chains; practice using them to write cohesive texts from bullet points
Tenor: authorial distance			
Declarative statements	✓	✓	Discuss the function of declarative statements; try expressing ideas or experiences in other moods and compare meanings

(continued)

Table 5.2 (continued)

Language features identified	Text book	Ly's writing	Language modeling ideas
Use of modality	✓		Encourage students to express expectations and predictions with modals; use highlighters and graphic organizers to discover in what circumstances a statement is true
Passive sentence construction	✓		'Translate' passive sentences into active to discover agency and understand what objectivity means in scientific contexts
Lack of connection to students' everyday experience	✓	✓	In class discussions, relate concepts to students' own lived experiences

was a powerful reminder that even though most designated ELLs at River City High were positioned as academically and linguistically deficient by standardized test scores and automatic "high needs" labels, they were neither. In fact, they possessed a great deal of genre and register knowledge relevant to learning science in English. John felt both pride and vindication in being able to systematically identify his multilingual students' already complex uses of language in science, even as he felt unsure about how exactly he would integrate modeling new ones into his existing teaching practice.

5.4.4 Stage 4: Experimenting with Language-Focused Curriculum Design and Implementation for His Unique Context

Drawing on his emerging DLK, John decided on two first moves as a language of science teacher: (1) include more extended writing in his instruction, and (2) model the zigzag pattern. These ideas were conjoined for John because if he was going to teach students about new language practices, he realized they were going to need more opportunities to notice and play with language than his typical lecture and worksheet routine provided. He reflected, "When it comes to writing, I just don't do it…Over time, it's something that I've given myself permission not to teach. Instead, I pass the buck and assume someone in another class will teach it. But it's time" (11/08/12). As a result, nine weeks into the process of DLK development, John took his first uncertain steps into disciplinary linguistic modeling by introducing the zigzag pattern. This was uncertain territory for students, too, one of whom replied, "Is this a real thing?" (11/14/12). John paused and challenged students to be the judge of that, guiding them to identify the flow of information in a preselected passage from the textbook. Afterward, he asked students to use the zigzag pattern in a paragraph-length response to a prompt. Some students talked and worked together on this task, others asked for individual support from John, but all students completed the task to produce an extended written response.

The remainder of the 2012–2013 school year, John maintained this focus on extended writing and the zigzag pattern. In subsequent years of the study, he experimented with modeling an expanded range of language features by designing what he called *functional language analysis worksheets* (Fang & Schleppegrell, 2008; see Appendix C for examples). Interestingly, all were related to the construction of content (field choices) and coherence (mode and genre choices), language features he identified in his earliest stages of DLK development.

By 2018, John had honed three main language modeling activities and regularly employed them across all of his ELL science courses, which comprised his full teaching assignment by that point. The first was *field analysis*, which he taught some aspects of in nearly every lesson. As shown in Fig. 5.4, field analysis involved guiding students to identify and highlight participants, processes, descriptions, and circumstances within a text. Students may also be asked to make lists of these aspects of field that are found in a certain text. John's second main modeling activity centered around *clause structure and connection*, where John guided students to identify connections between and across clauses (as in Fig. 5.3). He found teaching students theme/rheme patterns helped them see how information built up in a text, but also provided a way to identify key concepts and terms. He modeled how terms and topics that are part of a zigzag or repeated theme pattern are clues about what is important in the text. Toward the end of the study, he wrote, "We are using theme and rheme to develop vocabulary, so it is a two-for-one in teaching how meaning is made in science texts (lexical choice and structure)" (7/19/18). After this kind of modeling, he routinely asked students to use the list of terms and concepts they had identified to write short reading summaries. Third and finally, John modeled *nominalization*, a process of grammatical metaphor in which a verb or adjective is abstracted into a noun so more can be said about it (e.g., combust → combustion, rotate → rotation). John guided students to highlight nominalizations in a range of texts and transform them into active processes, and vice versa, as a way of supporting them to understand the concrete processes involved in a given content topic while also learning to manipulate grammatical metaphor in English themselves.

Moreover, by 2018, John routinely paired culturally relevant science texts with more traditional readings, noticing their influence on students' connection with the subject matter and interest in language analysis. For example, that year, John had a physical science class comprised largely of students who had arrived in River City from Puerto Rico after Hurricane Maria devastated the island. When teaching the concept of generating electricity with fossil fuels, he first selected an article about rebuilding the Puerto Rican electrical grid after the hurricane and modeled field analysis with this text. Afterward, students read a more generalized text about energy transformation as a means of generating electricity and John modeled nominalization. This pair of texts and modeling activities created space for students to read, discuss, Name ______________________ Block ________ Date ________

Functional Language Analysis Assignment ***Academic Content: Academic Language: Field.***

TOPIC: A study of *Field* by analyzing Science content on the Earth's Plate Motion Standards: MS-ESS2-3.

1. **LEARNING OBJECTIVES: I Can…** **Watch the teacher teach the lesson** ← Click Here
   a. **Define** the ***Field of Knowledge*** as the part of texts that communicate ideas, knowledge, information, and experiences.
   b. **Analyze** science texts for: **Field**: Participants/Entities, Process/Actions, Properties/Characteristics, & Circumstance.
   c. **Recognize** the **cause** of Earth's plate motion and the **effects** of the Earth's rocky tectonic plates moving and interacting.
2. **INSTRUCTIONS: Read, Discuss and Highlight using Functional Language Analysis**

- Academic lanaguge is the lanaguge that students need to learn to be successful in school. Academic lanaguge is different from everyday language beause it uses a more formal tone, has subject specific vocabuary terms, and relys on special academic grammar patterns to communicate ideas. Communicating ideas, knowledge and experiences in a text is known as building the ***Field of Knowledge***. The ***Field of Knowledge*** is made of the **Participants** (often nouns or noun phrases), the **Processes** (verbs and verb phrases), **Characteristics** or Properties (often adjectives and discriptions), **Circumstances** of where when and how (Prepositions and adverbs), and **Logical Connections** that create a flow of linked information (conjunctions). The **field** is often summarized with the question: "***Who did what to whom under what circumstances?***"

3. **INSTRUCTIONS: Read and Highlight using Functional Language Analysis** follow the key on the right.
   Main Ideas: The cause of the earth plates moving is the convection of the molten rock in the Earth's mantle. Plate Tectonics-The cause is convection in the mantle; the effect is movement of Earth's plates and geologic activity.

- **Cause and effect** is an important concept in science. Understanding why things happen (the cause) can help us explain what we experience in nature (the effects). For example, humans feel earthquakes which are caused by the movement of the earth plates at a transform plate boundary.
- The **Earth's plate boundaries** are the site of geologic action, such as volcanoes, earthquakes, rifts, and ocean ridges. Rifts and ocean ridges form at divergent plate boundaries where two plates are separating. Earthquakes are common occurrences at transform plate boundaries where two plates are sliding past each other. Earthquakes, volcanoes, and the formation of mountain ranges happen at convergent plates. When an ocean plate converges with a continental plate, the ocean plate goes under the continental plate. If two continental plates converge, large mountain ranges are formed.
- **Convection** currents of the hot fluid rock material in the mantle cause Earth's plate movement. Convection is the circulation of heat when hotter, less dense particles rise, and cooler denser particles fall. Radioactive elements, such as uranium, heat the Earth's interior. When material such as the mantle's fluid rock are heated, they expand and become less dense. These heated particles rise upward and meet the earth's crust. The Earth's crust cools the mantle's material causing it to become denser and return to deeper parts of the earth. The circular convection currents in the mantle push the continental plates above them. This is similar to how a surfboard is moved forward on a wave.

Functional Language Analysis KEY
Processes, Verbs, (PINK)
Participants, Entities, Nouns, Noun Phrases (YELLOW)
Properties, Descriptions, Characteristics, Adjectives (BLUE)
Circumstances, Prepositions and Prepositional Phrases (ORANGE)
Connecting Words, links between clauses (GREEN)

4. **INSTRUCTIONS: From the 3 paragraphs above, List 5 participants, processes, properties, and circumstances.**

#	Participant/ Entity/ People, Place, Things, Ideas (usually nouns or noun phrase)	Process/Action (usually verbs)	Property/Characteristic/ Qualities/Description (usually adjectives)	Circumstance/Context/ Setting/Place & Time (usually prepositions or adverbs)
1				
2				
3				
4				
5				

Do the Work. Do the Work Correctly. Learn the Material! ¡Haga el trabajo, haga el trabajo correctamente, aprenda el material! Levasseur (for classroom use only)

Fig. 5.4 DLK modeling through a field analysis activity

and write about generating electricity as a general process and in a specific, real-world context important to their lives and communities. While text selection is not an articulated part of DLK, we mention it here because it was an important part of what motivated students to engage with John and his language teaching efforts.

So, while John's DLK remained rooted in SFL theory and metalanguage over time, as in the three main identification and modeling activities outlined above, it expanded to include a wider range of culturally specific scientific texts and a wider range of metalanguage, as well. Over time, he adopted terms from traditional grammar and the state standards to connect with what students were familiar with from language arts classes and with what colleagues were familiar with from their use of state frameworks. For example, by 2018, John regularly talked with students and colleagues about *subject* and *predicate* rather than SFL's *theme* and *rheme*, and rather than *genres* he used *macrofunctions* (a term introduced in state policy and standards during this study).

5.5 Discussion and Reflection on DLK Development

John's ongoing experimentation with language feature identification and modeling was critical because his DLK was only emergent in his first year of ELL science teaching, and his context for applying this knowledge continued to shift. For example, in 2013–2018, John began teaching other designated ELL sciences, such as biology and physical science. He also worked with many more multilingual students who brought different ranges of cultural and linguistic resources with them to these classes. At the same time, ELL policies were changing in River City; the state adopted new English language development standards (WIDA, 2012), articulated new licensure requirements around teachers' development of DLK[2] (MA DESE, 2018), and began promoting their own metalanguage related to these changes (MA DESE, 2020). Therefore, John's DLK continued to develop in ways that accounted for these aspects of his context.

However, as he began teaching more designated ELL science classes, he realized that DLK was not the only kind of specialized knowledge needed to equitably teach his multilingual students, nor was his individual development enough to correct the systemic inequities that marginalized these students. He reflected:

> I used to think my role to increase social justice was simply being a good teacher, but I'm six years into [teaching ELL science classes] and I now recognize that I also have to be an advocate and play a deliberate role in changing school culture to truly care about and provide a quality education for ELL students. Besides designing lessons, I spend a lot of time trying to rectify multiple things continually keeping kids marginalized. Such as not providing

[2] In 2013, the Massachusetts Department of Elementary and Secondary Education launched the RETELL initiative (Rethinking Equity and Teaching for English Language Learners), which mandated a sheltered English endorsement for all core academic teachers, the goals of which aligned with DLK, including teachers' "knowledge of how language functions within academic content teaching and learning" and "protocols, methods, and strategies to integrate subject-area content, language, and literacy development" (MA DESE, 2018, p. 4).

> mandatory support classes from a licensed ESL teacher because they are hard to schedule, or recruiting for sports in all the classes except ELL ones. Ensuring that ELL students have complete access to all parts of the school community including sports, AP classes, ROTC, and content classes taught by the school's best content teachers needs to be prioritized by administration. The best English language acquisition happens in dynamic content classes where ELLs productively grapple with content and language.
>
> But to do a good job creating an ELL program, you need to be extremely flexible, invest in learning about the places and cultures of our students, and meet them where they are at, and admin just is not set up to do that. It's like a glitch in the matrix. My school community prioritizes quality content education but does not always value ELL education and students can become trapped in the ELL classes for far too many years. The whole issue of "long-term ELLs" is a key part of the system marginalizing these students. Especially when facing staffing shortages, the easiest thing to cut is attention to ELLs. Admin doesn't understand the importance of language development and invest in it systemically. They don't find PD in this area vital. They don't seek it out, so teachers are left on their own. But teachers cannot do this on their own. It takes leadership, commitment, and money. It has been a painful but important realization to recognize how deeply ELLs are marginalized in River City and grappling with the extent to which the system of schooling in America perpetuates the marginalization of these children.

This extended quote highlights how, for John, the work of attempting to meet multilingual students' civil rights in his context required not only DLK but advocacy knowledge, sociohistorical knowledge, truly knowing students, and the development of a critical stance for transforming inequities (Teemant, 2015). Moreover, it required an ability to identify inequities in his context much the same way DLK supports teachers in identifying language features in their contexts.

While John's experiences are not generalizable and his application of DLK was specific to the students in his classes and the local context in which he was teaching, the dilemma he faced as a content teacher wanting to fulfill his responsibility to *all* students and their civil rights remain relevant for other secondary teachers. The heightened language awareness, use of functional metalanguage, and new pedagogical knowledge John developed through ongoing experimentation over the long term are findings that echo across a body of research showing similar trends in hundreds of other K-12 content teachers' development of disciplinary linguistic knowledge (Accurso & Gebhard, 2020). Based on this collective research, we come to the conclusion that the process described in this chapter—building knowledge for language identification and making instructional space in a disciplinary classroom to model, interrogate, and play with different ways of making meaning—can be used in any context, even when linguistic practices differ from discipline to discipline, class to class, and school to school.

However, as we alluded to in the introduction to this chapter, in the wake of a global pandemic and widespread protests of racial injustice in the USA and around the world, many teachers, teacher educators, and education researchers—us included—are now considering how to do this work with the ongoing possibility of emergency school closures, online teaching and learning, and in ways that do not impose more harm on (multilingual) communities of color. Therefore, we close this chapter by discussing some implications of this research for science teacher education and professional development in these hard times.

5.6 Implications for Science Teacher Education and Professional Development

Based on our findings and subsequent reflections, we recommend that teacher educators who wish to support secondary science teachers in developing DLK to design more equitable, language-infused, twenty-first-century curriculum for multilingual students pursue the following actions:

1. *Center what often gets sidelined in DLK literature: students, power, and ideology.*

Findings from our study suggest that a critical piece of John's DLK development was being able to identify features of his students' *science* language practices as assets for further learning. However, in reflection, we believe it is critical that DLK be framed as a knowledge base for teachers to identify and build on *all* of a student's linguistic and cultural resources (Gebhard, 2019; Harman & Burke, 2020). Over the course of this study, John observed many ways in which multilingual children were problematically framed as deficient. To counter these discourses, we argue that teacher educators must articulate DLK as, in part, a knowledge base to affirm that multilingual students already language in ways that align with many of the linguistic demands of new standards (Flores, 2020). As John puts it:

> The system is broken and so the system reinforces and insists that marginalized students are broken. So we have to do the legwork to say to children that they are not broken. I want to start catching myself catching [my students'] language patterns more so we can be deliberately using and choosing language to learn and reflect.

Further building on this observation, we recommend DLK be articulated as a knowledge base for identifying, reflecting on, and actively transforming the influence of deficit ideologies on disciplinary linguistic practices in schools (e.g., white supremacy, English supremacy; see Accurso & Muzeta, 2020; Baker-Bell, 2020). Language education is not an ideologically neutral endeavor, and so building knowledge about language for this purpose must not be either (Hasan, 2005). Since DLK is built on a theory of text–context dynamics, we envision this as a process of exploring ideological aspects of context at the same time as identifying features of texts (e.g., Rosa, 2018).

2. *Explore post-pandemic ways of knowing and doing science.*

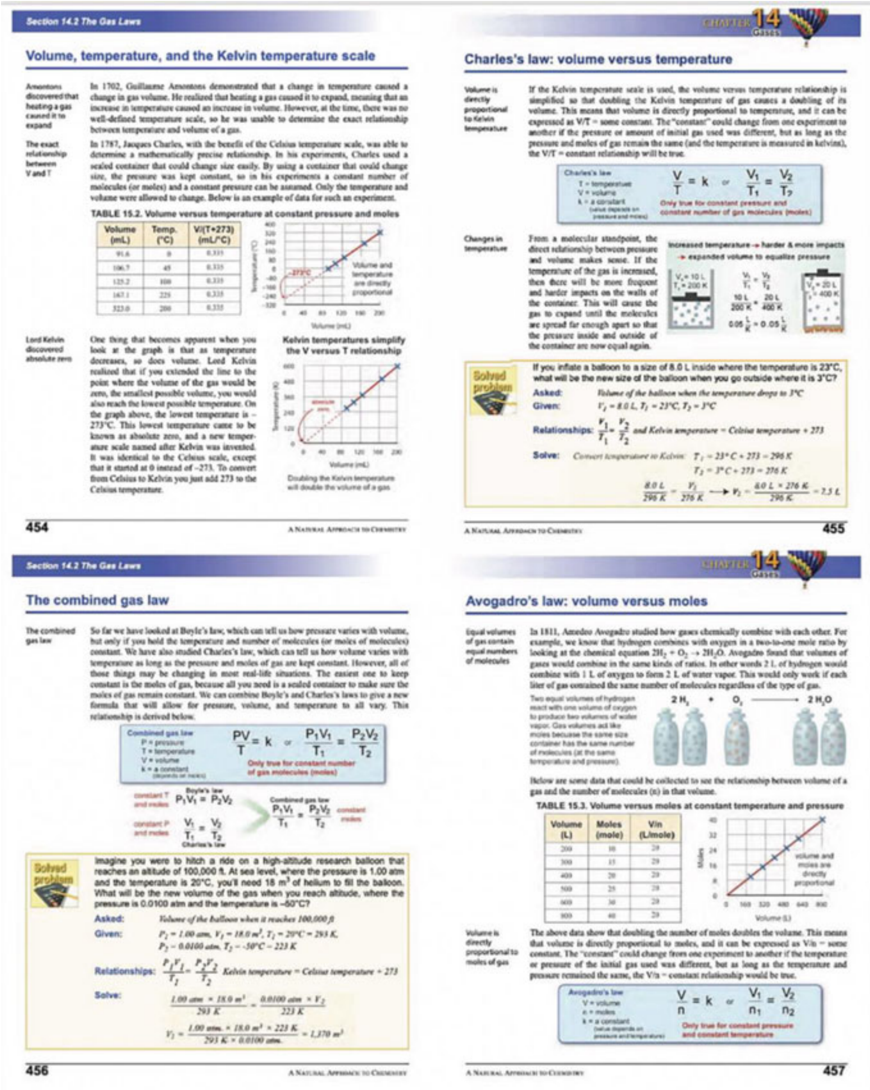
During a time of rapid change such as the one teachers are experiencing now, we are aware that many disciplines are developing new ways of doing their work. Therefore, we suggest teacher educators work together with teachers and other disciplinary experts to identify and model the ways language and other semiotic resources are being used to know and do science in post-pandemic classrooms (e.g., through a/synchronous video lessons, technology-enhanced simulations, the use of shared documents, across multiple modes in web conferencing platforms; Jones et al., 2020).

3. *Invest in long-term knowledge development channels.*

Finally, we note the long-term nature of DLK development revealed in our study. At the beginning of this project, John expressed a "need to learn the language of science and need to learn it fast." Yet this study and John's subsequent reflections suggest that this can be a long process of development. According to our findings, the stages of John's DLK development were iterative over a number of years, shaped by the affordances and constraints of the contexts in which development was taking place, and influenced by specific structurings of power and policy. Our data suggest John benefitted from continued support and collaboration from university researchers as he learned to teach language in science in rapidly changing times and in the face of structural inequities. The implication for teacher education—many forms of which are short and getting shorter—is to resist seeing DLK as the outcome of a single pre-service course or professional development workshop, or even something that is developed individually (Accurso & Gebhard, 2020; Teemant, 2015). Instead, we urge school leaders, teacher educators, and colleges of education to leverage their respective resources to invest in sustained and systemic learning through university-school or university-district partnerships. Within such community partnerships, teachers may be guided through stages of DLK development while also engaging in inquiry around aspects of the job that demand this knowledge base, with the ultimate goal of pursuing disciplinary instruction that is not unconsciously prescriptive, but consciously imaginative, engaging all students in exploring new ways of disciplinary meaning-making that promote linguistic, cultural, and disciplinary dexterity for a changing world.

Acknowledgements We want to thank Drs. Meg Gebhard, Betsy McEneaney, and Denise Ives, under whose guidance this study began, as well as John's first class of ELL Chemistry students, who inspired us to continue pursuing this inquiry even after they completed the course. We also thank the editors of this volume for their generative feedback on previous drafts of the chapter. The research reported here was part of a larger IRB-approved study of teacher development at the University of Massachusetts Amherst entitled "Analyzing Efforts to Improve Academic Literacy Practices," directed by Drs. Gebhard and McEneaney.

Appendix A: Excerpt from John's High-School Chemistry Textbook (Hsu et al., 2010)



Section 14.2 The Gas Laws

Volume, temperature, and the Kelvin temperature scale

Amontons discovered that heating a gas caused it to expand

In 1702, Guillaume Amontons demonstrated that a change in temperature caused a change in gas volume. He realized that heating a gas caused it to expand, meaning that an increase in temperature caused an increase in volume. However, at the time, there was no well-defined temperature scale, so he was unable to determine the exact relationship between temperature and volume of a gas.

The exact relationship between V and T

In 1787, Jacques Charles, with the benefit of the Celsius temperature scale, was able to determine a mathematically precise relationship. In his experiments, Charles used a sealed container that could change size easily. By using a container that could change size, the pressure was kept constant, so in his experiments a constant number of molecules (or moles) and a constant pressure can be assumed. Only the temperature and volume were allowed to change. Below is an example of data for such an experiment.

TABLE 15.2. Volume versus temperature at constant pressure and moles

Volume (mL)	Temp. (°C)	V/(T+273) (mL/°C)
91.6	0	0.335
106.7	45	0.335
125.2	100	0.335
167.1	225	0.335
323.0	200	0.335

Lord Kelvin discovered absolute zero

One thing that becomes apparent when you look at the graph is that as temperature decreases, so does volume. Lord Kelvin realized that if you extended the line to the point where the volume of the gas would be zero, the smallest possible volume, you would also reach the lowest possible temperature. On the graph above, the lowest temperature is –273°C. This lowest temperature came to be known as absolute zero, and a new temperature scale named after Kelvin was invented. It was identical to the Celsius scale, except that it started at 0 instead of –273. To convert from Celsius to Kelvin you just add 273 to the Celsius temperature.

Kelvin temperatures simplify the V versus T relationship

Doubling the Kelvin temperature will double the volume of a gas

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Chapter 14 Gases

Charles's law: volume versus temperature

Volume is directly proportional to Kelvin temperature

If the Kelvin temperature scale is used, the volume versus temperature relationship is simplified so that doubling the Kelvin temperature of gas causes a doubling of its volume. This means that volume is directly proportional to temperature, and it can be expressed as V/T = some constant. The "constant" could change from one experiment to another if the pressure or amount of initial gas used was different, but as long as the pressure and moles of gas remain the same (and the temperature is measured in kelvins), the V/T = constant relationship will be true.

Charles's law
T = temperature
V = volume
k = a constant (value depends on pressure and moles)

$$\frac{V}{T} = k \quad \text{or} \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Only true for constant pressure and constant number of gas molecules (moles)

Changes in temperature

From a molecular standpoint, the direct relationship between pressure and volume makes sense. If the temperature of the gas is increased, then there will be more frequent and harder impacts on the walls of the container. This will cause the gas to expand until the molecules are spread far enough apart so that the pressure inside and outside of the container are now equal again.

Solved problem

If you inflate a balloon to a size of 8.0 L inside where the temperature is 23°C, what will be the new size of the balloon when you go outside where it is 3°C?

Asked: Volume of the balloon when the temperature drops to 3°C

Given: $V_1 = 8.0\ L$, $T_1 = 23°C$, $T_2 = 3°C$

Relationships: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ and Kelvin temperature = Celsius temperature + 273

Solve: Convert temperature to Kelvin: $T_1 = 23°C + 273 = 296\ K$

$T_2 = 3°C + 273 = 276\ K$

$$\frac{8.0\ L}{296\ K} = \frac{V_2}{276\ K} \longrightarrow V_2 = \frac{8.0\ L \times 276\ K}{296\ K} = 7.5\ L$$

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Section 14.2 The Gas Laws

The combined gas law

The combined gas law

So far we have looked at Boyle's law, which can tell us how pressure varies with volume, but only if you hold the temperature and number of molecules (or moles of molecules) constant. We have also studied Charles's law, which can tell us how volume varies with temperature as long as the pressure and moles of gas are kept constant. However, all of those things may be changing in most real-life situations. The easiest one to keep constant is the moles of gas, because all you need is a sealed container to make sure the moles of gas remain constant. We can combine Boyle's and Charles's laws to give a new formula that will allow for pressure, volume, and temperature to all vary. This relationship is derived below.

Combined gas law
P = pressure
T = temperature
V = volume
k = a constant (depends on moles)

$$\frac{PV}{T} = k \quad \text{or} \quad \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Only true for constant number of gas molecules (moles)

Solved problem

Imagine you were to hitch a ride on a high-altitude research balloon that reaches an altitude of 100,000 ft. At sea level, where the pressure is 1.00 atm and the temperature is 20°C, you'll need 18 m³ of helium to fill the balloon. What will be the new volume of the gas when you reach altitude, where the pressure is 0.0100 atm and the temperature is –50°C?

Asked: Volume of the balloon when it reaches 100,000 ft

Given: $P_1 = 1.00\ atm$, $V_1 = 18.0\ m^3$, $T_1 = 20°C = 293\ K$, $P_2 = 0.0100\ atm$, $T_2 = -50°C = 223\ K$

Relationships: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ Kelvin temperature = Celsius temperature + 273

Solve:

$$\frac{1.00\ atm \times 18.0\ m^3}{293\ K} = \frac{0.0100\ atm \times V_2}{223\ K}$$

$$V_2 = \frac{1.00\ atm \times 18.0\ m^3 \times 223\ K}{293\ K \times 0.0100\ atm} = 1{,}370\ m^3$$

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Chapter 14 Gases

Avogadro's law: volume versus moles

Equal volumes of gas contain equal numbers of molecules

In 1811, Amedeo Avogadro studied how gases chemically combine with each other. For example, we know that hydrogen combines with oxygen in a two-to-one mole ratio by looking at the chemical equation $2H_2 + O_2 \rightarrow 2H_2O$. Avogadro found that volumes of gases would combine in the same kinds of ratios. In other words 2 L of hydrogen would combine with 1 L of oxygen to form 2 L of water vapor. This would only work if each liter of gas contained the same number of molecules regardless of the type of gas.

Two equal volumes of hydrogen react with one volume of oxygen to produce two volumes of water vapor. Gas volumes act like moles because the same size container has the same number of molecules (at the same temperature and pressure).

Below are some data that could be collected to see the relationship between volume of a gas and the number of molecules (n) in that volume.

TABLE 15.3. Volume versus moles at constant temperature and pressure

Volume (L)	Moles (mole)	V/n (L/mole)
200	10	20
300	15	20
400	20	20
500	25	20
600	30	20
800	40	20

Volume is directly proportional to moles of gas

The above data show that doubling the number of moles doubles the volume. This means that volume is directly proportional to moles, and it can be expressed as V/n = some constant. The "constant" could change from one experiment to another if the temperature or pressure of the initial gas used was different, but as long as the temperature and pressure remained the same, the V/n = constant relationship would be true.

Avogadro's law
V = volume
n = moles
k = a constant (value depends on pressure and temperature)

$$\frac{V}{n} = k \quad \text{or} \quad \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Only true for constant pressure and constant temperature

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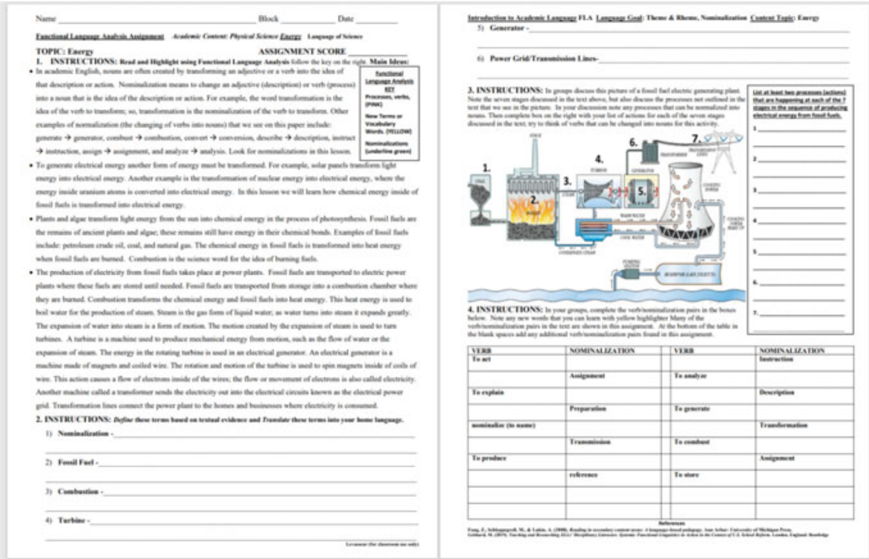
Appendix B: Multilingual Student Ly's Writing on Two Periodic Table Worksheets

Worksheet 1
Answer these questions
(1) What were the two most abundant elements made in the Big Bang? Where did the other elements come from? Hydrogen accounted for 75% of all atoms. Helium accounted for almost all of the remaining 25% with tiny amount of lithium and beryllium. Element come from carbon and oxygen, hydrogen, nitrogen.
(2) Describe the distribution of metals, nonmetals, and metalloids on the Periodic Table. Metal are malleable and shiny and conduct electricity and they're generally soild at room temperature. Nometal do not conduct electricity. Many nometal're gase or liquids. Metalloids have some properties similar to mets and nonmetal.
(3) Explain the phrase "You are made of star dust." You have atom in you that were present at the beginnig of space and time. Even more incredible is the fact that almost all of the other atom in ur body must have been product in the cores of exploding stars.
(4) Explain where on the periodic table the most electronegative and least electronegative elements are. the most electronegative and least electronegative elements are because in the right and the most at the left of the periodic table.
(5) Why is the atomic radius of sodium (Na) greater than the atomic radius of chlorine (Cl)? because chlorine have a strong positive charge a negative come together with the positive charge the atomic size get small and sodium have a less positive charge a negative charge back away from it so the atom is increase.
(6) Make a comparison of s, p, d, f blocks on the Periodic Table to metals, metalloids, and nonmetals. Where will they be?
s = metal, nonmetal
p = nonmental, metalloid, meta
d = is only metal
f = metal
Worksheet 2 (some questions repeat from Worksheet 1 to encourage paraphrasing)
Use the same technique to give an answer for the second question below. Use the question to guide your answer. Scan the text for a REASONABLE answer that completely addresses the question. Highlight the section of text that you will refer to. Rephrase the text in your own words. That's all it takes to get the right answer to a question on information
(7) What were the two most abundant elements made in the Big Bang? Where did the other elements come from? The other elements came either from a supernova or a star having a nuclear reaction.
Our next question to reconsider is not asking for information. It is asking for an explanation. Answer this question based on the text but in your own words. Be sure to give an explanation and not merely state facts
(8) Explain the phrase "You are made of star dust." You make of star dust" that mean having some star dust inside us. Stars provided the material from which the Earth was form. It make of helium and hydrogen.
(9) What is a supernova? Explain what happens during and after a supernova. Supernova blow all the heavy element it made back into space, they can condesse into a new star and planets such as solar system.

Appendix C: John's Application of DLK in the Form of a Functional Language Analysis Worksheet



Name ______ Block ______ Date ______

Functional Language Analysis Assignment *Academic Content: Physical Science Energy* Language of Science

TOPIC: Energy **ASSIGNMENT SCORE** ______

1. INSTRUCTIONS: Read and Highlight using Functional Language Analysis follow the key on the right. **Main Ideas:**

- In academic English, nouns are often created by transforming an adjective or a verb into the idea of that description or action. Nominalization means to change an adjective (description) or verb (process) into a noun that is the idea of the description or action. For example, the word transformation is the idea of the verb to transform; so, transformation is the nominalization of the verb to transform. Other examples of normalization (the changing of verbs into nouns) that we see on this paper include: generate → generator, combust → combustion, convert → conversion, describe → description, instruct → instruction, assign → assignment, and analyze → analysis. Look for nominalizations in this lesson.
- To generate electrical energy another form of energy must be transformed. For example, solar panels transform light energy into electrical energy. Another example is the transformation of nuclear energy into electrical energy, where the energy inside uranium atoms is converted into electrical energy. In this lesson we will learn how chemical energy inside of fossil fuels is transformed into electrical energy.
- Plants and algae transform light energy from the sun into chemical energy in the process of photosynthesis. Fossil fuels are the remains of ancient plants and algae; these remains still have energy in their chemical bonds. Examples of fossil fuels include: petroleum crude oil, coal, and natural gas. The chemical energy in fossil fuels is transformed into heat energy when fossil fuels are burned. Combustion is the science word for the idea of burning fuels.
- The production of electricity from fossil fuels takes place at power plants. Fossil fuels are transported to electric power plants where these fuels are stored until needed. Fossil fuels are transported from storage into a combustion chamber where they are burned. Combustion transforms the chemical energy and fossil fuels into heat energy. This heat energy is used to boil water for the production of steam. Steam is the gas form of liquid water; as water turns into steam it expands greatly. The expansion of water into steam is a form of motion. The motion created by the expansion of steam is used to turn turbines. A turbine is a machine used to produce mechanical energy from motion, such as the flow of water or the expansion of steam. The energy in the rotating turbine is used in an electrical generator. An electrical generator is a machine made of magnets and coiled wire. The rotation and motion of the turbine is used to spin magnets inside of coils of wire. This action causes a flow of electrons inside of the wires; the flow or movement of electrons is also called electricity. Another machine called a transformer sends the electricity out into the electrical circuits known as the electrical power grid. Transformation lines connect the power plant to the homes and businesses where electricity is consumed.

Functional Language Analysis KEY
Processes, verbs, (PINK)
New Terms or Vocabulary Words. (YELLOW)
Nominalizations (underline green)

2. INSTRUCTIONS: ***Define these terms based on textual evidence and Translate these terms into your home language.***

1) **Nominalization** - ______
2) **Fossil Fuel** - ______
3) **Combustion** - ______
4) **Turbine** - ______

Introduction to Academic Language FLA Language Goal: Theme & Rheme, Nominalization Content Topic: Energy

5) **Generator** - ______
6) **Power Grid/Transmission Lines**- ______

3. INSTRUCTIONS: In groups discuss this picture of a fossil fuel electric generating plant. Note the seven stages discussed in the text above, but also discuss the processes not outlined in the text that we see in the picture. In your discussion note any processes that can be normalized into nouns. Then complete box on the right with your list of actions for each of the seven stages discussed in the text; try to think of verbs that can be changed into nouns for this activity.

List at least two processes (actions) that are happening at each of the 7 stages in the sequence of producing electrical energy from fossil fuels.

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______

4. INSTRUCTIONS: In your groups, complete the verb/nominalization pairs in the boxes below. Note any new words that you can learn with yellow highlighter Many of the verb/nominalization pairs in the text are shown in this assignment. At the bottom of the table in the blank spaces add any additional verb/nominalization pairs found in this assignment.

VERB	NOMINALIZATION	VERB	NOMINALIZATION
To act			Instruction
	Assignment	To analyze	
To explain			Description
	Preparation	To generate	
nominalize (to name)			Transformation
	Transmission	To combust	
To produce			Assignment
	reference	To store	

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Chapter 6
From Image-to-Writing: A Teacher's PCK in Supporting Primary School Students in Making Sense of the Specialised Language of Science

Jennifer Yeo and Kim Chwee Daniel Tan

Abstract Learning scientific concepts is difficult for primary school students because of the highly technical, abstract and lexically dense language used to name and define entities and processes. Understanding scientific concepts entails comprehending how linguistic resources are used to bring across the semantic meanings of scientific concepts. However, this does not mean that science teachers should start teaching grammar. In this chapter, we advocate the transformative use of multimodal resources for making meaning in science. The perspective of multimodality highlights the disciplinary and pedagogical affordances of 'modes' which teachers can consider when designing supports for students' meaning-making. Specifically, we introduce an Image-to-Writing (I2W) approach devised to help teachers think about how they can engage students in the transformation of multimodal resources and socialize students into the language of science. We illustrate its application in teaching the concept of "pollination". We also extend the notion of pedagogical content knowledge to the types of multimodal-related knowledge that teachers need in order to enact I2W in a science classroom, introduce the concept of pedagogical-representational-content-knowledge (P-R-C-K) and identify components of P-R-C-K by examining a teacher's enactment of I2W for the concept of "pollination".

6.1 Introduction

Science is concerned with describing and explaining the world by observing and experimenting. In so doing, the world is interpreted as scientific processes, concepts and definitions that help make sense of natural phenomena (Flowerdew, 1992;

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Galili & Lehavi, 2006; Martin, 1993). A large part of primary school science learning involves learning the names of these concepts and comprehending their definitions as these concepts form the foundation for science learning at higher levels.

It is well documented in the science education literature that learning and comprehending science concepts pose a challenge to primary school students. The challenges have been largely attributed to students' naivety and prior knowledge of how the world works (diSessa, 1993), conflicts between students' everyday experiences and explanations taught in science lessons (Andersson, 1986), the abstractness of ideas (Herron, 1996) and human resistance to conceptual changes (Driver & Easley, 1978). Besides these experiential and cognitive reasons, the nature of scientific language has also been blamed for students' difficulties in learning science (Lemke, 1990). Science educators (e.g., Lemke, 1990; Wellington & Osborne, 2001) as well as linguists (e.g., Fang, 2004; Halliday & Martin, 1993; Schleppegrell, 2004) have detailed the unique characteristics of scientific language, including its technicality, abstractness and the lexical density that are different from the everyday language with which students are more familiar.

Pedagogical approaches to address the challenges of science concept learning often emphasize material experiences with the phenomenon, whether directly or indirectly, to trigger wonder, curiosity and inquiry (National Research Council, 2000). While the embodied experiences of these approaches no doubt play an important role in the development of conceptual understanding (Varela, Thompson, & Rosch, 1991), they do not directly address the issue of language difficulty. Given that meaning-making is mediated by language (Lemke, 1990; Mortimer & Scott, 2003), not mastering the language of science will significantly hamper scientific communication and reasoning. In this chapter, we describe how a multimodal pedagogical approach, Image-to-Writing (I2W) (Yeo et al., 2021), complements a more experiential approach to science learning and can address the language aspect for concepts such as "pollination". I2W is a proposed multimodal pedagogy intended to address the language difficulty of science concept learning.

Singapore's primary science syllabus is based on a science inquiry framework. Teachers are expected to engage students in questioning, collecting and using evidence and formulating and communicating explanations of the natural world in scientific terminology (MOE, 2013). The efficacy of an inquiry pedagogy, including I2W, is said to hinge upon a teacher's ability to plan and enact pedagogical moves that realize the intended meanings of the scientific concepts, principles and theories, in consideration of the profile of his/her students, the syllabus expectations and environmental context (Tay & Yeo, 2017). This ability is said to be dependent on a teacher's pedagogical content knowledge (PCK)—the transformation of content and pedagogical knowledge for teaching (Crochan-Smith, 2006; Shulman, 1986). Thus, we surmise that effective teachers need to have an awareness of the semiotic forms and characteristics that represent the scientific content and are able to select modes that are pedagogically apt for realizing the disciplinary meanings inscribed in the scientific language (Towndrow et al., 2013). By modes, we refer to semiotic resources for meaning-making (Kress, 2009; Kress et al., 2001). In primary science classrooms, teachers do not use words alone to convey scientific meanings but also diagrams, pictures, physical models, videos and gestures to help students unpack the abstract scientific ideas. Extending the notion of the language-related knowledge base for content teaching (LRKCT) (Seah et al., this volume), we refer to this multimodal-related knowledge of content and pedagogy as pedagogical-representational-content-knowledge (P-R-C-K). Thus, in this study, we identify a primary science teacher's P-R-C-K by examining how he enacted the I2W activity for pollination with his Grade 6 class.

6.2 Language of Science and Its Challenges

Studies that examine the language of science have highlighted its unique linguistic features that might be different from everyday language (e.g., Halliday & Martin, 1993; Lemke, 1990; Martin & Veel, 1998; Schleppegrell, 2004). These differences pose a language barrier to novice science learners, even when the scientific ideas are inscribed in the language the students use in their everyday communication. While the formal language of science might encompass multiple modes including linguistic, visual, mathematical symbols and gestures (Lemke, 1998), we focus on the linguistic aspects in this chapter. We identify three key aspects of the language of science—technicality, abstraction and information density—that pose linguistic challenges to young learners.

6.2.1 Technicality

In the process of scientific theorizing, concepts (e.g., pollination, photosynthesis, heat, force) are developed from concrete life experiences so that they can be further examined and critiqued. The turning of an experience (e.g., pollen grains are transferred from anther to stigma) into a scientific concept (e.g., pollination) is facilitated by the use of nouns. Functioning as an abbreviation to refer to these experiences, nouns can be used as a "shorthand" in subsequent discussion to create a flow of discourse in science (Halliday, 1998).

The scientific names given to real-life processes can pose a challenge to students' concept learning. Names such as "photosynthesis" are not commonly used in everyday discourses, and hence, some effort is needed to relate the terminology to the more familiar phenomena students encounter in their everyday life (e.g., plants make food). Other scientific names are a result of remodeling or re-semanticizing terminology that is used in everyday talk. For example, the word "heat" is commonly used as a verb in everyday talk to refer to the action of making something hot (e.g., mother heats up the milk for her baby); however in science, "heat" is used as a noun to refer to a particular form of energy that is transferred from one body to another. Such "terms of expressions … with a specialized field-specific meaning" (Wignell et al., 1993, p. 144) require students to establish new connections between the technical terms with the physical phenomena around them.

In addition, the technical terminology on its own gives little or no hint of what is meant or referred to. One cannot guess what the word "pollination" might mean by just looking at the word. Students who do not possess the technical vocabulary will most certainly struggle with comprehension of science texts and the communication of scientific ideas and knowledge.

6.2.2 Abstraction

Definitions are an essential component of concept development and learning. Their purpose is to identify technical terms with their referents. To do this, definitions of scientific concepts are often phrased as a relational clause using terms such as "is defined as", "means", "refers to" or simply "is". For example, the definition of pollination is commonly written as "Pollination is the transfer of pollen grains from the anther to the stigma of a flower". In constructing a definition, two changes to the grammar occur. First, the verbs or adjectives used to describe the process are converted into noun phrases. This remodeling of grammar from verbs to nouns ("to pollinate" becomes "pollination" or from verb phrases (e.g., wind transfers pollen grains) to noun phrases (e.g., transfer of pollen grains by wind…) is called nominalization (Martin, 1993). Second, the nominalized phrases remove lived experiences to build abstractions and generalizations (Martin, 1993). For example, in casual conversation about pollination, one would normally make specific reference to the actions taken by the agents (e.g., bees, birds, wind) in carrying pollen grains from the anther to the stigma. Nominalization, however, renders the concept to be agentless and hence removed from the world that children are familiar with. Students who are not familiar with the phenomenon and text construction would fail to identify the precise referents of the nominalized phrases and become frustrated with the ambiguity that nominalization engenders.

6.2.3 Information Density

Definitions tend to pack a large amount of information within a sentence. In the definition of pollination as stated earlier, there are five technical terms within one sentence/clause—pollination, pollen grains, anther, stigma and transfer. In comparison, an everyday narration of pollination consists of more than one sentence/clause with perhaps one or no technical terms per clause (e.g., a bee lands on a flower. Its body brushes against the anther of the flower. Some of the pollen grains on the flower are stuck to the bee's body.) In other words, definitions are often inscribed in information-dense sentences which can inflict a punishing load on human working memory (Millar, 1969). Children may feel overwhelmed during text processing and be confused by the embedded and often imbalanced nature of the clause structure. As Wellington and Osborne (2001) aptly point out, "… for many pupils, the greatest obstacle in learning science—and also the most important achievement—is to learn its language" (p. 3).

6.3 An Image-to-Writing Approach as a Complement to Experiential Science Activities

Science is more than just empirical work. Science is "one and the same time both material and semiotic practices" (Halliday, 1998, p. 228). Students need to be able to cope with its language resources in order to make meaning. It is clear that the language of science is central to the process of learning science, particularly in the comprehension of scientific definitions. Without a sense of what words mean in the context of their use and why science is written in particular forms, science remains an alien language to students. To become scientifically literate, students must ultimately be proficient in the specialized language of science. Students must be able to employ appropriate linguistics resources to communicate what they have learned from empirical activities and from what they have read.

Current recommendations for science pedagogy do not, however, demand attention to the specialized language of science. Instead, they emphasize gaining experience with natural phenomena. These include hands-on experimentation (e.g., investigating the variables affecting germination) and observation of phenomena (e.g., processes of pollination and fertilization of plants). While these pedagogical approaches are consistent with inquiry-based science (Schwab, 1962) and the use of visualization in scientific practices (Gooding, 2004), they seem to lose sight of the semiotic means through which scientific knowledge is constructed. While we are not advocating that science teachers turn their lessons into grammar classes, we agree with Fang (2004) that an explicit focus on how the specialized language of science comes about and its relation to the physical phenomenon can have the best potential to maximize learning and promote scientific literacy for all students. The I2W approach was designed to complement the more experiential and visual pedagogical approaches that tend to dominate science classrooms.

6.3.1 The Learning Stages of Image-to-Writing Approach

The I2W approach is a sequence of tasks that engages students with constructing and working with visual representations to think about a particular concept before formal scientific language is introduced. It comprises three main stages: (1) exploring a phenomenon, (2) creating and transforming images and (3) transduction of images to writing (Fig. 6.1).

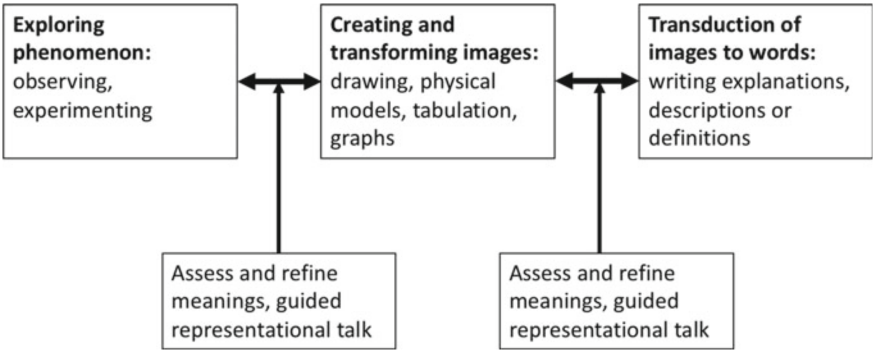


Fig. 6.1 Image-to-Writing approach

The I2W learning process with a semiotic focus embeds itself within the more experiential processes of science learning. Like the more traditional experiential approaches, the learning process is anchored by a key question about a physical phenomenon that drives the inquiry process which involves students making observations of phenomena and/or hands-on experiments. However, instead of proceeding immediately to the conclusion of the inquiry, students are engaged in creating and working with a series of images to represent observations and meanings made about the phenomena. Students use these images to help them think and reason about the relationships between concepts. Formal scientific language, which is often inscribed in written form including technical terminology and mathematical symbols, is introduced at a later stage or when appropriate, to name entities and to describe relationships between entities. Such a semiotic process resembles the visualization practices that scientists use in their inquiry (Yeo et al., 2021).

Underpinning the semiotic sequence of science concept learning are two key concepts—design (New London Group, 2000) and multimodality (Kress, 2009). "Design" considers teaching and learning as a meaning-making activity, while "multimodality" foregrounds the meaning-making potential of representations for engendering science learning.

6.4 Teaching and Learning as Design

Science teaching and learning can be seen as an activity that involves the remaking of meanings from one mode to another (Kress et al., 2001; Pozzer-Ardenghi & Roth, 2010). The concept of design sees meaning as emerging from the interweaving between and across modes within a multimodal system (Kress et al., 2001). In a science classroom for example, Kress et al. (2001) showed how a biology teacher used a sequence of simple to complex images of the blood circulatory system, complemented by verbal explanation and gestures, to demonstrate the detailed process of blood flow in the body that would otherwise be invisible to human eyes. In a more student-centered activity using the Representation Construction Approach (Tytler et al., 2013), students were engaged in a sequence of representational challenges to learn the concept of "force" involving different modes, ranging from everyday to scientific language and from informal to formal drawings. The transformation within a particular mode and transduction across modes (Kress, 1997) helped to reshape everyday actions and words related to pushes and pulls to the technical representations of the specialized noun, "force".

From this perspective, curriculum developers and teachers are the designers of this meaning-making process; their job is to select and create an ensemble of semiotic resources that provides the ground for remodeling and re-semanticizing of language as ideas are realized (Bezermer & Kress, 2008). This also means that teachers need to have the knowledge of the representational possibilities that different modes can afford and ability to select representations that are apt for the meaning-making of a particular concept to students of a particular age, culture and abilities, in a specific context.

6.4.1 Meaning-Making Potential of Modes and P-R-C-K

The concept of "design" assumes that meaning is created through multiple modes (Kress & van Leeuwen, 2001) and focuses our attention on the meaning-making potential of these modes (Jewitt, 2006, 2008). Drawing on the notion that different modes have different specialized affordances, Airey and Linder (2017) identified two types of modal affordances in science teaching and learning—disciplinary and pedagogical.

Airey and Linder (2017) defined the disciplinary affordance of modes as the agreed meaning-making functions that a semiotic resource fulfills for a disciplinary community. As described by Lemke (1998), science is defined by a unique set of language resources drawing from linguistics, mathematical symbols, graphs, tables and images for their capability to produce meanings that matter to scientists. A scientific concept, therefore, can be perceived to be a network of semantic meanings, assembled across multiple modes of representations (Tang & Tan, 2017, p. 22), each chosen and used for its potential to construct and extend meanings. For example, the concept of "speed" can be inscribed in a number of formal modes such as verbal (i.e., speed is the rate of change in distance moved), mathematical (i.e., $v = d/t$) and graphical form showing pattern of change of distance with time. While the textual expression may be merely the verbalization of its mathematical and graphical forms, the mathematical mode allows for algebraic operations to be performed and hence its variables quantified at a particular instance of time or time interval and the graphical form displaying patterns of changes of displacement over time that the textual or the mathematical modes cannot. Even in written forms, there can be different orientational meanings. For example, the concept of pollination can be described from a third-person view (e.g., the wind/insect carries pollen grain from the anther to the stigma of a flower) or as a nominalized noun phrase (the transfer of pollen grain from anther to the stigma of a flower). The latter is commonly found in science textbooks as it produces a generalized description of the process and allows it to be identified with the technical term "pollination". The former, on the other hand, is more characteristic of everyday discourses as it identifies specific agent (wind/insect), target (pollen grain) and source/destination (anther/stigma) with the action of transfer. Thus, the ultimate goal of science education should be to socialize students into these different modes of the formal language of science.

While a goal of science education is to socialize students into the language of science, this goal should not be the starting point because of the abstract and technical nature of scientific language (Halliday & Martin, 1993). Traditionally, teachers sequence learning to progress from empirical/specific ideas to abstract/general ones (Mortimer & Scott, 2003). This may involve students observing a phenomenon either through a demonstration, hands-on experimentation, an animation or even a virtual reality representation before the theoretical and generalized ideas are introduced or derived. Since learning entails a dynamic transformation of modes, learning a concept calls for pedagogical considerations in selecting and sequencing the modes to support and make explicit this abstraction process through a sequence of representational passes whereby meanings are re-made through the transformation and transduction of modes.

For example, Yeo et al. (2021) illustrated how a science teacher introduced the concept of "heat" as the transfer of energy from an object of higher temperature to an object of lower temperature by having his primary school students construct informal energy diagrams and use them to explain how an object's temperature decreases/increases. While the formal inscription of the concept of "heat" is typically made using written text, at least at the primary school level, diagrams in this case were used as informal representations that helped to bridge students' understanding of the more familiar phenomenon of hot objects cooling down when submerged in a cooler environment. The diagrams made use of crosses in place of the more quantitative use of mathematical symbols such as numerals and algebraic equations to think about the transfer of an abstract entity called "energy" between two objects of different temperature. In that sense, while the energy diagrams were not an institutionalized mode to think about energy transfer, they possessed pedagogical affordances to help students think about the notion of heat as energy transfer between objects.

Airey and Linder (2017, p. 107) defined pedagogical affordance as "the aptness of a semiotic resource for the teaching and learning of some particular educational content". In other words, if teaching and learning a scientific concept are remodeling and re-semanticizing of language, curriculum designers and teachers need to consider the meanings that can be inscribed in different modes, representing a particular concept, and orchestrate an ensemble of representational passes based on their pedagogical affordances to support students' construction of scientific meanings. In this respect, pedagogical-representational-content-knowledge (P-R-C-K) would be the knowledge transformed from the knowledge base related to the representational aspects of the scientific concept (e.g., pollination) and the pedagogy (i.e., I2W).

In the following sections, we illustrate how considerations of disciplinary and pedagogical affordances of modes are applied to the design of an I2W activity to support the material and semiotic means needed for the conceptual and language development of the concept of "pollination" for primary school students. In addition, we also examine how a primary school science teacher enacted the I2W activity with his Grade 6 students so as to identify the P-R-C-K that teachers might need to carry out such science activities with a focus on its language.

6.5 Design of I2W Activity for "Pollination"

The activity to learn the concept of pollination consisted of five representational stages. Each is marked by the translation of one mode to another, except the first. The five stages are summarized in Fig. 6.2.

Representational Stage 1: Watching Video Animation on Pollination

Pollination is a process that involves the transfer of very small pollen particles which may not be visible to the naked eye. As a result, it is often difficult to observe the process in nature. Therefore, observations of pollination for classroom teaching often rely on animations to allow students to have a closer look at the process. In that sense, the animation possesses pedagogical affordance in helping students make the necessary observations that would be difficult in real life.

In a "classical" approach to science concept learning which perceives the visualization to be presenting the same concept but in a different representational form (Tang et al., 2014), teachers would similarly show students the animation to help them "see" the microscopic process that is hard to observe. However, teachers tend to race through teaching the concept after watching the animation, without addressing how the visual images lead to the written definition (Eilam, 2012). To address this, we designed a representational transformation and transduction sequence to engage students in relating the animation to the written definition of pollination.

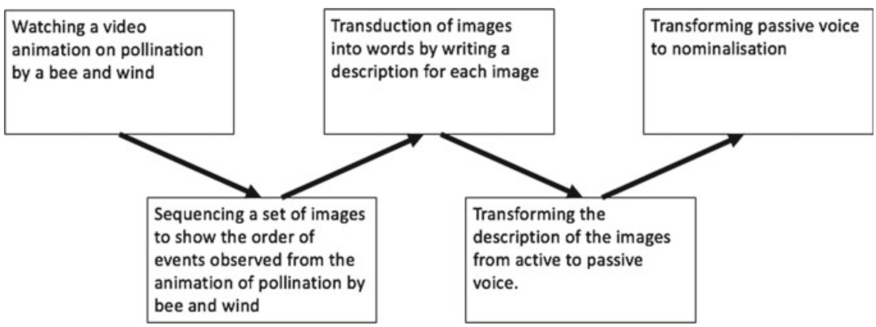


Fig. 6.2 Representational learning stages for the concept of pollination

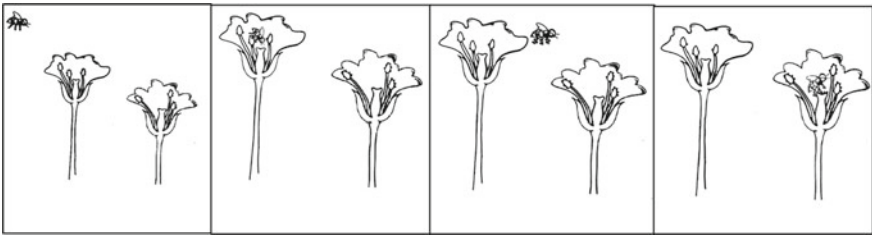


Fig. 6.3 Sequence of images for pollination by bee

Representational Stage 2: Sequencing a Set of Pictures Depicting Events of Pollination

An animation can be considered a set of dynamic images that are shown in succession so that entities appear as if they are moving (Kress & van Leeuwen, 2006). In the animation of pollination used in this lesson, iconic images were used to give learners a sense of the real thing. However, it is difficult to examine in detail the rapid changing images of pollination in an animation. The animation may also consist of other entities (e.g., petals and leaves) that do not matter in the concept. Therefore, the sequencing of the images in Stage 2 plays two pedagogical purposes. Figure 6.3 shows the sequence of images.

First, the dynamic images are made static through the sequence of static images so that key details in each event can be highlighted and discussed. Second, the images are redrawn to show the cross-section of the flower so that attention is directed toward (1) the pollen grains (represented by the dots of anther and/or the bee in the pictures of Fig. 6.3), (2) its location before and after its transfer and (3) the agent doing the transfer.

Representational Stage 3: Transduction of Images to Informal Writing (Description of Event)

The definition of "pollination" as learnt at the primary school level is inscribed in a long noun phrase that highlights the target (pollen grains) rather than the agent of the process (bee or wind) and necessitates the mention of the location and destination of the pollen grains in the process of transfer. To induct primary school children to this complex grammatical form, the language structure they are familiar with, that is, the description of each image in the active voice (e.g., the bee lands on the anther. The bee picks up pollen grain on its body. The bee flies to the stigma…) is the starting point. In this stage, students write descriptions of the event as illustrated by each image of the process of pollination.

Representational Stage 4: Transformation from Active Voice to Passive Voice

This stage involves the rewriting of the description of the events of pollination from active to passive voice. The active voice names the agent of the process (bee and wind) as the subject, highlighting the action it takes. In a passive voice, the target of the process is made the subject of the sentence, highlighting the action being taken on it. To prompt students to write the description in passive voice, the students are asked the question "what happens to the pollen grain?" Their likely answer would be: The pollen grains were transferred from the anther to the stigma by the wind/bee. However, wind and bee are just two possible agents in the transfer of pollen grains; there could be other agents. To increase the generalizability of the description of pollination, students are taught that the varying agents in pollination need not be mentioned, e.g., the pollen grains were transferred from the anther to the stigma. The two sentences are compared to make clear the differences in their degree of generalizability. Thus, the description of the pollination process written in passive voice possesses the disciplinary affordance in the generation of the definition of pollination.

Representational Stage 5: Transformation from Process to Definition

In this final stage, students are prompted to nominalize the process clause (e.g., pollination is the process whereby pollen grains are transferred from the anther to stigma). This can be done by the teacher introducing the name of the process "pollination" if he/she has not done so and then asking the students to write down in one sentence "what is pollination" to make it as generalizable as possible.

6.6 Teacher's Role in the Enactment of I2W

The teacher plays an important role at every stage of the I2W activity. As illustrated in Fig. 6.1, the teacher needs to look out for any conceptual errors or difficulties students are facing as he/she supports students in shifting their conceptual ideas from specific (actions by bees and wind) to generalization (actions taken on pollen grains). At the same time, the teacher is expected to discuss the representational forms, how they relate to the conceptual ideas and look out for any representational challenges students experience.

To carry out the role effectively, teachers need to develop not only disciplinary and pedagogical knowledge but also knowledge about disciplinary and pedagogical affordances of the different modes being used in the activity. In the light of the professional knowledge teachers should possess to carry out a lesson effectively, Shulman (1986) coined the term pedagogical content knowledge (PCK). While representational knowledge may be perceived as a component of disciplinary and pedagogical knowledge, we specifically refer to this representational knowledge as "pedagogical-representational-content-knowledge" (P-R-C-K) to highlight the representational component of PCK from the more traditional focus on conceptual ideas in the concept of PCK. We think this distinction is meaningful as having P-R-C-K can increase one's alertness to the representational possibilities that any form can afford, in which contexts and for whom, how and why (Towndrow et al., 2013). We further draw from Cochran-Smith's (2006) constructivist view of PCK (which she terms it as pedagogical content knowing, PCKg), which perceives it as an ongoing and active transformation of knowledge "on the go" and thus observable from the enactment in the classroom.

In the next section, we examine one teacher's (Mr. N) implementation of the I2W activities to identify the P-R-C-K demonstrated by him in addressing the language component of science concept learning.

Background of Mr. N

Mr. N was one of the teacher participants in a larger research project that developed a representation-based approach (I2W) to support primary school students in the learning of abstract concepts of science and to examine its efficacy in developing both conceptual and representational competencies (Yeo et al., 2021). In the first phase of the project, the team co-designed and developed a lesson package with primary school science teachers on the teaching and learning of the concepts of temperature and heat with Mr. N being one of the teachers involved. He also carried out the activities with one class of students and was engaged in the reflection on the activities and their enactment on a weekly basis. For the third phase, which was the design and implementation of I2W activity for pollination, Mr. N continued to play a major role in the design of the activities on the topic of reproduction in plants. During the implementation stage, being more experienced with the I2W approach, he adapted some of the learning tasks to make them more appropriate for the profile of students he was teaching. For example, since Mr. N felt that his students were of higher ability, in the representational Stage 3 of the activity, he instructed the students to write their own description of images rather than using the sentences that were pre-printed on word cards and intended to help students with the descriptions of each image.

6.6.1 Mr. N's Orchestration of Modes in the Teaching of Pollination Through I2W Approach

The enacted activity consisted of four representational episodes because Mr. N had combined Stages 2 and 3 together. Our description focuses on whole class talk when the students had completed each representational task assigned by Mr. N. The four episodes are summarized in Table 6.1.

Episode 1: Naming Process Illustrated in the Animation "Pollination"

At the end of the two animations showing pollination by bee and wind, students were asked to name the process shown on the video. Some students called out "germination", while others said it was "pollination". Without hesitation, Mr. N directly affirmed that "it's called pollination". Scientific terminology is considered as symbols which bear no physical resemblance to their referents and are linked purely by convention (Chandler, 1994); it is appropriate for Mr. N to affirm the name

Table 6.1 Four episodes in Mr. N's enactment of I2W for pollination

Episode	Representational activity	Conceptual and representational talk
1	Watching animations of the methods of pollination (bee and wind)	*Representational talk*: naming the process shown on the video as pollination
2	Sequencing the order of pollination of each method (bee and wind) and writing a narrative of the phenomenon	*Conceptual talk*: description of each image in the sequence of pollination by bee and wind
3	Rewriting the narrative account as a personal account (what happened to me if I were a pollen grain)	*Conceptual talk*: location of pollen grains before and after transfer
4	Rewriting of personal recount to a single sentence to define pollination	*Representational talk*: meaning of the technical words used and their synonyms

of the process observed. The name also plays a complementary role to the two animations so that it can be used as a shorthand when making reference to the common process taking place in both animations and in the subsequent activities.

Episode 2: Sequencing the Images and Writing Description for Each Image

In this episode, Mr. N combined representational Stages 2 and 3 together whereby students would sequence the images for each means of pollination and then write a description of the images. To ensure that students wrote a more narrative description in the third person, Mr. N instructed the students to "write down the whole process, what is it (bee or wind) doing? … what does the first picture actually show you, … where is it moving". In so doing, Mr. N did away with the grammatical term "active voice" though the students would have learnt it in their English language classes.

At the end of this group activity of sequencing images and writing descriptions, Mr. N invited two groups to present their responses. For the pollination by bee, Student A read out "Insect carries pollen grain from the anther of the first (flower) then transfers (to) the stigma of the …". For the method by wind, Student B read the group's response, "the wind will blow the pollen grains from the anther of the flower to the stigma of another flower. Then the pollen grains will land on the stigma". Satisfied with the descriptions written by the students, Mr. N then directed the students to the next representational task, that is, rewriting the description from active to passive voice.

Episode 3: From Writing Narrative to Personal Recount

To prompt students to rewrite the description of pollination in passive voice, Mr. N instructed the students to write a personal recount to describe what would have happened to them if they were a pollen grain. During the post-lesson interview, Mr. N explained that this was done to prompt the students toward nominalization as they were "seeing (the phenomenon) as a third party (referring to episode 2). … when they imagine (themselves as a pollen grain), they will imagine how they are being 'transferred', the word will actually come out". Mr. N's reframing of the writing of passive voice as a personal recount indicates his awareness of the grammatical resources used in such a genre and its similarities with that of a scientific definition of pollination. In addition, the term "transfer" is an important technical word used in the definition of "pollination" to highlight the action taken on the pollen grains. However, Mr. N was also aware that students would be more interested in humanizing the pollen grains; therefore, he also specified in his instructions that, "please don't tell me … one sunny day, I was sitting on the anther".

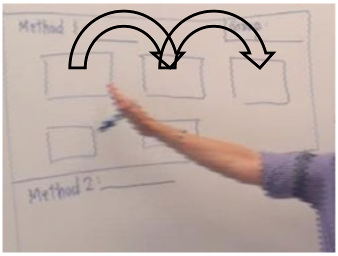
After the completion of the representational task, Mr. N nominated two groups to share their writing. Describing pollination by bees, Student X said "If I were a pollen grain, I would stick onto the body of a bee and be carried to the stigma of another flower". For pollination by wind, Student U described it as "so the wind blew towards the flower and I got carried away to the opposite flower and landed on the stigma". Noticing that the students had missed out on mentioning the location of the pollen grains before the transfer, which is an important conceptual component of the definition of pollination, Mr. N then prompted the student to "first tell me where were you? … so many parts where?". Refining his response, Student U replied, "I was on the anther. … The wind blew towards the flower … then I got carried away to the opposite flower … landed on the stigma". While Mr. N had directed students to the need to specify the original location of the pollen grains, he could also have linked the meaning of the word "carry" with its spatial connotations (i.e., from one place to another).

Episode 4: From Personal Recount to Nominalized Phrase

In this episode, Mr. N prompted students, in a whole-class discussion setting, to construct the definition of pollination with the question "You have described the whole thing, but if I now ask you, how do you tell me what is pollination?" This elicited a series of questions and answers that mostly targeted the representational aspect of the definition. Table 6.2 shows an excerpt of the questions and answers and the focus in the representational talk.

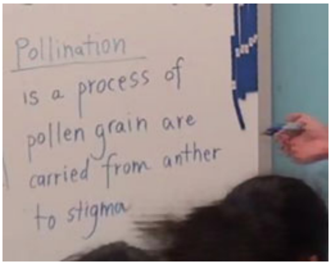
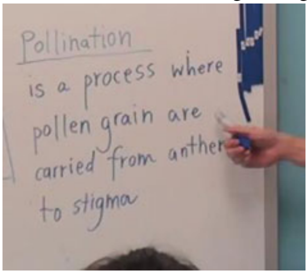
As can be seen from the excerpt above, the definition of pollination in a nominalized form was elicited through a constant turn-by-turn question and answer between teacher and students. This was unlike the representational Stages 2 and 3, whereby students were able to write the description of the events observed from the video in narrative (active and passive voice) form with few problems. From the teacher-prompted parts of the interactions with students, we see a mix of conceptual and representational support provided by Mr. N. An example of conceptual talk can be seen in Turns 47–48. The word "process" is a technical term used commonly in science to refer to a series of actions taken to produce a particular outcome which is not common in everyday talk among the children. By discussing the meaning of the word "process", Mr. N was signposting that the definition of pollination entailed a series of actions as he gestured with his hands from one box to another on the board, verbalizing that "there are different actions" (Turn 47) that "leads to something" (Turn 48). Mr. N's hand gestures across the boxes drawn earlier to represent the stages of pollination (in Episode 2) directed the reference of "process" to the events

Table 6.2 Excerpt of question and answer in Episode 4

Turn	Speaker	Spoken text	Focus of talk
45	T	You have described the whole thing, but if I now ask you how do you tell me what is pollination?	
46	S	*(a process)	
47	T	Okay, you know why is it called a process? Can you see that all these are, there are the different actions right?  *Hand gestured across the boxes to illustrate process*	Conceptual talk—illustrating the meaning of a technical word by gesturing on the image of rows of boxes
48	T	It leads to something, so that, that's why it's called a process. A process of what?	
49	S	(inaudible)	
50	T	A process? What? … What have you been talking about? It's a process of?	Representational talk—writing a nominalized phrase, grammar (changing pollen grains "is" to "are")
51	S	*(reproduced …)	
52	T	Reproduced? Based on all these, then how can we actually phrase it into a statement about pollination? It's a process what? Process of doing what? What is happening?	
53	S	Oh pollination is (mumblings of students)	
54	T	Ah, pollen grains	
55	S	Pollen grains?	
56	S	Is a (inaudible)	
57	T	Are?	
58	S	*(carried)	
59	T	Carried, yes	
60	S	*(from …)	
61	T	From? Which part of the flower? …	
62	S	Yes	
63	T	Anther to? To?	

(continued)

Table 6.2 (continued)

Turn	Speaker	Spoken text	Focus of talk
64	S	Stigma  *Teacher wrote the definition elicited from students on the board*	
65	T	Okay, let's look at this one, do you all agree with what she said? Pollination is a process of, or is a process where pollen grains. Are you all listening there? Carried from anther to stigma. Agree?  *Teacher changed "of" to "where"*	Representational talk—replacing conjunction from "of" to "where"
69	T	If I don't use the word 'carry', what is another word I can also use?	Representational talk—alternative word(s) to "carry"
70	S	Transferred, brought over	
71	T	Brought over?	
72	S	Transported	
73	T	Transport? No, not transported. Sorry, Harry? Can you speak louder?	
74	S	Transferred	
75	T	I can also use the word 'transferred' ah. …	

Speech is almost inaudible in the video recording but inferred from the teacher's habit of repeating students' responses to the whole class shown in the animation. Together with his hand gestures, the sentence starter, "It's a process of?" (Turn 48) facilitated the nominalization of the events of pollination as well as the question "how can we actually phrase it into a statement about pollination?" (Turn 52). The fact that the students could provide the correct answers to Mr. N's prompts suggests that they did not have much problem with the concept. Rather, we perceive Mr. N's prompts to be addressing the language aspect of the definition in providing clear details about the "process" of pollination. In another instance (Turns 69–75) of Mr. N, addressing the language aspect of science learning was also observed. In that case, the word "transfer" is the technical term often used in the definition of pollination, although "carry" is also acceptable in this instance.

6.7 Pedagogical-Representational-Content-Knowledge of Mr. N

From Mr. N's enactment of the I2W activity for pollination, we identify the following language-related knowledge bases (Seah et al., this volume) related to the content and pedagogy that influenced Mr. N's P-R-C-K:

(1) *Knowledge about the use of nouns as naming words.* The use of nouns for naming some things or processes is purely by convention rather than logic. Therefore, to learn that the noun "pollination" is a name given to the process of transfer of pollen grains from anther to stigma of a flower, cannot be arrived at through inquiry. Instead of letting students discover the terminology, Mr. N was observed to be telling the students the name of the process at the onset of the activity. Knowledge about the language of naming directed Mr. N's focus to unpacking its meaning instead. The I2W approach was thus the means to allow students to establish connections between the technical term and the physical phenomenon.

(2) *Knowledge about the non-content words used in everyday language.* The transduction of the concept of pollination presented in casual visual mode to formal written form can be a semiotic challenge for young children. By asking students to write a narrative of each image is to engage them first with the concrete familiar social language of everyday spoken interaction whereby information density is generally low (Fang, 2004). Written in active voice, non-content words such as verbs, prepositions, conjunctions, adverbs are commonly used to join an average of 2–3 content words (e.g., pollen grains, bee, anther) per clause in everyday talk (Halliday, 1993). However, students seldom think about the form of language they use in everyday conversations, not least the technical naming of these grammatical resources (e.g., active voice). Besides, the language characteristics here were not the key focus of learning. Therefore, while the lesson plan might have indicated the shift from visual mode to informal writing in active voice, we observed Mr. N asking students to describe the events taking

place in the animation video using active voice without actually using the technical grammatical terms. We attribute this pedagogical action to his knowledge about language, in addition to the knowledge about students' use of language and knowledge about the pedagogical affordance of the use of active voice in I2W.

(3) *Knowledge of genres (e.g., personal recount) and their related grammatical features.* The definition of "pollination" is a "thing-oriented" genre that removes animated objects (e.g., bee) from the phenomenon and highlights the process (whereby pollen grains are transferred from anther to stigma) by reconstruing them as nominalization (Martin, 1993; Schleppegrell, 2004). This genre is typically challenging to young children who are more familiar with a narrative way of talking whereby the agent (e.g., bee) of the process is foregrounded. The definition of pollination, in this case, is a complex noun phrase (i.e., process whereby pollen grains are transferred from anther to stigma) embedding a relative clause (i.e., whereby pollen grains … stigma) within the nominal group. Recognizing that the grammatical characteristics of the relative clause are used also in personal recount, a genre students are familiar with, Mr. N saw it as a means to bridge students between the grammatical resources used in everyday description of events with a less familiar nominalization of scientific processes. In this case, we see how the knowledge of the language characteristics of different genres as well as the knowledge of students' language competence help Mr. N introduce this intermediate stage of transformation of the written mode.

(4) Knowledge of technicality and their meanings (e.g., transfer and carry). While science learning tends to emphasize the use of specialized terminologies, science teachers should also be aware of alternative words that are able to realize the intended scientific meanings and highlight them. On this note, we observe Mr. N taking time to explain to the students why "carry" is apt to bring across the same idea as "transfer". Conversely, teachers should also highlight why certain words cannot be used in place of these technical terms. For example, the word "transport" cannot replace the word "transfer" in the definition of pollination as "transport" involves being taken from one place to another by a vehicle, ship or aircraft. Explaining to the students about the semantic affordance of these terminologies would help them understand the peculiarities of scientific language in relation to the phenomenon. We see this when Mr. N was explaining the meaning of the word "process". This was in response to a student's query as to why the word "process" need to be used. In explaining the meaning of "process" in the context of "pollination", he used gestures as a visual representation to realize its meaning as a series of events or steps. In this respect, the knowledge of the aptness of visual modes (e.g., gesture) is also important to realize the sequential meaning of "process".

(5) Knowledge of the complementary function of the disciplinary and pedagogical affordances of different semiotic modes. While the knowledge of language is important, as discussed above, the knowledge of how one mode pedagogically complements another in relation to the disciplinary meanings to be realized is

equally crucial. We see two instances in Mr. N's lesson described. The first instance is observed in Episode 1. The technical term for the process (i.e., pollination) as well as the animated events share similar disciplinary meanings but provide different information. The word "pollination" merely gives a name to the process but shares little information about what it is, while the animations show the stages of the process taking place. The ability to see the complementary roles of text and images in teaching the disciplinary meaning of "pollination" provides the purpose of the pedagogical actions taken to unpack the meaning of "pollination" in the subsequent episodes. Similarly, we see the complementary roles of different semiotic modes in Episode 4. Here, we see Mr. N's hand gesture across the drawn boxes on the whiteboard as complementing the disciplinary-oriented word "process" as he urged students to elaborate on what "process" they were referring to. From the students' responses, we infer that his hand gestures would have directed the students' attention toward the events of pollination they were discussing in the preceding episodes. Ainsworth (1999) identifies this complementary role of different semiotic modes as one of the functions of multiple representations. The two instances further suggest that a teacher's orchestration of the complementary purpose of multiple representations for science meaning-making is an integral of the knowledge of the disciplinary and pedagogical affordances of the semiotic modes (e.g., the textual word "process" and the hand gesture moving across the boxes). In that sense, PRCK can be perceived as a unique professional knowledge that a science teacher should possess.

6.8 Conclusion

Science concept learning is challenging because of the technical, abstract and information-dense sentences used to define them. In this chapter, we describe I2W as a pedagogical approach to address the language challenges students face with science concept learning and illustrate its application in designing an I2W activity on "pollination". We further explain how the design takes into account the disciplinary and pedagogical affordances of various modes when selecting and creating an ensemble of semiotic resources to realize the conceptual meanings of pollination. Data from earlier phases and also this phase have shown that the I2W approach is able to develop students' conceptual understanding and language competencies (see Yeo et al., 2021). We further illustrate its enactment in a classroom and identify the teacher's P-R-C-K which was demonstrated in the process. We believe that the identified representational knowledge had helped him to better select and use the appropriate modes in disciplinary and pedagogical appropriate ways such as reframing some of the representational tasks appropriate for his students and the content, specifying the language boundaries for each task and discussing the various meanings of technical terms with the students. The language-related knowledge base was found to influence the teacher's choice of representations for pedagogical and disciplinary purposes. Further, the knowledge of the complementary roles of semiotic modes for both disciplinary and pedagogical purposes in science meaning-making suggests the value of considering PRCK as a unique professional knowledge, separate from PCK. The knowledge base suggests the necessity to consider it as part of teachers' professional knowledge in addition to PCK and its components. However, our study is merely scratching the tip of the iceberg. More work needs to be done to examine this set of professional knowledge and perhaps incorporate it into the larger PCK framework.

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Chapter 7
Teachers' Language-Based Knowledge to Support Students' Science Learning

Vaughan Prain

Abstract This chapter puts a case for how teachers' language-based knowledge to support students' science learning needs to extend beyond a linguistic focus to include all the multi-modal representations through which this learning is shown. Teachers need to know how to guide student collaborative meaning-making in and across verbal, visual, mathematical, and actional modes. A representation construction approach is described that aims to address this challenge through teachers guiding students to invent, share, critique, and refine representations of phenomena related to targeted concepts. Two case studies of secondary school science topics using this approach are reported. They indicate that students can learn through representation construction and review if their teachers have thorough topic knowledge enabling them to frame the inquiry, elicit and respond to student input, and prompt and confirm student integrative meaning-making across modes. While these case studies point to requisite teacher knowledge to develop students' science literacy, more research is needed across different tasks, multiple science topics at different levels, and different cohorts of students, to clarify how this teacher knowledge can be acquired and applied more broadly.

7.1 Introduction

In this chapter, I outline a representation construction approach (RCA) to science teaching that identifies the teacher language-based knowledge necessary to integrate practical inquiry, representational work, and pedagogical strategies to enable students to acquire and apply this disciplinary learning. Drawing on socio-semiotic theories (Peirce, 1998; Vygotsky, 1981), RCA entails guided inquiry where students create, share, critique, and refine representations that address topic-specific conceptual challenges, as a basis for learning how knowledge claims are produced, justified,

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and shared in science. Drawing on research on two secondary school science topics using RCA, I outline (a) what teacher language-based knowledge was necessary to frame and enact these topics, (b) what integrative teacher strategies were used to guide student learning, (c) student learning outcomes, and (d) the implications for the roles of disciplinary literacy in this learning.

There are now compelling and wide-ranging prescriptions on what teachers should know about language as well as how they should incorporate this knowledge into guiding student science learning (Adger et al., 2018; Andrews & Lin, 2017; Keys et al., 1999; Tang & Danielsson, 2018; Yore & Treagust, 2006). This language-based knowledge includes the literacies that make up the content of this subject, such as topic terminology, key concepts, and practical inquiry and testing processes and their rationales. As well, teachers are expected to understand symbolic meaning-making processes in science, including the literacies entailed in constructing and interpreting the multi-modal representations through which scientific explanations are made, reasoned about, agreed upon, and shared. Here, language is defined broadly to include the languages of visual and mathematical representations. At the same time, teachers are also expected to know when, why, and how to apply generic and topic-specific pedagogical literacies, such as explicit and informal teaching and learning strategies, task challenges, guided discussion, heuristics, scaffolds, and routines to enable and integrate these other learning outcomes (Andrews & Lin, 2017; Bunch, 2013; Tang & Putra, 2018; Tytler et al., 2020). More generally, teachers are expected to know how to make student learning engaging, meaningful, and creative rather than rote and dogmatic.

7.2 Language-Based Knowledge for Teaching Science

There is growing recognition that teachers' language-related knowledge base for content teaching (LRKCT) is critical for effective teaching in every subject. Teachers need to know not only the specialist language of their subject but also how to engage students' own language resources to acquire disciplinary literacy (Andrews & Lin, 2017; Morton, 2018; Tang & Putra, 2018). This complex interlocking network of knowledge about what, how, when, and why students learn (as content, process, resource, and outcome) is particularly applicable to teaching and learning in science, where students are expected to acquire a discipline-specific multi-modal literacy. They are meant to learn how to conduct guided inquiry, reason about data, and share claims using a purpose-built grammar and vocabulary (Halliday & Martin, 1993). To be effective, science teachers, as a basic requirement, need to know the particular literacies that make up the content of their subject, such as topic terminology, key concepts, and how they fit together (Bunch, 2013; Seah, 2020). They also need to know the practical inquiry and testing processes whereby knowledge claims in this subject are generated, judged, refined, and shared (Keys et al., 1999). In addition, they need to know how to use students' vernacular language as a main resource for this disciplinary learning (Gee, 2004; Hand et al., 2003; Lemke, 2002; Yore & Treagust, 2006).

This foundational account of language-based knowledge has been supplemented over the last twenty years by research on the multi-modal nature of meaning-seeking, meaning-making, and meaning-sharing in learning science (Ainsworth et al., 2011; Kress & van Leeuwen, 2006; Lemke, 2004; diSessa, 2004; Unsworth, 2006). Teachers are now expected to understand a subject's symbolic meaning-making processes, including the literacies entailed in constructing and interpreting multi-modal representations. Here, the meaning of language is extended beyond linguistic or verbal modes to include mathematical, visual, and embodied (enacted) representations. Teachers are expected to understand how the integration of these modes is crucial in scientific claim-making because each mode does different but complementary work, based on the affordances of different modes (Lemke, 2003; Prain & Waldrip, 2006; Tytler et al., 2020). For example, diagrams need to be annotated or accompanied by extended explanation to clarify and complement what is being represented and claimed visually and spatially. Writing's linearity, specificity, grammatical structures, and category rules enable writers to clarify and inspect for self and others causal relations between categories and conceptual groupings. By contrast, visual and mathematical languages are better designed to measure degrees or patterns of changes of state over time (Lemke, 2002).

This multi-modal claim-making in science poses challenges for teachers' own knowledge base as well as for how they teach their students these semiotic or meaning-making processes and their coordination (Tang & Putra, 2018; Unsworth, 2006). Teachers need to understand the components, purposes, and functional structures of visual representations such as graphs, tables, and diagrams to induct students effectively into how to use them to learn and share scientific claims. Teachers are also expected to know when, why, and how to apply generic and topic-specific pedagogical literacies to teach their students this disciplinary meaning-making. There is no shortage of advice on how to proceed, with researchers proposing many teaching and learning strategies. These include generative task challenges, guided discussion, heuristics on learning progressions, and explicit initial scaffolding of the grammar evident in scientific reasoning (Andrews & Lin, 2017; Bunch, 2013; Keys et al., 1999; Tang & Putra, 2018; Tytler et al., 2013). More generally, teachers are also expected to know how to make this learning engaging, meaningful, and creative rather than rote and dogmatic.

In this chapter, I outline one possible approach to science teaching, identifying the LRKCT to guide this representational work. The RCA has been developed and trialled over the last fifteen years across primary and secondary school science topics (Prain & Waldrip, 2006; Tytler et al., 2020) and aligns with studies on student model-based reasoning through representation construction and analyses (Lehrer & Schauble, 2006a, b, 2019). This approach focuses on multi-modal student representation construction as a resource for reasoning and claim-making in science, with positive results in teacher and student learning gains (Hubber, 2013; Tytler et al., 2013). RCA evolved over time to clarify what exactly teachers need to know about the languages of science. Drawing on socio-semiotic theories of meaning-seeking and meaning-making (Peirce, 1992, 1998; Vygotsky, 1981), RCA entails guided inquiry where students create, share, critique, and refine representations that address topic-specific conceptual challenges. The signature feature entails teachers eliciting students' creative representation-seeking and refinement as a basis for how they learn both content and the underpinning rationale for this subject's disciplinary literacies. As will be discussed later, this focus on students' creative input poses both significant challenges for teachers, as well as opportunities for deeper learning and strong student engagement (Prain, 2019; Tytler et al., 2013).

I begin by reviewing the warrants for this creative focus, the principles that underpin RCA, and the LRKCT required of teachers to enact these principles. Drawing then on research on two school science topics where two teachers used this approach, I consider (a) the teacher LRKCT necessary to frame, enact, and assess student learning in these topics, (b) what integrative teacher strategies were used to guide this learning, (c) learning outcomes, and (d) the implications for future research.

7.3 Warrants for the RCA to Student Learning

RCA sits within the tradition of grounding teaching and learning in science in practical inquiry (Gee, 2004; Lemke, 2004; Manz et al., 2020). These inquiry experiences are expected to engage students in wanting to explore and explain phenomena and to induct them into the what, how, and why of scientific investigations. In participating in inquiry, students are expected to reason speculatively, draw on prior understandings, undertake multiple sampling of data, and use perceptual clues to interpret ongoing inquiry. They are also expected to learn how and why represented data need to be analysed as the basis for making justifiable scientific claims.

In foregrounding student creative input into inquiry processes, advocates of RCA claim that this immersive approach is warranted on epistemic, epistemological, and motivational grounds (Lehrer & Schauble, 2019; Prain & Tytler, 2012). The epistemic justification is based on the claim that by having a guided first-hand experience of the challenges entailed in framing, experimenting with, and refining inquiry processes, students learn the core nature, purposes, and productive constraints on knowledge production in science. Students' creative input is guided by the teacher's understanding of disciplinary constraints (Ferguson & Prain, 2019). These constraints include broad criteria for undertaking investigations, such as logical plausibility, practical feasibility in leading to testable ideas, and adequacy of sampling and data collection. There are also representational constraints, including communicative clarity, internal coherence and completeness in what is represented, and the need to establish correspondence with features of the target phenomena. In addressing these constraints, students are guided to understand the value of, and the need for, representational conventions. As noted by Lehrer and Schauble (2019), RCA goes beyond teaching structures and strategies as recipes to follow, but rather encourages students to consider when, how, and why particular strategies or procedures and their representation are productive, or why and how they might need modification to address new complexities or emergent problems.

In RCA, students can come to understand the aptness of multi-modal literacy practices through which inquiry is shaped, justified, and reported. In being guided to decide what to attend to, and how, and work out how relevant adequate data can be collected and analysed to make and review claims, students are participating in processes that align with how scientists make, justify, and qualify knowledge claims. They can also learn about the inevitable trade-off between sufficient sampling and certainty of claims. In experimenting with different representational choices, students are learning (a) about the need for representational adequacy, coherence, and correspondence with referents and (b) the aptness and communicative efficiency of the conventions in science literacies. In this process, students are also engaging in creative practices that align with how scientists model complex systems, reason, and make claims. This creative reasoning, if effectively guided by the teacher, provides a workable, meaningful induction into what can be known and why from systematic scientific inquiry.

The pedagogical justification draws on both theoretical and practical warrants. Following Vygotsky (1981) and Peirce (1998), student learning processes are theorized as guided creative use of cultural symbolic tools to analyse and solve problems and make claims (Vygotsky, 1981). From a semiotic perspective, students construct and revise signs to generate, consolidate, and share meanings through making imaginative links between signs, objects, and their application to real-world phenomena (Peirce, 1998). Research in which students have participated in RCA has found that they have learnt not only prescribed topic content, but also about the varied purposes and specific affordances of different disciplinary representations as tools for imagining, reasoning, and claim-making (Ainsworth et al., 2011; Lehrer & Schauble, 2006a; Tytler et al., 2013; Waldrip et al., 2006, 2010). Students have also come to understand when and why scientific and mathematical representational practices are useful and trustworthy. As well, they have also found this approach to science learning more engaging than past practices (Tytler et al., 2013).

7.4 Principles of Representation Construction Pedagogy and Teacher's LRKCT

In designing and framing inquiry, the teacher guides students to understand topics through a process where they visualize, collect, represent, interpret, and model data as a basis for making and refining science claims. Material inquiry, observation, instrument development and use, and explanation are recursively integrated into claim-making. With teacher guidance, students are expected to invent, critique, revise, and refine multi-modal representations in response to conceptual challenges. The following principles are based on inductive trialling of this approach across varied primary and secondary school science topics (Tytler et al., 2013). RCA does not entail a tightly structured step-by-step template of teacher strategies, but rather is based on a broad framework of key principles that need to be adapted to the needs, interests, and capabilities of particular student cohorts, outlined in three broad but interlocking stages below.

7.4.1 The Approach is Based on a Sequence of Representational Challenges in Topics

In planning a topic, the teacher identifies key scientific concepts and processes to be learnt and also knows how these concepts are represented canonically as well as in textbooks for developmental pedagogical purposes. This knowledge of both target concepts and how they are represented conventionally provides the basis for devising a sequence of representational challenges that contextualize target concepts. For example, in the topic of the properties of light, where students are expected to learn the value of ray diagrams to show the amount and directionality of light, the teacher establishes the need for an explanatory representation based on student exploration of light boxes and lenses and recognition of the nature of the phenomena involved.

The teacher guides students to consider what ideas and evidence are needed to explain what is happening, leading to what kinds of data (and amount) could be collected and how such data could be represented for analysis and claim-making. The teacher deliberately chooses inquiry events such as exploring manipulation of lens that open up productive questions relevant to students engaging with key concepts. Exploratory processes include direct perceptual and/or virtual experience of the phenomenon, as well as discussion about how to devise and implement relevant data collection. In this inquiry into possible causes of phenomena, and how such dimensions can be quantified and represented, the teacher explicitly encourages students' creative reasoning and assessment. The teacher guides productive initial framing of the inquiry, builds on students' verbal responses; teacher questions (verbal representational challenges) student responses to further guide the students' attempts at subsequent multi-modal representations.

Students construct representations individually, in pairs, or small groups, to explore and make claims about phenomena. The challenge, at each stage in the topic, should be sufficiently open-ended and not pre-determined to produce noticeable variation in students' work. Students are challenged, individually or in groups, to invent a representation that makes a causal claim about the phenomena. Preferably, the teacher should know in advance what entry understandings and representational resources students are likely to bring to this task, and depending on the topic, it might clarify or introduce some representational resources underpinning a key concept (Hubber et al., 2010; Waldrip & Prain, 2017; Tytler et al., 2013). The introduction of a representational challenge is highly context dependent, based on the above. The teacher then circulates to support students to coordinate their representations across visual and linguistic modes to develop explanatory adequacy.

7.4.2 Representations Are Explicitly Analysed and Refined

The teacher guides comparative review and evaluation of students' representations, focusing on similarities and differences within and across a sequence of representational challenges. Variation in students' work can give the teacher confirmatory insight into the students' conceptual and representational resources at this point in the topic. This variation is also the basis for teacher-led discussion about what could or should be represented and how. In this way, conceptual learning is mediated through a representational focus on how student signs can be interpreted, modified, and developed. This can entail the teacher selecting some examples of student representations for explicit whole-class analyses. The teacher's knowledge of how the key concepts are traditionally represented (and the entailed multi-modal literacies) guides her critique and comparative review and feedback around the variation in students' work. Guidance can entail strategic questioning of students to compare, clarify, extend, and justify their intended and realized meanings (for self and others) in their representations. The teacher guides the framing of success criteria for effective representation, focusing on students making judgements about the degree of clarity, internal coherence, completeness, and correspondence with key features of the target phenomena (or theoretical model) to be represented. The teacher guides an emerging consensus about what is important to represent and effective ways to achieve this. This includes a meaningful contextual consolidation of key topic terminology embedded in discussion. With older students, or students with sustained experience of RCA, consolidation can also entail guided moderation about the completeness and comparative clarity of student-invented, canonical, and textbook pedagogical representations (Tytler et al., 2013).

Depending on student age, the teacher guides discussion on the use, degree, and effectiveness of different conventions in representations, noting the preference for symbolic abstraction in science representations and encouraging the class to arrive at a consensus about which conventions are useful for representing concepts and processes and why. Younger students often produce a mix of iconic (pictorial resemblance) and lexical (graphical) signs in their representations to anchor their claims, and this can be interpreted as a transitional development in learning the conventions of scientific representations, rather than as an error. When appropriate in topics, the teacher explicitly focuses on function and form in different presentations, with timely clarification of parts and their purposes in, for example, graphs, tables, diagrams, and flowcharts (Unsworth, 2006).

Through ongoing representation refinement, the teacher guides students to understand the selective purpose of any representation and therefore the need to construct multiple representations to address different aspects of topics and concepts. For example, for students to understand sound waves, they need to coordinate wave diagrams, time-sequenced representations of air particle movement, and pressure variation (Ainsworth et al., 2011). The teacher and students participate in a continuous, embedded process of assessing the clarity and adequacy of explanatory accounts.

7.4.3 Consolidation and Extension

In consolidating and extending students' understanding and use of topic concepts and relevant conventions, the teacher guides students to address new and related representational challenges. They may be expected to imagine and coordinate different representations to address new problems or to re-purpose them to explain new systems or processes (Manz et al., 2020). Again, the teacher's role is to guide open-ended inquiry but also provide explicit teaching and clarification, depending on the capabilities of students and the clarity and completeness of their representations. Given that a key feature of the RCA is to build on creative input from students, the teacher is tasked with guiding and responding to this creativity in ways that advance the inquiry and support disciplinary learning.

7.5 Teacher Language-Based Knowledge Required to Enact This Pedagogy

To guide students effectively in this approach to learning science, the teacher needs to know multiple forms and uses of language (Morton, 2018). This includes a deep understanding of key concepts and processes in the target topic and how these concepts are represented within and across modes. Fundamental to this approach, and to any other effective approach to science learning, the teacher needs to know the specialist content language of the subject. In inducting students into the multi-modal nature of scientific claims, the teacher also needs to know the affordances of different modes and how they need to be coordinated to make persuasive claims about target topics (Prain & Tytler, 2012).

Further, the teacher needs to have a deep understanding of what exactly is entailed in the cognitive process of integrating modes for scientific meaning-making and how to guide students' ability to do this. More precisely, the teacher needs to understand and promote in students the process of "transduction" (Kress, 2000, p. 159), namely the creative interpretive work whereby the meaning of a sign in one mode is remade into a sign in a different mode, and the role of this transduction in supporting student model-based reasoning. For example, the teacher needs to support students in how to transduce meanings in a 3D experimental or investigative experience of the topic into verbalized inferences. This embodied and linguistic sign-making then needs to be transduced into multi-modal texts that integrate visual, mathematical, and linguistic meanings. At the same time, modal meanings are not simply interchangeable, as noted by Lemke (2002), and the teacher needs to understand and incorporate into guided inquiry how modes complement one another in claim-making. For example, patterns in numbers in a graph need to be interpreted linguistically in a transductive process whereby these patterns are named and interpreted as trends. Both modes are then needed to make a subsequent claim.

By implication, the teacher needs to know both how modes have purpose-built features to support constructing or interpreting new meanings (Kress and van Leeuwin, 2006; Lemke, 2002, 2003, 2004; Unsworth, 2006) and also how to guide student meaning-making within and across modes. The teacher's knowledge of her students' experiences and language resources should partly inform the exact nature of the representational challenges and the expected degree of difficulty for particular student groups and year levels. As often noted, the teacher needs to build an inquiry discourse that grounds specialist language in the students' vernacular language (Hand et al., 2003; Morton, 2018; Yore & Tragust, 2006). Designers of national science curricula presume developmental levels of student readiness for different topics, but teachers are expected to know in advance how topic concepts can be contextualized meaningfully for learners. In the RCA, the teacher aims to provide representational challenges that both (a) focus students' reasoning generatively on target concepts and (b) enable students to engage creatively with, and come to understand, the logic and necessity of the conventions through which these concepts are instantiated and shared. Where appropriate in a sequence of representational challenges, the teacher will also need to know how to clarify student understanding through direct teaching of any of the forms of knowledge noted above.

In the next section, I briefly review two studies of secondary school science topics (Nash et al., 2018; Waldrip & Prain, 2017), where two teachers enacted RCA in an Australian curricular context of a national science curriculum. In this curriculum, students are expected to develop both scientific knowledge and inquiry skills and also understand that science is a human endeavour (Australian Curriculum, 2021). While the content to be learnt is specified, methods for achieving this learning are presented as indicative rather than tightly prescribed. I identify some of the LRKCT required and demonstrated in each case study. A lot more space would be needed to cover all areas of this knowledge at both the macro-level (of topic and procedure expertise) and at the micro-level (of guiding or directing student annotations and grammatical choices). Here, I focus on how the two teachers sought to develop students' understandings of the multi-modal nature and demands of scientific reasoning, focusing mainly on teacher prompting and guidance of student transduction of meanings, illustrating stages one and two of RCA above, although other teacher language-based knowledge is clearly in play.

7.5.1 Case Study One: Year 10: Atomic Structure and Electron Shells: Isotopes and Half-Lives

In this case study, a class of twenty Year 10 students was taking a non-preferred compulsory science subject, where the teacher had considerable flexibility in topic focus. Collected qualitative data included researcher classroom observations and video-taping of 10 lessons, teacher and student interviews, and analyses of student work samples. Informed consent was obtained from the participant teacher and students. A descriptive framework from past research on student creative reasoning (Tytler et al., 2013) was used to analyse how students integrated linguistic, visual, spatial reasoning as well as embodied practical activity to build and justify claims. Data analyses were carried out in two phases: (a) video analysis by two researchers independently (and then through mutual agreement) about identified categories and non-linguistic components of reasoning processes (Tytler et al., 2013) and (b) further case interpretation. All the classroom videos in which students or teachers used creative prompts or actions were viewed, noting students' use of representations as tools to show emerging reasoning and understanding. Four students from the class, based on the teachers' view of representativeness of the classes' abilities and interests, were interviewed to identify perceptions of the extent to which the lessons were engaging and why. These students reflected high and low achievement scores, motivation, interest, and engagement as perceived by Brian, a pseudonym for their teacher.

Brian, who had over twenty years of science teaching experience, aimed to increase student engagement by continually eliciting their reasoning about the phenomena being studied. In every topic, he would continually ask students to make, explain, and justify their claims. He often started a lesson with a question and brought everyday materials for students to use to experiment with and prompt speculative thinking. This broadly matches stage one in RCA. Typically, he started a new topic by seeking students' current understanding of relevant concepts and then asked clarificatory questions where students were expected to justify their views to the whole class. He often set student group work to build understandings, and this class had a high degree of observed student–teacher and student–student interactions. He invited students to propose multiple creative solutions, encouraging them to attempt different approaches with the everyday materials, eliciting student meaning-seeking and claim-making. In the normal routine of lesson sequences, students were expected to propose claims about a topic or concept, develop inquiry questions, trial practical tests of the explanatory value of their ideas, check for supportive evidence for their claims in textbook or internet resources, and attempt subsequent revised experiments and refinements. This broadly matches stage two in RCA, but indicates the recursive nature of the stages. Here, he sought to induct students into the language through which science inquiry and reasoning processes are framed and substantiated, using their own vernacular language as a resource for this learning (Hand et al., 2003; Morton, 2018).

From previous discussion of the topic of genetics, he raised the topic of radioactive materials with the class. Many students came from farms with genetic breeding programmes, where they had observed and experienced labelling of radioactive materials. One of the terms students raised was "half-life" in the discussion about genetics. Based on interview data and classroom observation, Brian willingly deviated from planned learning goals if he considered that a new focus deepened student interest and understanding. In this particular case, he asked them to explain what they thought this meant, with their verbal representations revealing mixed understandings of this concept. He then consciously chose questions, practical activities, and possible scenarios to challenge their current understandings.

To facilitate deeper reflections on the meaning of half-life, he proposed that students address the representational challenge of demonstrating a model of probability in half-life decay using M&Ms (a coloured confection with the letter M on one side). The students were not told how to do this but were expected to devise an explanatory model through which to make a claim about this decay. The students were expected to transduce one sign system (commercial advertising and colour variation of the confection) into a potential explanatory model of decay probability. The same transductive challenge is evident when students are expected to use laboratory instruments to sample data and propose explanatory diagrammatic, captioned models. Some students mistakenly placed their M&Ms in a linear fashion, alternating marked and unmarked sides, assuming an orderly pattern. They could not describe how their explanation illustrated half-life. A few students chose to tip the M&Ms onto their tables and removed any M&Ms that did not have the lettering facing upwards, in an attempt to enact probability. The M&Ms that faced downwards were considered as decayed and removed from the packet of M&Ms. They repeated this activity with the remaining M&Ms and plotted results (Fig. 7.1).

Other students, after some discussion linked to previous experiences where they had seen half-life graphs, adopted a different approach. Drawing on these imaginative responses, Brian probed students further to justify their understandings in relation to authorized views represented in textbooks. Finally, he asked students in their groups to compare the general shape of their graphs from this activity with published half-life graphs to determine how these different graphs supported the concept of half-life and the differences between the graphs. Students then talked about how the shape of the graph differed if the isotope had a longer or shorter half-life. Brian had accustomed these students to explain their ideas, challenge one another, and justify claims and understandings. For these students, it was natural for lessons to conclude with discussion about the part that chance had played in the process. In this way, students built explanatory shared accounts that connected past and current experiences. In the following guided exchange, he prompts students to justify their reasoning and consider the accuracy of their model:

Teacher: Will your rate of decay ever become zero?

Student: Yes. Because you will have none left.

Teacher: Can you show me why?

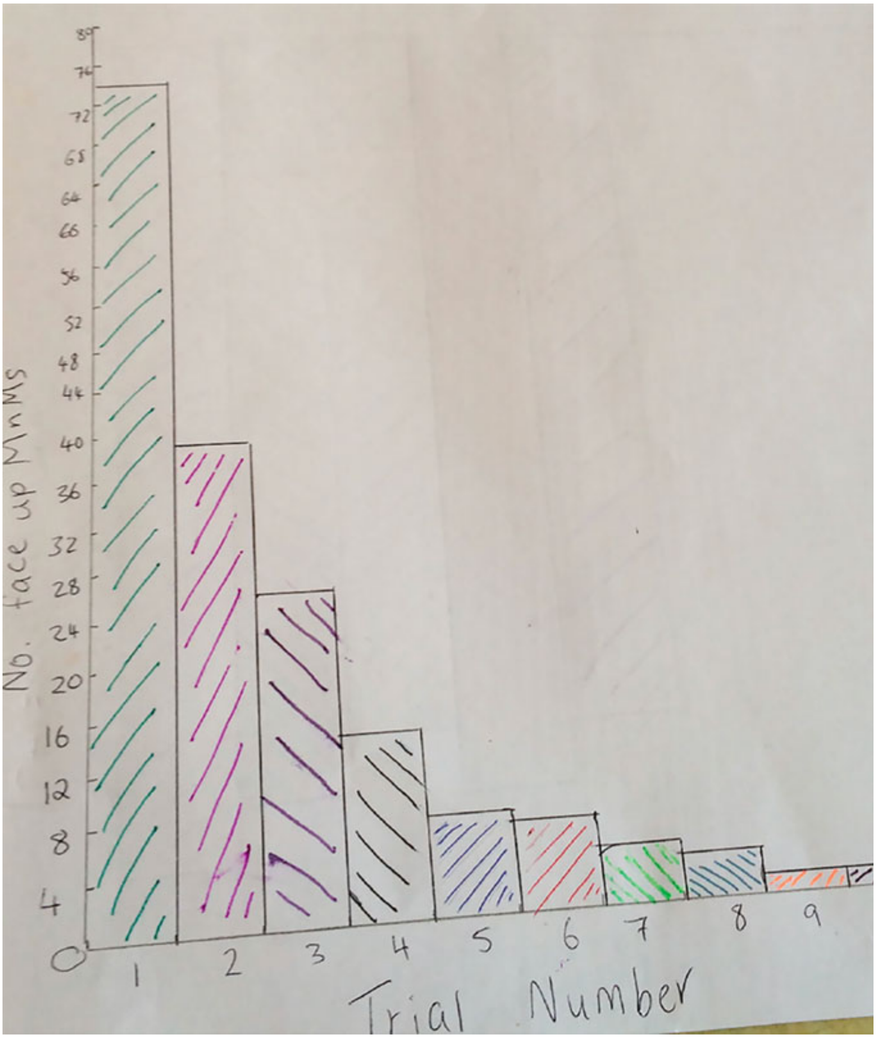

Fig. 7.1 Student half-life graph

Student: Find 24 decay, we have 28 left. If 13 decay, we have 15 left. If 8 decay, we have 7 left … eventually one decays and we have none left.

Teacher: Is this what happens in real life?

The resultant discussion explored the issue of large numbers of atoms decaying. Brian wanted the class to understand whether their results applied to larger-scale contexts and what happened when the radioactive component became very small. The group eventually concluded that the rate of decay would decrease so much that it might be difficult to detect:

Teacher: What patterns did you find in your graph?

Carl: Mine was fairly even.

Eva: Mine wasn't. It wasn't even because it involved chance. Mine halved every time.

Ben: That's different from what we got.

Teacher: What would happen in real life?

(pause).

Teacher: What could affect half-lives and how they decay?

Ben: The temperature. It can't decay if it is frozen.

Carl: In areas where it is frozen, there is no radioactivity decay.

Gwen: But there is always background radiation.

Teacher: You mean that in Antarctica that there is no radio-active decay?

Carl: There is always background radiation. It is found everywhere. It is just another chemical.

Teacher: How does this affect how isotopes decay?

Steve: It mixes with another element. If they have different half-lives, what would be its half-life?

Gwen: Would it affect its half-life?

Ben: They would keep their own half-life.

Brian prompted the students to engage in purposeful, collaborative, transductive meaning-making in which they interpreted mathematical data to make logical verbal inferences about potential claims. They were practising how to use/interpret different modes to play complementary roles in coordinated claim-making. He expected them to coordinate relevant observations, past experiences, and logical inference as part of this meaning-making. He also judiciously used his specialist knowledge about the topic to frame new verbal challenges on the fly to add to their emerging understanding. Through his material representational challenges, follow-up questions, and prompts, he inducted the class into practising using a graph as a purpose-built measuring tool for ordering data and from which warranted inferences can be made and reviewed. He invited the students to re-purpose the graph from being an initial record of data sampling to a resource for modelling probability in half-life decay. This short sequence demonstrates how his deep knowledge of the subject, his use of an inquiry discourse, and his agile engagement with the students' verbal reasoning were integrated to support learning.

Brian worked consistently to develop a supportive inquiry ethos in his class, eliciting and expecting ongoing inquisitive responses. He modelled his own enthusiasm for scientific meaning-seeking processes and would ask students for evidence of patterns, gently challenge their assertions, ask for other explanations, and encourage students' speculation. When students checked claims, Brian tended to elicit students' collaborative or imaginative responses. Student collaboration was evident when he prioritized evidence-checking. In a follow-up interview, he claimed various gains from this approach. He felt the students were more engaged and that their learning improved:

I got a lot out of it [teaching this way]. I gained more in terms of questioning and listening carefully to what they were saying and learning. There was more this year of students saying "If we do this then what does that mean … ? There were more 'why' questions. There were more "what if" questions. It helped students when they listened to each other".

He claimed to trial new strategies, such as asking students to list three things they knew about a number of elements. He believed that compared to other classes, "there was (sic) more students at the higher level, and they were more insightful, on track and had more complex responses". He noted that there was more detail in the drawings and that they all knew how to draw electron shells. He claimed that "being asked to reason frustrated some kids. It was confronting for some to start with. The emphasis on reasoning pushed them to think more about the topic". Some students expected the teacher to resolve student questions on the spot and found the lack of an immediate response frustrating, especially if they had to wait for a subsequent class. He claimed that at first, students were not able to articulate reasons or justifications, but that by the end of the topic, they could explain and justify their thinking. "Even if their justification was wrong, this allowed me to address their understanding". Brian viewed teaching as necessitating careful planning, where each activity, set of questions, discussions, served particular purposes for student conceptual understanding and that this understanding needed to be tracked closely. However, he also recognized that he had to be adaptive to unplanned learning opportunities. For him, learning involved mutual student and teacher understanding and student–student dialogue, where the teacher facilitated reasoning whereby students meaningfully linked their background experiences, practical demonstrations, and their evidence-based claims.

7.5.2 Teacher LRKCT

This brief account of a lesson segment highlighted how an experienced teacher integrated different forms of language-based knowledge to support student learning. His specialist topic knowledge, his understanding of how to set up productive ways for students to practise transductive meaning-making through workable practical experimentation and interpretation, and his follow-up guided discussion, all contributed to this outcome. The experimental task and the simple resources to engage with it were well-chosen to match the students' capabilities and the potential for guided learning, leading to what his students saw as meaningful clarification. This account of how the teacher integrated his language-based knowledge also points to the need for teachers in general to be creative, as well as their students, in how they enact this pedagogy.

7.5.3 Case Study Two: Respiration in Year 11 Biology

In this topic, in what was a completely novel approach for the students, Andrew, a pseudonym for their teacher, had taught senior biology for over 15 years, focused on guiding them to construct an improvised model to represent their understanding of the process of cellular respiration (Nash et al., 2018). To achieve this, the students were expected to use a range of teacher-provided generic objects, such as coloured sweets, laminated diagrams of mitochondria, coloured plasticine, toothpicks, and coloured ice cream sticks. As with the previous case study example, the resources for this improvisation (and their simplicity) were chosen to encourage the students to abstract their understanding and reason about key elements and their relationships, rather than focus on, or be distracted by, the properties of the objects. This process broadly matches stage two in RCA. The students were expected to practise model-based reasoning, based on partial topic knowledge. After presenting a brief introductory PowerPoint on key components of cellular respiration, (prescribed content as part of the Year 11 biology curriculum), the teacher challenged the class to work in groups to represent their model.

Research in this case study took the form of a mixed methods approach. The types of data collected included classroom observations, interviews with the teacher and six students, records of student work, and student scores on tests and examinations. Informed consent was obtained from the participant teacher and students. The analysis of representations was guided by Gilbert and Treagust's (2009) analysis of chemistry representations. Four categories of macro-, micro-, submicro-, and symbolic were used to determine the level of student understanding of respiration.

During the construction process, the teacher circulated around groups to provide assistance when required, answered questions, and prompted students to consider omissions and inconsistencies in their emerging and speculative representations. When complete, each group's representation was recorded on a video or on poster paper. Selected groups then explained their reasoning in their representations to the class. During this discussion, the teacher asked further questions about whether each group's representation was clear, coherent, and captured everything relevant to the topic, with invited supportive peer feedback. The students were then required to complete an individual written summary sheet of what they had learnt as a personal learning record of what was learnt from their own and other group representations.

Students responded in a variety of ways to this challenge, integrating 3D objects with 2D formats. Most representations integrated chemical symbols for atoms and molecules, arrows for the steps in the process, numerals for the numbers of molecules and atoms, and written text for labels. At the macro-level, the teacher considered students' use of words to name chemical inputs and outputs and energy produced. The micro-level considered students' use of words, diagrams, or laminated pictures of cell structures (cytosol, mitochondria, cristae, and matrix). The submicro-level entailed interpretation of students' use of plasticine models of molecular and atomic components of water, carbon dioxide, glucose, and oxygen, and the symbolic level focused on students' use of symbols such as CO_2, O_2, H_2O, C_6H_{12}, O_6, and ATP, and chemical equations, and the plus sign. Analyses of the students' work demonstrated different levels of entry and emerging knowledge. Groups with a more advanced understanding of respiration included all macro-, micro-, submicro-, and symbolic elements in their representations. Groups with a simplistic understanding of respiration represented the process at a macro-level only. Subsequent analyses of pre- and post-test learning outcomes between this class and a comparable control group, who were taught in a more traditional manner, indicated stronger learning gains for the experimental group (Nash et al., 2018). Analysis of a four-student focus-group interview also indicated identified learning gains. The students perceived this structured creative activity as enjoyable and that "having some control over their own learning was also a gain". The students appreciated the opportunity to think for themselves and Anne commented, "It made us think more". To make their own sense of the concepts rather than passively sit at a desk listening to the teacher, or copying notes from a board, was important for students. This view is supported by another student, "I liked how you made it and you had a visual picture in your mind". The students saw that being able to visualize the process of respiration enhanced their ability to memorize the concept. Emma preferred the visual aspect of the structured creative activity and commented, "It was good to put it visually, instead of just words; to actually see it".

7.5.4 Teacher LRKCT

As with the first case study, to guide student learning effectively, Andrew needed deep subject knowledge about relevant chemistry concepts and processes and their integrated representation. He also needed to know how to support students in the transductive process in which they were expected to interpret and integrate meanings within and across the multiple levels of representation in chemistry. Tasking the students with creating an improvised model that required them to link 3D and 2D semiotic signs, and supporting their reasoning in this process, was one way to enable students to practise this necessary transductive meaning-making in science.

7.6 Conclusions and Implications

The RCA has demonstrated some success in engaging cohorts of students and promoting multi-modal reasoning and learning. However, this approach also raises a range of questions about (a) how LRKCT is conceptualized in relation to science learning, (b) teacher professional learning, and (c) future research in subject learning. While recognizing that vernacular, pedagogical, and disciplinary languages entail both the processes and outcomes of subject learning, there is less emphasis in the LRKCT model (see Seah et al., this volume) on the multi-modal nature of this learning. To learn to reason in science, students need to develop competence in using and integrating both linguistic and non-linguistic modes, including visual, mathematical, and embodied/actional modes, as shown in the two case studies. Perhaps, "disciplinary language" in the model needs to be pluralized to "languages" to recognize this fundamental aspect of science learning. While oral and written languages are crucial resources for learning, science learning is not reducible to a single mode. The concept of transduction provides a way to understand what is at stake in the learning to integrate modes, but mere naming of the challenge is only a starting point for what teachers should know and do to guide students to understand and practise this meaning-making. This raises the question of how teachers effectively acquire this knowledge, what learning tasks enable students to practise multi-modal reasoning, and how teachers should assess this reasoning formatively and in summative testing. The two case studies offer contingent examples of learning tasks and teacher support for this process, but no single practice can be a toolkit for covering all the requisite language knowledge and its application in student learning. Andrew and Brian participated in intensive and ongoing researcher support to focus on student reasoning in their classes, and past research with RCA indicates the need for such an approach with science teachers in general (Tytler et al., 2013).

More research is needed across different tasks, multiple science topics at different levels, and different cohorts of students to inform further clarification, uptake, and application of this teacher knowledge. Given the changing context of science learning within STEM programmes, and the use of new technologies to support this learning, assessing student progress in learning to reason within and across modes will need to draw on ongoing empirical studies. There is no easy solution to the question of how teachers acquire requisite conceptual and practical knowledge of how science is learnt, but analyses of teacher responses in enacting a RCA indicated that their participation deepened this knowledge (Hubber, 2013).

In this chapter, I have outlined one creative approach to how teachers can apply their knowledge of the languages of science to productive student meaning-making within and across the modes of these languages. I have also claimed that conceptualizing this process as transduction entails unpacking further what students do (or are expected to do) when they integrate or coordinate modes. The challenges and opportunities entailed in understanding and promoting student transduction of meanings in learning science need to be included in an emerging map of what teachers should know and do in relation to these languages.

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Part II
Studies in Social Science and TLA

Chapter 8
Beyond the Word Hunt: Teaching the Ways We Construe Causation in History Education

Jason C. Fitzgerald

Abstract In order to make sense of the world, social studies instruction focuses heavily on comprehending the past through the historical thinking process. This process engages students in analyzing a variety of texts by sourcing, contextualizing, and corroborating accounts. Central to this process is understanding what happened, when, and why. Thus, causation is a central concern of historical thinking. However, social studies teachers rarely teach cause–effect structures beyond the word hunt for causal signals (e.g., *because*, *so*, *thus*, etc.) even though causation is expressed in many different ways across texts commonly found in the classroom. History textbooks and primary source documents, for example, use other causal constructions as frequently if not more frequently than these causal signals. Drawing on a systemic functional linguistics perspective, this chapter uses the cases of three high-frequency causal constructions—cause circumstantial, causative, and causal asyndetic constructions—to illustrate the importance of teachers' disciplinary language knowledge to support instruction and students' knowledge about language to engage in sophisticated disciplinary reading and writing. This chapter also focuses on practical strategies that social studies teachers can employ to develop their students' disciplinary language knowledge using texts already in the mainstream classroom.

8.1 Introduction

Across geographic contexts, social studies teachers are engaging students in the types "of reading, investigating, analyzing, critiquing, writing, and reasoning required to learn and form complex knowledge in the history discipline…" (Bennett, 2011, p. 52). Students learn these skills by using a variety of sources across myriad genres from disparate eras. These sources add authentic complexity to the often-taught traditional historical narratives (Seixas, 1996). Their authenticity, however, requires

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students to have sophisticated disciplinary literacy skills to comprehend, synthesize, and compose texts historically.

Students' abilities to comprehend, synthesize, and compose texts are in large part related to their abilities to recognize, evaluate, and use features of text cohesion. *Cohesion* refers to "the connection that exists between elements in the text" (Renkema, 2004, p. 49). Text elements are realized via authors' lexical and grammatical choices. By determining the lexical and grammatical features of a text, readers are able to structure information into mental representations that integrate with their prior knowledge, leading to their comprehension of any given text (Kintsch, 1998). Specific to historical thinking, the better students are able to recognize the temporal and causal connections within a text, the better they are able to comprehend an author's meaning (Schleppegrell & Achugar, 2003).

Among the various ways that authors create text cohesion, the ways that authors construe causation are the most important for comprehending historical narratives (Trabasso & Broek, 1985). To aid students' recognition of cause–effect constructions, teachers often instruct their students to identify explicit cause–effect signals, typically conjunctions like *because* and *so* (Meyer & Poon, 2001). However, there are other more implicit forms of causal cohesion present across historical texts that are equally important for students' comprehension and historical thinking.

8.2 Beyond the Word Hunt

In the educational contexts of the USA (Ravitch, 2014) and many Westernized countries throughout the world (Sahlberg, 2011), high-stakes testing cultures value teaching discrete language skills. Such cultures produce language instruction that focuses on mastering sounds, words, and sentence construction decontextualized from authentic texts (Gebhard & Harman, 2011). This focus is contrary to the work of genre theorists (e.g., Rose & Martin, 2012), who argue that language is best taught through engagement with authentic texts (Barton et al., 2000).

Genre-based theories and pedagogies are based on social constructivism (Bernstein, 1996; Halliday, 1985; Vygotsky, 1978), recognizing the reciprocal interactions between texts, context, and discourse. These understandings of language argue that language is grounded in daily interaction and use, where language is functionally applied for communication purposes within varied communities (Rose & Martin, 2012). For the purposes of schooling, students' language resources are imported from home contexts and can be variously developed for more abstract disciplinary contexts through mediated apprenticeship (Lee, 1995). Encouraging and apprenticing students to engage authentic texts enables students to learn both texts' language and context, the parts and the whole, of the text in various levels of abstraction.

Systemic functional linguistics (SFL) has been operationalized to support students' comprehension and analysis of both the context (e.g., genre and register) and language (e.g., discourse, lexico-grammar, and expression) of texts (Rose & Martin, 2012). This work is based on Halliday's (1985) work, demonstrating that context and culture influence variations in texts through field, tenor, and mode. These situated variations provide teachers with a framework to apprentice students' analysis of text, developing their authentic language proficiencies across registers, known as the teaching–learning cycle (Gibbons, 2002).

8.3 SFL in the Classroom

Due to its focus on authentic language, SFL has proven useful for classroom instruction (e.g., Berg & Huang, 2015; Brisk & Zisselsberger, 2011). A hurdle to such implementation in the USA, however, has been a lack of teacher language awareness (Lindahl, 2019). Beginning in teacher preparation programs, a heavy focus on literacy strategies but not language awareness leads to professional learning gaps around issues of language instruction (Lucas et al., 2008). While teaching SFL-based pedagogies does increase pre-service teachers' language awareness skills, it is not always successful at reducing feelings of inadequacy about language instruction (Swierzbin & Reimer, 2019).

Genre-based teacher preparation programs for in-service teachers fare better for supporting teachers' language awareness. For example, Mary Schleppegrell and her colleagues began the California History Project to support English as a Second Language (ESL) teachers' use of SFL pedagogies (Schleppegrell et al., 2004). This work mirrored some of the efforts from the Sydney School's *Write It Right* project (Rose & Martin, 2012).

From the context of SFL-based pedagogies in the Sydney School, Coffin's (2004, 2006) work has focused on how students express, among other things, causation in their social studies writing. Coffin examined student work samples through a functional linguistic perspective. Important to this study, her functional linguistic methodology distanced her work on causation from many linguists who have taken a more psycholinguistic approach to the topic (i.e., Tapiero et al., 2002). A functionalist approach allowed for a specific focus on the instructional implications of her work.

8.4 Teaching Causation in US History Classes

When students are taught to identify a text's causal relationships by locating cause-and-effect signals, they are more successful in comprehending texts than when they do not have such instruction (Meyer & Poon, 2001). These signals are explicit words and phrases that alert readers to the cause-and-effect connections that are important for comprehending the passage (e.g., *because*, *so*, *thus*, and *as a result*). Identification strategies, which train students to add importance to words and phrases that signal causation (e.g., as a result, because, since, etc.), have been developed to help students recognize these signals and interpret the relationships they create. Researchers have found that when elementary, secondary, and post-secondary students are taught to use these strategies, they recall more information and explain relationships within expository passages better than students without such instruction (Williams et al., 2007).

However, such signal words (conjunctive elements) are only one way that authors create causal cohesion (Coffin, 2006). History textbook authors, for example, use non-conjunctive forms of cohesion to make causal connections more often than conjunctive forms (Fitzgerald, 2014). Only 23% of the causal connections identified across a sample of middle and high school American History textbooks were constructed using conjunctive elements. In order for students to deepen their disciplinary reading, they need to be able to recognize these other, non-conjunctive structures that comprise approximately 77% of the remaining causal connections. While textbooks contain more causal constructions than commonly used historical primary source documents, similar types of constructions are used across both text sets (Fitzgerald, 2019). Whether reading primarily from textbooks or primary source documents, students cannot expect to identify all of the cause-and-effect relationships in a text by looking for *because* and *so*; they need to go beyond the word hunt.

8.5 Non-conjunctive Forms of Causal Cohesion

Across sample historical sources, non-conjunctive causal cohesion comes in three main forms: (1) cause circumstantial, (2) causative, and (3) causal asyndetic constructions. Examples of these constructions can be found in the two passages below, both from a popular middle school US history textbook (Davidson & Castillo, 2000). Portions of these passages will be highlighted in the rest of the chapter, illustrating these three main forms of non-conjunctive causation.

1. Example Text 1 "Expecting the war to break out soon, the British government called a meeting of colonial leaders. It took place in Albany, New York. The British wanted the colonies to agree to cooperate in defending themselves against the French. The British also invited the Iroquois tribes to the meeting. They hoped to form an alliance with the Iroquois against the French" (Davidson & Castillo, 2000, p. 141).

2. Example Text 2 On the American side, Washington at first refused to accept African-American soldiers. But the British offer of freedom to enslaved people made Washington change his policy. By the end of the war, some 7000 African-Americans had served on the American side, including 2000 in the navy. African-Americans also served in northern militias and state armies. Most southern states, however, refused to accept African-American soldiers. Slave owners feared armed slave revolts" (Davidson & Castillo, 2000, p. 187).

8.6 Cause Circumstantial Constructions

Authors use circumstantial constructions to convey a variety of information, including time, place, manner, and reason. We see this in Example Text 1: "Expecting the war to break out soon, the British government called a meeting of colonial leaders" (Davidson & Castillo, 2000, p. 141). While not all circumstantial elements are causal, in the first sentence of the first passage, the authors employ circumstantial phrases to explain the reasoning behind events. In this example, we know that "the British government called a meeting of colonial leaders" *because* they expected "the war to break out soon."

Cause circumstantial constructions can be challenging for struggling readers for two reasons. First, they condense the text, expressing more than one idea in a sentence. Condensing ideas means that students have to unpack two or more ideas per sentence, keeping track of who did what and why (Schleppegrell, 2004). For struggling readers, keeping track of such information throughout the whole of the text can slow reading fluency and inhibit comprehension.

Second, writers who use cause circumstantial constructions often assume that a reader has knowledge about an event that he/she may not. Cause circumstantial constructions allow authors to set a specific circumstance as a "point of departure" for the sentence, as in the example above. For students who are struggling to identify the subject of the sentence in order to sustain a narrative's coherence, circumstantial departures can make texts confusing. In the sentence from Example Text 1 above, the subject of the sentence, "the British government," does not appear until the eighth word in the sentence. This construction can be especially daunting for students reading history texts where "the British government," "the king," and "George III" can be used synonymously. Keeping track of synonymous "historical agents" that are sometimes buried within the structure of a sentence takes a considerable amount of working memory. Readers who struggle with fluency can quickly become lost among the words (Nokes, 2011).

Teachers can help students to identify, understand, and evaluate circumstantial elements by making the purpose of circumstantial elements explicit. After highlighting prepositional phrases and dependent clauses, students can determine whether each circumstance is being used for the purpose of relating (1) time, (2) place, (3) manner (e.g., how something is done), or (4) reason. Requiring students to slow their reading pace to identify these important cohesive elements enables struggling readers to understand the gist of the text's structure, improving reading comprehension (Chambliss, 1995).

Table 8.1 provides examples of each purpose taken from primary source documents and a sample textbook. By using these labels for circumstantial elements (i.e., time, place, manner, and reason), students can begin to better understand the ways in which an author ties together the text and interrogate the plausibility of such connections. Some circumstantial elements (such as time and place) lead more often than others to *temporal* circumstantial elements whereas others, such as manner and reason, often *cause* circumstantial elements.

For example, after identifying the first Reason cause circumstantial element in Table 8.1 as *cause circumstantial*, a teacher might lead students to question whether or not the writs of assistance were (1) employed to stop colonial smuggling or (2) for other purposes like intimidating rabble-rousers, as James Otis suggested. Maybe they were used for both purposes. In either case, identifying the cause circumstantial construction enables teachers to apprentice students in the critical evaluation of historical claims, deepening historical reading practices.

Table 8.1 Examples of circumstantial constructions in history texts

Circumstance	Example
Time/Duration	"**By the middle of the 1700s**, France and Britain each controlled large areas of North America…" (Davidson & Castillo, 2000, p. 140) "[O]ne morning all on a Sudden, **about 8 or 9 o'clock** there came a messenger…" (Cole, 1740)
Place/Location	"Quebec, the capital of New France, was located on a high cliff, **overlooking the St. Lawrence River**" (Davidson & Castillo, 2000, p. 143) "**Being among the hindmost in market-street**, I had the curiosity to learn how far he could be heard…" (Franklin, 1793)
Manner (How?)	"**By defeating France**, Britain solved one problem" (Davidson & Castillo, 2000, p. 145) "At 2 o'clock we began our march **by wading through a very long ford up to our middles**" (Barker, 1775)
Reason (Why?)	"**To help customs officers find illegal goods**, they were allow to use writs of assistance…" (Davidson & Castillo, 2000, p. 148) "**Viewing you in this Light…** I desire you not to preach in this parish…" (Henchman, 1745)

8.7 Causatives

A slightly less challenging construction involves the use of causatives, verbs that indicate that an Agent compels an Actor to carry out an action, to indicate cause–effect. From Example Text 2: "But the British offer of freedom to enslaved people made Washington change his policy" (Davidson & Castillo, 2000, p. 184). In this example, Washington is the Actor but not the Agent/Initiator. Rather, the author notes that it was "the British offer of freedom to enslaved people" that "made" (the causative verb) "Washington change his policy." The causative verb *made* indicates the reason for Washington's decision. Similar verbs like *forced*, *compelled*, *ordered*, and *help* also enable Agents to cause Actors to do something.

While the causal purpose of causatives is not terribly difficult for readers to deduce, the types of Agents and Actors to which history texts ascribe agentive power can limit the struggling students' abilities to comprehend cause–effect relationships in a text. In the example above, the Agent of the sentence is "the British offer of freedom to enslaved people"—a non-human initiator. In order for a reader to understand how such an offer could cause Washington to take action, the reader must understand the context of the American Revolution, the context of slavery in all of the thirteen colonies, and the decisions that both enslaved African-Americans and white colonists were making in response to the offer. All three of these contexts (and maybe more) are wrapped up in one's understanding of this noun phrase. Unlike human Agents, non-human Agents expressed in dense noun phrases can inhibit the reader's ability to explain the otherwise simple causal relationship expressed in the sentence (Beck et al., 1989).

Teachers can help students analyze such constructions by explaining the purpose of the causative verbs and asking them to identify such verbs throughout a given text. Then, teachers can instruct students to identify who the Agents, Actors, and Goals ("things being acted upon") are in each sentence as in the sentence from Example Text 2:

But the British offer of freedom to enslaved people	Made	Washington	Change	His policy
Agent	Causative verb	Actor	Verb	Goal

8.8 Causal Asyndetic Construction (CACs)

Example Text 3 "The British also invited the Iroquois tribes to the meeting. They hoped to form an alliance with the Iroquois against the French" (Davidson & Castillo, 2000, p. 141).

Unlike the use of cause circumstantial and causative constructions, which both construct causal relationships within sentences, causal asyndetic constructions (CACs) express causation between sentences without the use of cause–effect signal words. These constructions use the contexts of two, side-by-side sentences to imply a causal relationship. Such relationships are constructed via verb choices that are non-causative. Instead, the verbs that authors use to create CACs are (1) Mental, (2) Verbal, (3) Relational, or (4) include Modals (e.g., *could*, *would*, *might*, etc.).

Together, the two sentences in Example Text 3 imply that the British hope of forming an alliance caused them to invite the Iroquois to the meeting. The verb *to hope* is a type of verb that suggests an actor's mental action, one of desire. That hope creates a circumstance by which the actor, in this case *the British*, is enabled, encouraged, or compelled to act. To be sure, *to hope* is non-causative; rather, the use of this single verb creates a circumstance (a bit like a cause circumstantial construction) that implies a causal relationship between two sentences.

Teachers can support their students' understanding of these implied causal relationships by helping students identify specific verbs (See examples in Table 8.2) that typically construe CAC relationships (Fitzgerald, 2014). While it is important to note that authors can use these verbs without creating CACs, the presence of such verbs provides a potential for CAC construction. So as not to be overwhelming, identifying such features as CACs can be used to lead students in discussions about how causation is represented, not to add additional content to already over-stretched curriculum and lesson plans. Given the variety of causal constructions, engaging in such discussions only as they serve students' comprehension and address the learning demands of the instructional texts is important not to overburden the class. Intentional selection and inclusion of these discussions are important.

Table 8.2 CAC verb types and examples

Verb type	Examples
Mental	
• Cognition	*Decide, know, think*
• Emotion	*Feared, liked, loved, felt*
• Desideration	*Want, hope*
• Perception	*Saw, heard, felt*
Verbal	*Said, ordered*
Relational	*Is, was*
Modals	*Could, should, would, might*

8.9 Causal Language, Not Just Signal Words

In order for students to understand history and learn how to construct histories in complex ways, they need to be able to engage texts critically. Doing so requires that they are able to comprehend and craft complex texts that express ideas in shades of meaning. Modeling the dominant ways that cause and effect is construed in historical sources and writing is a step toward this goal. The better students are able to identify and explain the cause–effect relationships in a text, the better their text comprehension will be. To provide such modeling, social studies teachers need to shift their own language, discussing causal language with their students, not just signal words.

Doing so can foster deeper historical thinking in the social studies classroom. By exploring historical cause via traditional signal words as well as cause circumstantial, causative, and causal asyndetic constructions, students can discuss (1) what can be said about the claims of a text, (2) what counts as evidence for historical claims (e.g., evaluating a figure's feelings), and (3) how an author can frame cause/effect relationships with varying degrees of certainty. By thinking deeply about causal language, not simply looking for signal words, students' historical reading and writing abilities can be more precise and their historical thinking can improve.

8.10 Classroom Applications

Unfortunately, content areas teachers in the USA have historically lacked opportunities to learn such disciplinary linguistic knowledge (DLK) (Zwiers, 2008). Whereas much of the focus on DLK in the USA has been on supporting English Language Learners (Turkan et al., 2014) and not on supporting general education students in the content areas, general education teachers have received extensive training in literacy strategies (e.g., brainstorming, turn-and-talk, Know-Wonder-Learn charts, etc.) not DLK (Gebhard & Harman, 2011). The strong literacy-based educational focus in the USA often drowns out calls for a more expansive grammar education, similar to the Australian grammar wars (Christie, 2010). Without a more expansive grammar education, students' knowledge about language (KAL) (Andrews & Lin, 2017) remains underdeveloped, making engagement with novel and complex texts (i.e., many of the texts used in history education) more difficult.

The edTPA, a summative performance assessment of teacher candidates' planning, implementation, and assessment of instruction commonly used in the USA (Fitzgerald & Schpakow, 2021), has begun to change this situation. In part, the edTPA specifically assesses teacher candidates' abilities to recognize and teach language demands related to vocabulary, syntax, and discourse. This requirement forces preservice teachers to consider content-specific DLK on which to make instructional decisions regarding text selection, guided support, and assessment evaluation.

Before K-12 students can expand their knowledge about language (KAL) (Andrews & Lin, 2017), social studies teachers need to be able to recognize causal processes in texts that extend beyond the word hunt. Identifying these processes requires teachers to pre-read their instructional texts not just for content but for the text's language demands. In doing so, creating graphic organizers tailored to the causal syntax of the text would enable students to more readily see the connections between ideas and implicitly train them to recognize the various causal structures discussed in this chapter.

It is important to note here that instructional explanations, the verbal descriptions that teachers provide as part of their instruction (Leinhardt, 1997, 2001), are language from which students build their knowledge about language (KAL). In addition to providing structured ways for students to use and organize printed text materials, teachers' language should also mirror the processes of the texts. In one study, a high school social studies teacher frequently replaced causal processes with temporal connectors (e.g., replacing "caused" with "and then") (Fitzgerald, 2011). These changes reduced the high school students' abilities to make causal connections in their own writing. The ways in which teachers intentionally and unintentionally model disciplinary language impact students' knowledge about language (Frances Christie & Maton, 2011; Martin et al., 2010; Maton et al., 2017).

However, K-12 students' KAL cannot be left to chance on implicit reception of language knowledge. For example, in a study on causal asyndetic constructions, strong readers were able to identify the causal relationships between the two clauses but could not explain how they knew those relationships existed; poor readers did not recognize the causal relationship between sentences at all (Fitzgerald, 2012). Even when readers are able to deduce the meaning and relationship of clauses, they are not always able to explain those relationships in a way that builds their knowledge about language. Here, Mary Schleppegrell and her colleagues (Achugar & Schleppegrell, 2005; Fang & Schleppegrell, 2010; Schleppegrell & Achugar, 2003; Schleppegrell et al., 2004) argue that teachers should lead their students in language analyses of various verbs (identifying "action verbs," "thinking/feeling/saying verbs," and "relating verbs"), identifying actors, actions, and receivers of action, and identifying participants, thinking/feeling/saying verbs/ and messages in texts (See examples in Appendix). These explicit ways of modeling how language works apprentices them to understand the working of disciplinary language (Rose & Martin, 2012).

8.11 Conclusion

Since causation is one of the most important features of historical writing (Coffin, 2006) and the most important for comprehending historical texts (Trabasso & Broek, 1985), teachers need to not only become familiar with the ways it is represented in text but also explicitly support students' knowledge of these constructions. Providing students with the tools and the instructional apprenticeship to recognize and craft these constructions can help students become better disciplinary readers and writers. From cause circumstantial to causative and causal asyndetic constructions, there are a variety of causal constructions in history textbooks. Developing teachers' disciplinary language knowledge and students' knowledge about language related to causal constructions move everyone beyond the word hunt.

Appendix: Examples of Language Analysis for History Textbooks

Analyzing Verbs

Action verbs (events)	Thinking/feeling/saying verbs (opinion or citing)	Relating verbs (giving background/defining)
• Arrive	• Yelled	• Known
• Fill	• Jeered	• Became
• Hire	• Called	• Should be
• Grow	• Replied	
• Fire		

Identifying Actors and Actions

Agent	Action	Receiver of action
Soldiers	Hire…out	Themselves
Soldiers	Fire	[Youths?]
[Soldiers]	Kill	Attucks and four laborers
Attucks and four others	Gave	Their lives
[People]	Arrested	Redcoats
John Adams	Defends	Redcoats

Identifying Participant Messages

Participant	Thinking/saying/feeling verb	Message
Soldiers and street youths	Yelled	Insults at each other
The youths	Would yell	"Lobsters for sale!", referring to the soldiers' red coats
The soldiers	Jeered	"Yankees!". [see next sentence]
They [sons of liberty?]	Said	That attucks and the four others had given their lives for freedom

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Chapter 9
The Language of Historical Thinking Read-Alouds

Melissa Wrenn and Julie Stanley

Abstract This action research study investigates how pre-service teachers implemented a historical thinking read-aloud lesson in their elementary practicum classrooms. Data sources included 19 sets of pre-service teachers' lesson plans, transcripts from videos of teaching, and reflections. Data were collected from three groups of pre-service teachers across two semesters. Using qualitative analysis methods, the researchers determined key differences between pre-service teachers across two semesters. Pre-service teachers in the second semester showed more compliance between the lesson plan and their teaching. Most notably, pedagogical and dialogic language knowledge scaffolded the pre-service teachers' critical practice in the teaching of the historical thinking read-aloud lessons. The researchers situate the findings within an action research context by explaining the instructional practices they associate with these different outcomes in how the pre-service teachers learned and demonstrated their language knowledge, as they followed their instructional practices across two semesters with three groups of students.

9.1 The Language of Historical Thinking Read-Alouds

Language is understood as a social construct; thus, understandings of language are conflated by social purposes (Kress, 2005), power (Nieto, 2002), and identity (Gee, 2004). From a functional position, language can be both expressed and received in a variety of settings and for a variety of purposes (Halliday, 1977, 1978). When linguistic exchanges happen in classrooms, students need proficiency across several

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academic registers, which requires teachers to be adept at making complex linguistic processes transparent (Schleppegrell, 2012). In this chapter, we explore the confluence of these aspects of language as part of an exploration of pre-service teachers' (PST) historical thinking read-aloud (HTRA) lessons, which is part of a larger action research investigation into strategies to support PSTs' planning and teaching of academic language (AL) in elementary social studies. Currently, little research exists to support PSTs in the teaching and planning of AL for elementary social studies, and this study offers important insights into how PSTs plan for and enact academic discourse through HTRA lessons. We begin this chapter by exploring existing literature on the nexus of language and read-alouds. Then, we present our research methods including a three-phase analysis process, followed by the findings and related discussion. Finally, we share concluding thoughts and implications for supporting PSTs in the planning and teaching of HTRAs.

9.2 Review of the Literature

9.2.1 Role of Language

Social interactions and interpersonal skills have a reciprocal relationship (Vygotsky, 1978), as anyone who has observed how children learn can attest. In a classic illustration, Halliday's (1977) influential work on systemic functional linguistics was informed by his observations of his son, Nigel, whom he watched linguistically explore the small world of his living room. Halliday (1977, 1978) describes semantic pathways along which individuals make contextualized decisions that inform their linguistic transactions. These linguistic choices are also present in academic settings, though children need support when engaging with academic registers that require knowledge about language (Schleppegrell, 2012) and the language of teaching and learning (see Fillmore & Snow, 2000). For example, considerations of young children's discursive interactions were documented via case study research in a preschool classroom with Haitian American children by Ballenger (1999) who observed children's energetic interactions with text and the world around them and used these interactions as opportunities to build their language knowledge. We posit Ballenger's knowledge of her students, knowledge of the role of language, and knowledge of language informed her instructional decisions and served as a model for elevating all three components in practice.

Importantly, how teachers manage interactions around language can either support or hinder learning, and having language knowledge as a teacher means that one values the linguistic diversity and perspectives of all students (Nieto, 2002). While Nieto's (2002) work was related to English learners and the subtractive practices associated with deficit thinking, her philosophy set the stage for critical pedagogy around language/literacy.

Pedagogical language knowledge and dialogic language knowledge can work in tandem to support teachers' abilities to develop and maintain strong classroom discourse. Bunch (2013) synthesized existing research on pedagogical language knowledge. While his research focused primarily on teachers of English learners, he posited that "the pedagogical *language* knowledge of mainstream teachers can be construed as knowledge of language *directly related to disciplinary teaching and learning and situated in the particular (and multiple) contexts in which teaching and learning take place*" (p. 307; italics in original). Dialogic language knowledge reflects an understanding that classroom discourse can operate along a continuum from monologic to dialogic talk, which dialogic representing student-centered and student-driven conversations (see Alexander, 2006; Reznitskaya, 2012). Our primary purpose was to find strategies to support PSTs' planning and teaching of academic language (see Wrenn & Stanley, 2022), and as such, developing their pedagogical language knowledge and dialogic language knowledge through these lenses was fundamental to this action research study.

Through this process of working to find strategies to support our PSTs, it became very clear to as part of the action research process that there were differences between students from the first semester (i.e., Groups 1 and 2) and the second semester (i.e., Group 3). In particular, earlier analysis demonstrated that Group 3's HTRA lessons were markedly more aligned with critical talk moves (Schieble et al. 2020). Although Schieble et al. (2020) focused on critical conversations in middle school English Language Arts (ELA) classrooms, we maintain that the families of critical talk moves, including inquiry, disruptive, and inclusive talk moves (Schieble et al., 2020) are inherently embedded in the function of the HTRA with social studies teaching. Thus, applying critical talk moves through data analysis became of high interest as we parsed out what strategies were best supporting our PSTs with academic language associated with their teaching of the social studies read-alouds.

9.2.2 Historical Thinking Read-Alouds

Historical thinking read-aloud (HTRAs) lessons are planned around historical thinking concepts (Krutka & Bauml, 2018). Types of historical thinking include historical significance, historical perspectives, cause and consequence, continuity and change, primary sources, and ethical dimensions (Center for the Study of Historical Consciousness, 2014). Additionally, HTRAs integrate disciplinary literacy and literacy skills into one lesson plan. At its most basic level, disciplinary literacy refers to "literacy skills specialized to history, science, mathematics, literature, or other subject matter," (Shanahan & Shanahan, 2008, p. 44), yet it should also be inquiry-driven and socially oriented (Moje, 2008). Moje's (2015) explanation of disciplinary literacy includes a strong social-cultural connection.

Over the past decade, scholars have steadily been progressing toward a new construct—critical disciplinary literacy (CDL). CDL refers to the practice of unpacking dynamics of power and culture within disciplinary settings (Dyches, 2018). Understandings of CDL informed the analysis of our data, but our PSTs planned their HTRA with a disciplinary literacy focus. We wanted our PSTs to teach against single stories and shed light on critical narratives (e.g., Tschida et al., 2014) juxtaposed with historical thinking (Wineburg, 2001). However, it was through the analysis process that we began to see patterns associated with CDL emerge over time. Research on expanding the HTRA into a uniquely CDL lesson plan exists (Wrenn & Gallagher, 2021); however, at the time of this action research study, our primary goal was to support our PSTs in the development of an HTRA lesson that was designed to foster academic discourse among their elementary students.

9.2.3 Read-Alouds

Teachers conduct read-alouds in a variety of contexts, and they have been widely recognized as an effective practice in literacy classrooms (National Institute of Child Health & Human Development, 2000). An effective read-aloud involves a teacher reading a book to a group of elementary students and engaging them in conversations before, during, and after reading (e.g., Barrentine, 1996). Importantly, older elementary students benefit from read-alouds. For example, in a year-long study of a literacy–curriculum program, Walpole et al. (2017) found that read-alouds were associated with gains in fluency and comprehension for third and fifth-grade students. Not only are read-alouds an effective strategy to support comprehension, but also, this strategy may also increase exposure to content knowledge. For example, upper elementary teachers may rely upon read-alouds for integrating ELA and social studies (Brugar & Whitlock, 2019). Brugar and Whitlock (2019) interviewed eight fifth-grade teachers and concluded that seven of them used read-alouds as part of their regular instruction, and four of the teachers believed historical fiction was also an important part of integrating ELA and social studies. While these studies did not focus on HTRAs, they do suggest read-alouds are an important part of elementary students' learning across the curriculum.

9.2.4 Texts for HTRAs

With the implementation of the Common Core State Standards (Common Core State Standards Initiative, 2010), most states in the USA began to emphasize more informational text in elementary classrooms. While 80–90% of elementary teachers depend on basal readers and other commercially packaged materials for their reading curricula, the more rigorous Common Core State Standards necessitate supplemental informational texts to meet the goal of 50% exposure to the informational genre (Braker-Walters, 2014). However, this transition is challenging because young students traditionally receive little instructional reading time devoted to informational texts (Duke, 2000). Duke's (2000) landmark study brought to light that her first-grade participants only received 3.6 min of exposure to informational text per day. According to Duke (2000), informational texts may include informational-narrative (i.e., information presented using plot), informational-poetic (i.e., information explained in poem form), and informational (e.g., biographies). In addition, we included historical fiction as an option for PSTs during the planning of their HTRA lesson because historical fiction can also develop historical thinking (Wineburg, 2001). In this study, PSTs used picture books in the form of informational-narrative, informational texts, or historical fiction for their HTRA lessons.

9.2.5 HTRAs and Research Trends

In this study, PSTs integrated ELA and social studies by aligning with a hybridity approach, which makes them "more likely to foster disciplinary literacy in equitable and lasting ways" (Hinchman & O'Brien, 2019, p. 526). This way of integrating acknowledges the discipline-specific way of thinking and fills a gap left by recent US literacy standards which do not fully address disciplinary ideologies (see Hinchman & O'Brien, 2019). It was our intent that the HTRAs would create a space for our PSTs to engage elementary students in conversations about a historical person or event through a pedagogical approach that equally privileged literacy and social studies. This merging of research and practice around literacy-based read-alouds and disciplinary thinking clearly aligns with the hybridity approach (Hinchman & O'Brien, 2019), which privileges the affordances of literacy and the given discipline.

Both the HTRA and research on hybridity are new areas of research, but we feel that in this case, history, namely historical thinking, was the discipline, and listening comprehension and discussion were the literacy skills. This study supports the current call for more research that demonstrates the juxtaposition of authentic disciplinary literacy and literacy practices (Hinchman & O'Brien, 2019). We were guided by the question: How does pre-service teachers' knowledge of the role of language influence historical thinking read-aloud lessons?

9.3 Methods

In this study, we investigated the HTRAs of elementary education undergraduate students. This research was part of a larger action research study designed to investigate PSTs' academic discourse practices and the strategies that support them (see Wrenn & Stanley, 2022). In the following sections, we describe each aspect of the methods beginning with the research context and ending with an in-depth explanation of the analysis process.

9.3.1 Context

This study took place at a large, regional university in the southeastern USA. The university is situated within a rural area that is classified as a high-poverty area and reflects many of the larger economic disparities in the southeastern USA. About 1,000 students are enrolled in its elementary education program. Research was conducted in the spring 2019 and fall 2019 semesters as part of a larger, collaborative action research study focused on investigating academic language practices and supportive strategies in elementary social studies instruction (see Wrenn & Stanley, 2022).

9.3.2 Participants

Altogether, 61 PSTs consented to participate in the larger study via a research process approved by the university's Institutional Review Board (UMCIRB 18-002,568). Due to attrition, 60 were included in the HTRA study. All the students were female and predominantly white. Notably, racial demographics were not collected from participants, but participants reflected the program's demographics and the larger racial disparity in elementary teacher preparation programs in the USA (King, 2018).

All participants were dually enrolled in social studies methods and a related practicum for grades 3–5. PSTs taught all the lessons they planned for their social studies, math, science, and reading courses within the practicum at local elementary schools. Students were placed in triads for planning and teaching, with some PSTs in dyads; groupings depended upon availability and space in the practicum setting. Within their assigned dyad or triad, PSTs co-planned the HTRA lesson, co-taught it in the practicum setting, and co-wrote one group reflection. Groups 1 and 2 received the same methods instruction; however, Group 1's cooperating teachers engaged in professional learning communities (PLC) with the researchers (i.e., university-based cooperating teachers, authors of this chapter) as part of the larger study. At the PLC meetings, classroom teachers and the researchers discussed topics and strategies related to AL. There was no difference in performance across the two groups as measured by classroom assignments and teaching of lessons as scored on a rubric (Wrenn & Stanley, 2020).

Group 1. In the spring semester of 2019, Melissa taught the social studies methods course, and Julie taught the related practicum to Group 1 ($n = 19$). PSTs were divided into three triads and five dyads and placed in third, fourth, fifth, and sixth grade classrooms. Groups 1 and 2 received identical classroom instruction about academic language.

Group 2. In the spring semester of 2019, Melissa taught the social studies methods course, and Julie taught the related practicum to Group 2 ($n = 20$). PSTs were divided into six triads and one dyad; all PSTs were placed in third-grade classrooms.

Group 3. In the fall semester of 2019, Melissa taught both the social studies methods course and the related practicum to Group 3 ($n = 21$). PSTs were divided into seven triads and placed into third-grade classrooms. Additionally, she adjusted instruction related to disciplinary literacy and academic discourse based upon the lessons learned through the first semester of the action research study. Notably, Group 3 participated in focused mini-lessons on academic language and more explicit guidance on discursive strategies than Groups 1 and 2.

9.3.3 Instructional Differences Across Semesters

In order to fully understand how pedagogical and dialogic language knowledge influenced the PSTs' practice, we must first explain their language learning experiences. These differences can be described in three main categories—modeling language, mini-lessons, and equity-oriented stance. In the following sections, we explain these differences to illustrate the pedagogical and dialogic language knowledge opportunities that Group 3 had as part of their coursework.

Modeling Language. One example of the differences between the first semester and second semester of the study was how Melissa modeled the HTRA in class. Melissa used the RAND model of comprehension (Snow, 2002) both semesters to help PSTs conceptualize the sociocultural influence of comprehension. While she modeled in both semesters, with Group 3 she explained the rationale for this lesson by connecting it to their knowledge about expressive and receptive language. Additionally, with Group 3 Melissa more clearly articulated that it was the goal of the HTRA to capitalize on what they knew about students and language to identify questions designed to engage elementary students and build a bridge between where the children were developmentally and where the PSTs wanted to push them in terms of historical thinking.

Mini-Lessons. Another difference was the implementation of academic language mini-lessons for Group 3. While focused instruction on academic language demands occurred with Groups 1 and 2, Group 3 received more comprehensive instruction. For example, Group 3's mini-lessons involved activities like identifying examples and non-examples of revoicing (O'Connor & Michaels, 1993) or examining a variety of language functions, then creating a chart to illustrate how language functions and social studies standards aligned. While Melissa asked Groups 1 and 2 to identify the academic language demands in the standards, they did not create charts that required careful analysis. Finally, she did not make the discursive connection by having a class discussion around their findings, as she did with Group 3. Additionally, Group 3 PSTs received explicit instruction on academic registers (Schleppegrell, 2012) and applications for social studies lessons. Thus, PSTs in Group 3 had been taught more pedagogical language knowledge than Groups 1 and 2.

Equity-oriented stance. Simultaneously, Melissa strengthened her position on equity literacy (Gorski & Swalwell, 2015) and worked to articulate more clearly the role of critical narratives in social studies education. For example, in both semesters, she taught Socratic seminar and debate as ways to engage elementary students in meaningful discussion. The two methods privilege dialogic talk; however, for Group

3, Melissa intentionally asked PSTs to consider classroom talk through an equity lens by aligning discourse with critical narratives (e.g., historical events from multiple perspectives). Another key difference regarding equity and language was in book selection across the two semesters. PSTs in Group 3 learned more about how to select texts that challenge dominant narratives (e.g., single-storied views of history) and how to align those texts with equity-oriented questions.

9.3.4 Data Sources

A lesson plan template used for this study was designed to elicit historical thinking among elementary students (Krutka & Bauml, 2018). We obtained the HTRA lesson plan template through a collaborative planning meeting between members of our academic department and Dr. Dan Krutka in the fall of 2018. The HTRA template (Krutka & Bauml, 2018) appealed to us because of its potential for supporting PSTs in leading discussions about text with elementary students. Also, being new to teaching social studies methods, Melissa found it useful for supporting PSTs in the teaching of historical thinking.

Data sources included lesson plans ($n = 19$), transcripts of videos from teaching ($n = 19$), and PSTs' self-reflections of their teaching ($n = 19$). Due to technical difficulties three sets of lessons plans and related data from Group 1 were excluded from this data set. Altogether, the HTRA teaching artifacts included 19 sets which consisted of the following: one lesson plan, one video, one transcript of video, and one self-reflection conducted as a group. Additionally, pre-assessments and post-assessments were conducted as part of the larger study. The pre-assessment results confirm that all PSTs, regardless of grouping, had similar understandings of academic language and social studies at the beginning of the course.

9.3.5 Data Analysis

Using Saldaña (2016) as a guide, Melissa conducted data analysis in a series of phases—pre coding, first cycle coding, second cycle coding; she was the lead researcher on the project and conducted the analysis for this study independently. Julie confirmed the analysis and participated in the writing of the results. In the following sections, we describe each phase in detail and provide supportive examples to ensure reliability and consistency (Merriam, 2009).

Pre-cycle Coding. During data collection, Melissa wrote researcher memos and reflections about instruction related to the HTRA lessons, and we discussed the PSTs' teaching of the lessons together. For the fall semester with Group 3 students, Melissa reflected on this process independently. Post hoc, Melissa read through the lesson plans, reflections, and transcripts for each dyad/triad. Through this process, Melissa wrote analytic memos through which she noticed that PSTs asked questions during their teaching that were not in their lesson plans; these observations informed the first cycle of coding (Saldaña, 2016).

First Cycle Coding. Melissa engaged in a two-step, first cycle coding process. First, she applied an approach similar to exploratory coding (Saldaña, 2016), as she compared the questions PSTs had written in their lesson plans to those that they asked to elementary students. Melissa manually coded the lesson plans and transcripts to determine which questions were approved during the planning process and which ones were added during teaching by PSTs. She also noted questions that were semantically similar to those planned but may have been syntactically different; she counted these as being approved during the lesson submission process. While coding, Melissa observed that PSTs' questions and comments which were outside of the lesson plan were not as open-ended and often less critical when compared to approved questions (see Table 9.1). One group's reflection said they were trying to teach the dominant narrative of Columbus because their elementary students "didn't know anything about him." This statement exemplifies the difficulty some PSTs had with teaching against single stories and becoming more critical (e.g., Tschida et al., 2014). At this point, Melissa engaged in a critical conversation with a knowledgeable colleague to determine if her data analysis was reliable and discussed appropriate coding options based upon the exploratory coding process (Merriam & Tisdell, 2016). Ultimately, she decided to conduct a more deductive analysis of the questions PSTs asked to reduce the impact of her own bias as the practitioner–researcher because she wanted the PSTs to perform better over time.

For the next part of first cycle coding, Melissa transferred all data in NVivo 12, a qualitative software program, and began structural coding (Saldaña, 2016). Then, she focused on the transcripts to further understand the nuances of PSTs' teaching of the HTRAs. Melissa coded each transcript using a priori codes based upon three families of critical talk moves, including inquiry, disruptive, and inclusive talk moves (Schieble et al., 2020) and counter-qualities that she determined based upon literature

Table 9.1 Excerpt showing questions planned compared to questions asked

Group	Title of children's book	Main questions planned	Main questions asked	Probing questions planned	Probing questions asked
1	I dissent: Ruth Bader Ginsburg makes her mark (Levy, 2016)	5	5	5	0
3	I dissent: Ruth Bader Ginsburg makes her mark (Levy, 2016)	6	6	6	5
3	I dissent: Ruth Bader Ginsburg makes her mark (Levy, 2016)	5	5	5	4

on discursive practices. Throughout this process, Melissa wrote analytic memos and conducted visual analysis (i.e., tree maps, word clouds) to look for emerging patterns. Data from this cycle is represented in Table 9.2.

PSTs showed evidence of different types of critical talk moves (Schieble et al., 2020); Schieble et al. (2020) list a fourth critical talk move, action talk moves, that was not included in the analysis process in this study. In addition to critical talk moves, Melissa noted that PSTs also practiced what she considered to be non-critical talk moves. Non-critical talk moves occurred when PSTs engaged students in conversation designed to elicit general knowledge, shared wrong information with

Table 9.2 Data examples of talk moves

Types of talk moves analyzed with associated sample data
Inquiry talk moves (Schieble et al., 2020) examples from data: • *Why do you think African American children were not able to receive the same education?* • *Ok so, what evidence shows that the Otis school and other businesses thought that the white race was the more superior race?* • *Why do you think that Ruth was the first Jewish woman to be on the Supreme Court?*
Disruptive talk moves (Schieble et al., 2020) Examples from data: • *Historically in the USA, African Americans were denied the right to vote. This is a real story about the challenges African Americans faced when trying to gain the right to vote* • *So that made a big difference in how women looked in the law with jobs and stuff. Normally, it is just a male role for them to study law and work in courts and as judges and things like that so she made a big move to actually go*
Inclusive talk moves (Schieble et al., 2020) Examples from data: • *So how do you think that made them feel? So I'm hearing you say you think they would feel sad* • *So, what do you think it would be like to attend this school that you and your community built together?*
General knowledge talk moves (researcher code) Examples from data: • *I am testing your knowledge, is an address absolute or relative location?* • *He mailed himself all the way up to Philadelphia Pennsylvania. I don't know if you all have ever been to Pennsylvania. It is a pretty long ride to Pennsylvania today. Back then, he had to take a train and then get on a boat. It was a long travel and actually took him 27 h in that box. They traveled over 350 miles*
Promoting wrong information (researcher code) Examples from data: • *So freedom means you can do what you want to as long as you are not breaking the law, right?* • *That was the first English child…that was part American Indian and part English*
Limiting talk moves (researcher code) Examples from data: • *Well, we are going to keep reading. I promise we will have a section at the end where you can say all of your comments* • *Did you want to say something? Very good. These are all good ideas*

Table 9.3 Attempting critical talk moves with example data

Attempting critical talk moves	Examples from data
Questions that appear to attempt to be critical, but do not help students unpack dominant ideologies	*Who can raise their hand and tell me something they learned about Harriet Tubman today that they didn't know before today? Ok, so he learned that she helped slaves escape. So you learned that she was a nurse who helped people get better.* *Why do you think that's unfair that he can't read and vote? Way back in the day black people were not always educated, so was that fair do you think? If no one taught them how to read, is that fair?*

their students, and enacted limiting talk moves that did not provide space for their students to participate in the conversation.

In addition to analyzing data for critical and non-critical talk moves, Melissa noted that PSTs often attempted to engage their students in critical talk moves, but they were not successful (see Table 9.3). We believe that identifying attempts helped us better understand how PSTs were implementing academic discourse during the HTRA lessons.

After coding all the data, Melissa double-coded them with the aid of a graduate assistant who played the role of critical partner. Together, they tested data against codes and compared samples from different categories to determine credibility (Merriam & Tisdell, 2016).

Second Cycle Coding. For second cycle coding, Melissa applied theoretical coding (Corbin & Strauss, 2008) to better understand how PSTs engaged in more critical and discursively productive HTRAs. She reviewed the data analysis from the first cycle to determine the core concept that "explains the total experience" (Corbin & Strauss, 2008, p. 265) and its associated multiple realities. Through this process, Melissa created a series of diagrams to support the progression toward a grounded theory. Finally, she shared the analysis and results with the same colleague who first served as her critical partner to ensure reliability.

9.3.6 Researcher Positioning

In qualitative methods the researcher is the tool for analysis which makes explaining researcher bias and positioning a crucial part of quality research (Merriam & Tisdell, 2016). We are white females from the southeastern USA. Much of Melissa's youth was spent as part of a military family, and her years spent living in various regions of the USA contributed to an inherent interest in how people engage in discourse in and out of school settings. Additionally, her doctoral program was in curriculum and instruction with a focus on literacy education, and social studies methods is a new area of instruction for her. Julie has worked in a range of schools and community settings (rural, suburban, and urban) and developed an interest in the power and use of language. Much of her interests are grounded in her lived experiences in rural poverty.

Recently, we have been purposefully working to enact an anti-racist approach (Kendi, 2019) and equity literacy (Gorski & Swalwell, 2015) into our professional practice. This work has generated a season of reflection for both of us, and we have built upon related developments in our own critical consciousness to implement immediate changes to discourse around text and disciplinary literacy in our courses. As a result, our developing understanding in these critical areas influenced how we positioned knowledge, equity, and discourse across the two semesters of this study. For Group 3, Melissa's new knowledge impacted aspects of the study such as which texts she approved for use in the read-alouds, the questions she approved in lesson plans, and the stronger connection to inquiry and advocacy over time. These developments are not limitations; rather, they offer important insights into how our values as the practitioner–researcher changed during this study.

9.3.7 Limitations

While this study adheres to the rigorous expectations of qualitative action research, some limitations do exist. First, we were both the professor and researcher of these courses, and participants could have perceived a power-imbalance because of the nature of our relationship. Also, because of our roles as action–researchers, we could have unknowingly biased the findings; we worked to combat this possibility by employing critical partners outside of the study throughout data collection and at each phase of analysis. Even with steps in place for triangulation and reliability, another scholar may have interpreted the data differently, and as such, this work is not generalizable to other settings and populations. Additionally, due to the qualitative nature of the study, these findings are not generalizable to other contexts and populations. Due to IRB limitations, only the PSTs' voices were allowed to be transcribed. Despite these limitations, the present study has much to offer the research and practice spaces devoted to the nexus of language and learning.

9.4 Findings

Through a rigorous analysis process, we sought the answer to the question: How does pre-service teachers' knowledge of the role of language influence HTRA lessons? We provide the answer to this question in two parts. First, we explain the overarching theory that emerged from data analysis—*Pedagogical and dialogic language knowledge scaffolded our PSTs' critical practice in HTRAs*. Then, we provide the key ways that PSTs demonstrated their language knowledge in the HTRA lessons to establish how the ways PSTs' learned language knowledge manifested itself into their teaching.

9.4.1 Learning Language Knowledge

The aim of this action research study was to understand how PSTs' knowledge of the role of language influenced the teaching of their HTRA lessons, and in this section, we present the overarching theory supported by our analysis—*Pedagogical and dialogic language knowledge scaffolded our PSTs' critical practice in teaching HTRAs.* Within the action research study, we closely evaluated our teaching practices and students' needs regarding discourse, and our instructional decisions became the route for PSTs to build capacity for language knowledge.

Given the nature of action research, our instructional methods influenced the study's outcomes. For example, as the primary researcher and methods professor of the course in which the lesson plans were created, Melissa made numerous changes in her instructional practices from the first semester with Groups 1 and 2 to the second semester with Group 3. The action research evidence supported what Melissa intuitively felt—she needed to improve her teaching of the "why" and the "how" of language use within social studies lessons. With that in mind, she approached the fall 2019 semester differently than the spring 2019, and Group 3 received more purposeful instruction regarding pedagogical language knowledge (see Bunch, 2013) and academically productive talk (e.g., O'Connor & Michaels, 2019).

To maintain rigor via action research, Melissa charted the action research cycles from Semester 1 to Semester 2 and documented how she taught the HTRA in her methods course during Semester 1, revisions she wanted to make in Semester 2, instructional adjustments that she actually implemented in Semester 2, comparative differences from Semester 1 to Semester 2, and suggested changes for future instruction. She also expanded her chart notations, as seen in the following excerpt from her researcher memos:

> I believe that the best way to do that at this point is to use the HTRA lesson. I made some major changes to the roll out of that in order to build the relationship between academic language and concept knowledge. This is based off of students' "need to know" from the exit ticket and what I am seeing in practicum… My plan is to be very purposeful by explaining the point of the lesson is to deepen students' ability to think historically thinking by facilitating a discussion around a picture book. I will connect this back to inquiry. (9/27/19)

Overall, we anticipated that PSTs who learned more about pedagogical practices to support meaningful conversations in social studies would have stronger teaching experiences in the practicum setting. Data analysis supports this hypothesis. For example, students in all three groups learned how to set expectations when beginning the HTRA, and the HTRA lesson is intended to support elementary students' knowledge in social studies. Therefore, it was not surprising that in all 19 of the HTRA lessons, PSTs included setting expectations for learning, and 16 of them supported their elementary students' general content knowledge. Also, for 12 of the HTRA lessons, PSTs used talk moves that align with inquiry talk moves to deepen their elementary students' thinking. We expected that some PSTs would not demonstrate proficiency in this area, as facilitating talk is a difficult skill to master.

We did not anticipate that Group 3 would show a marked increase in adhering to the lesson plan and trying elements associated with critical academic discourse. To illustrate, students in Group 3 were more likely to attempt an inquiry-based talk move. They also had a higher number of attempts at critical questions per lesson and were more likely to engage in inclusive talk moves such as asking their elementary students to imagine they were faced with the decisions of the historical figures in the selected texts. We argue that Group 3's increased knowledge of language, as evidenced through Melissa's improved academic language strategies in the second semester of the action research study, clearly corresponds with more critical discourse. Therefore, our overarching theory is *Pedagogical and dialogic language knowledge scaffolded our PSTs' critical practice in teaching HTRAs.*

9.4.2 Demonstrating Language Knowledge

We believe the most powerful way to understand how PSTs' language knowledge is through their planning and teaching of it. The data analysis process illustrated two main trends in how PSTs' knowledge of the role of language influenced their HTRA lessons. First, PST made mistakes in their teaching that affected the efficacy of their HTRA lessons. Second, PSTs engaged in specific instructional decisions that increased the critical discourse of their HTRA lessons. In the following sections, we will discuss each of these themes using rich, thick descriptions (Merriam, 2009).

9.4.3 Making Mistakes

Despite PSTs' careful planning, they made mistakes with content knowledge and also engaged in linguistic decisions that did not promote equity. Aligning language with content experiences is part of pedagogical language knowledge (Bunch, 2013). For example, Bunch (2013) explained that studies included for his analysis had to "be linked in some direct way to the texts, activities, or practices at the center of mainstream academic instruction" (p. 308). Additionally, dialogic talk and classroom content are closely associated, as seen in the academic discussion matrix (Elizabeth et al., 2012), which includes criteria for information and evidence in which students are evaluated based on how they "present relevant, accurate information, and require contributions to be accompanied by verifiable evidence" (p. 27). Issues of equity are closely tied to national suggestions for social studies instruction (see National Council for the Social Studies, 2013), and equity is an important part of critical conversations (Schieble et al., 2020). Therefore, for the purposes of this study, content knowledge and equity were intimately connected with PSTs' pedagogical and dialogical language knowledge. In the following sections, we explain how PSTs made mistakes with content knowledge and equity by providing examples from the data.

Content . If teaching occurred in a vacuum, PSTs' lessons would follow their scripts and a sea of opportunities for meaningful, discipline-specific discourse would ensue. However, that was not the case for this population of PSTs despite their best intentions as future educators. As they taught, PSTs engaged in problematic practices that were not part of their approved lesson plans. Specifically, PSTs in all three groups ($n = 7$) shared and confirmed inaccurate information during the teaching of the HTRAs to their elementary students. This occurred in two lessons from Group 1, two lessons from Group 2, and three lessons from Group 3. For example, during a read-aloud lesson on Christopher Columbus, one PST said, "[The crew] had to read the map the whole time to know where they were going." While maps were an important part of sea voyages in the fifteenth century, sailors relied on a versatile toolbox to support navigation. In another instance, one PST replied to a student's comment about Ruth Bader Ginsburg, a United States Supreme Court justice, by saying, "So she dissented with all types of laws that the USA had." While Ginsburg is well known for dissenting, she does not have a history of dissenting "all types of laws the USA had." Some critics may view the latter example as indicative of the PST's attempt to make the concept accessible to the elementary students, but we classified it as misinformation because the response is not historically accurate.

Wrong information was not limited to social studies content knowledge. Literacy content knowledge issues also arose in the HTRAs. Specifically, PSTs had a difficult time determining the literary genre of the texts they selected, as noted in Melissa's researcher memos. This difficulty represented itself as an error in practice when one triad was reading *Ron's Big Mission* (Blue, 2009). A PST explained to third-grade students that the text genre was "fiction" and "a biography." This error in genre understanding was not evident in the original lesson plan. The selected text was biographical and written as a narrative, which is a possible explanation for this PST's error; nevertheless, it was not fiction as the PST told the elementary student.

Even when the implementation of the lesson plan was closely followed, PSTs' non-sanctioned comments created a space for critical errors. For example, one dyad from Group 1 planned and taught a HTRA lesson using the book, *Pocahontas* (d'Aulaire & d'Aulaire, 1946/1998). This was one of the stronger lesson plans in Group 1, and they adhered to their lesson plan with more compliance than any other teaching team in Groups 1 and 2. Despite their ability to execute their lesson plan, they still shared incorrect information with their fourth-grade students. For example, one PST said to their fourth-grade students about Pocahontas' child, "That was the first English child; this was a child that was part American Indian and part English."

Equity . PSTs fostered dominant narratives in 15 of the 19 lessons taught. Reinforcement of the dominant narrative occurred in four lessons from Group 1, five lessons from Group 2, and six lessons from Group 3. In this study, dominant narratives refer to ways of thinking that reinforce White, male, Eurocentric perspectives. Dominant narratives about women were reinforced when PSTs made or confirmed assumptions that women did not work outside of the home prior to the women's suffrage movement. While that was likely true for many economically privileged White women, economically disadvantaged women and women of color had been working outside of their homes for centuries.

Another dominant narrative that PSTs reinforced was that racial discrimination has ended. One group of PSTs said, "Think about now how everybody obviously it's not just White people at one school or just African Americans at one school; we are now equal." This statement illustrates how racism made its way into the HTRA lessons because here the PSTs implicitly confirm the racist idea that somehow people of different races were not actually equal. Similarly, one PST asked why a man of color was denied the right to vote in the story. She was seeking an answer related to Jim Crow laws. These laws refer to the widespread discriminatory practices designed to keep people of color from voting even after receiving approval in the United States Constitution. The PST said, "Because he couldn't read; that was the excuse he used." Referring to a person not being able to read as an "excuse" for not voting is problematic. Instead of making these instructional decisions, PSTs should have emphasized how people of color were not treated equally under the law or in practice; instead, they implicitly adopted a stance that suggests an absence of systemic racism. The data analysis tool used for this study explicitly defines what disrupting racist ideas looks like in classrooms (i.e., Schieble et al., 2020). Likewise, Kendi (2019) argues that an anti-racist stance requires intentionally challenging the status quo; for these reasons, we believe this example and others like it represent instructional errors.

9.4.4 Increasing Critical Talk

PSTs engaged in specific instructional decisions that helped them increase critical, academic discourse in their HTRAs—compliance and talk moves. Through their capacity to make these instructional decisions, PSTs demonstrated competency with pedagogic and dialogic language knowledge because they adhered to their lesson plans, which aligns with an understanding of how pedagogy works. Moreover, "critical conversations build students' literacies for full participation in civic life and democracy" (Schieble et al., 2020, p.13), which aligns with national social studies guidelines for standards (see National Council for the Social Studies, 2013) and the social studies goals for the HTRA lesson. In the following sections, we explain how PSTs demonstrated compliance and talk moves by providing examples from the data.

Compliance . Asking the follow-up questions included in the lesson plans maximized critical discourse. All three groups ($n = 19$) included follow-up questions in their plans that were designed to elicit discourse around historical thinking. Sample follow-up questions were: (a) "Why do you think Mary had such a big impact?" (Group 1), (b) "What did [Harriet Tubman] have to gain by helping President Lincoln?" (Group 2), and (c) "Why do you think Henry had to be creative?" (Group 3). Unfortunately, Groups 1 and 2 did not ask the follow-up questions as planned. Of the 25 follow-up questions written in Group 1's lesson plans, five were asked. Of the 31 follow-up questions written in Group 2's lesson plans, eight were asked. On the other hand, of the 37 follow-up questions written in Group 3's lesson plans, 34 were asked.

Additionally, longer HTRAs were associated with more critical discourse. This difference is because PSTs who taught longer lessons were more likely to implement the lesson as planned, including the follow-up questions. Importantly, PSTs in all three groups were advised to keep their HTRA lessons to 30 min or less to respect the expectations of the clinical teachers. Group 1 PSTs taught their HTRAs in an average of 17 min, and only one of the five dyads/triads included in this study asked any of the follow-up questions included in their lesson plans. Group 2 PSTs taught their HTRAs in an average of 25 min, and two of the seven dyads/triads asked follow-up questions included in their lesson plans.

Group 3 PSTs taught their HTRAs in an average of 32 min, and all seven triads asked the follow-up questions in their lesson plans. Group 3 students had learned more about the value of critical discourse in social studies teaching. Moreover, Group 3 PSTs privileged follow-up questions in the HTRAs as a tool to promote deep, dialogic discussion around historical thinking concepts. While establishing causation is beyond the scope of the present study, data analysis clearly indicated that Groups 1 and 2 did not ask the follow-up questions as planned, yet Group 3 did. Overall, when PSTs were more compliant with asking the follow-up questions, their lessons were longer, and they included more critical discourse.

Talk moves. The notion of generating more talk as seen in this study aligns with Schieble et al. (2020) category of inclusive talk moves. While generating more talk is not necessarily indicative of critical discourse, opportunities for critical talk were supported when PSTs in this study used generative talk moves. Repeated instances of PSTs making evaluative comments in response to elementary students' discourse occurred across the three groups. In each group, evaluative comments reflected the historically dominant talk pattern of IRE commonly associated with classroom discourse (Cazden, 2001). PSTs' evaluative comments were regularly affirming; typical comments included, "Very good, good job. So that's exactly what happened, good job," or "That's a good idea." Despite including affirmations, such comments did little to promote discourse about the text and associated historical thinking.

Importantly, Group 3 had more instances of talk of this nature on average per lesson ($n = 10.7$) than the average of Groups 1 and 2 ($n = 1.94$). Additionally, Group 3 had substantially more attempts at hearing multiple students' perspectives and often combined evaluation with a generative talk move. A typical Group 3 response was, "That is a good question. Can anyone answer her question? Can you say it again?" On the one hand, it is logical to assume that longer lessons would afford more opportunities for critical talk. However, we see this outcome as a difference in the way Group 3 demonstrated its knowledge of language because these PSTs privileged their students' perspectives in ways that the other groups did not.

In addition to the act of questioning, PSTs' word choice was an important talk move in implementing more critical lessons. "Think" was the most common word used in all three groups, which is logical because PSTs were often asking their elementary students about their thoughts. However, there were differences in other frequently used words. In later analysis, Melissa had already noticed differences in the word choice from the transcripts and determined that lessons from Group 3 were more critical. Therefore, she ran queries for word frequency in Nvivo 12 and generated pictorial images such as word clouds and tree maps that showed word choice across all groups. Then, she went back to the transcripts to see the context in which these patterns occurred. This process showed "good" and "anybody" were among the top 10 words used across all Group 1 and Group 2 HTRA lessons. "Good" generally came from evaluative statements, and "anybody" usually came from PSTs asking if anyone wanted to answer the questions. In contrast, Group 3 PSTs' common words included "women" and "vote." Both words were related to the historical issues centering the lessons of many groups. This evidence suggests a tighter connection among language, pedagogy, and disciplinary thinking in Group 3's HTRAs compared to Groups 1 and 2. Considering the differences between strictly evaluative (i.e., Groups 1 and 2) and evaluative and generative (i.e., Group 3) are vital for understanding how critical discourse emerged in these HTRAs. In summary, the discipline was driving the discussion in Group 3 in ways that it did not in Groups 1 and 2.

9.5 Discussion

Operating within the hybridity (e.g., Hinchman & O'Brien, 2019) afforded by the HTRA (Krutka & Bauml, 2018) fosters dual development in both literacy skills and disciplinary ones. For example, PSTs in all three groups integrated speaking and listening with historical thinking through HTRAs, which illustrates its efficacy as a tool to promote hybridity in elementary classrooms. HTRAs (Krutka & Bauml, 2018) offer a tool to support elementary students in thinking historically (Wineburg, 2001). Lessons, such as HTRAs, that integrate literacy and historical thinking in the form of read-alouds create a space for educators to use children's language and the language of text to promote critical learning, as evidenced in this study because when PSTs had stronger knowledge of language, their teaching of the HTRAs became more critical.

Our intention was to investigate the relationship between language knowledge and the teaching of HTRAs. We did not approach the study anticipating finding the association of language knowledge and critical discourse; however, data analysis shows stark differences in PSTs' teaching of HTRAs when they had stronger university classroom experiences focused on academic discourse. Notably the instructional strategies used with Group 3 were associated with PSTs having increased critical discourse in their HTRA lessons. In particular, our PSTs who had more knowledge of language illustrated such through increased compliance with follow-up questions and generative talk moves were associated with more critically oriented lessons. Being able to engage elementary students in discourse around civic issues is a fundamental part of social studies teaching (see National Council for the Social Studies, 2013), and as such, PSTs should be prepared for these conversations to take a critical turn. However, as seen in this study, a prerequisite for being able to engage elementary students in critical talk moves is a strong understanding of pedagogical and dialogic language knowledge. In short, our PSTs needed to understand how the language of social studies worked and how to foster classroom conversations as part of their social studies methods experience, and PSTs with opportunities to better understand these constructs were also more likely to bring elements of critical conversations into their teaching of the HTRA.

Our data analysis illustrated how our specific practices as instructors (i.e., focused mini-lessons, targeted practice) were associated with different outcomes across semesters with our PSTs (i.e., more compliance, more critical talk moves). These differences reflect the desired improvements of practice, just as any effective action research study should (Putman & Rock, 2018); however, not everyone has the time or resources for such a study. One supplemental option is to consider the purposeful planning associated with HTRAs (Krutka & Bauml, 2018), which affords teachers a way of focusing a read-aloud to purposefully engage their students in a critical conversation that explores systems of power and oppression within the historical context of a given text. Elementary teachers are already integrating ELA and social studies via read-alouds (Brugar & Whitlock, 2019), so adding the critical aspect to HTRAs is a logical next step (see Wrenn & Gallagher, 2021). By developing critical disciplinary read-alouds, PSTs and others interested in the potential for purposefully apply critical pedagogy as an equally important component to historical thinking and literacy development (Wrenn & Gallagher, 2021).

Importantly, framing read-alouds in this way aligns practice and research because as scholars move toward increasing understanding of CDL as aligning equity and disciplinary thinking (Dyches, 2018), teachers can engage in opportunities for linguistic meaning making that privilege students' voices and language histories (Nieto, 2002). While we echo Nieto's (2002) call for linguistic inclusion and believe students and teachers should be adept at moving along academic registers by facilitating talk in a variety of instructional contexts (Schleppegrell, 2012), the critical nature of discourse should also be privileged in methods courses. It is difficult for PSTs to engage elementary students in critical discourse, and as noted in the findings, they will make mistakes. For most, if not all, of our PSTs, this was their first experience with an historical read-aloud. We suspect nervousness caused some PSTs to rush through their HTRAs, forgetting to ask the well-crafted questions in their lesson plans. However, nervousness alone does not account for the differences across the two semesters. Instead, we maintain the instructional practices developed through our action research and the subsequent pedagogical and dialogic language knowledge of our PSTs contributed to the differences across semesters.

At times, PSTs were unsure how to formulate a response in a way that elicited higher order thinking in students. As a result, many opportunities to deepen elementary students' thinking were missed or avoided. In the future, we can implement more rehearsal during class time with an increased focus on developing talk moves prior to the HTRA with elementary students and continue to build upon the language lessons incorporated with Group 3. Live coaching is another option; Melissa has continued to modify instruction and subsequently has added the strategy of watching the HTRA recording with her PSTs. During these feedback sessions, Melissa helps PSTs identify places where the dominant narrative is being reinforced and discusses ways to avoid that in discourse. Other teacher educators may find this strategy helpful when supporting PSTs, who are often White and female, find pockets of implicit bias in their HTRA lessons.

Much like existing observations of young children (e.g., Ballenger, 1999; Halliday, 1977), we were also learning. The outside work that we did as teacher educators on equity literacy (Gorski & Swalwell, 2015) and anti-racism (Kendi, 2019) informed our practice in real time, as seen by Melissa's instructional changes in Group 3. We cannot separate our learning from our PSTs' learning; in the same way that they cannot separate their learning about critical narratives and language with types of questions they asked their elementary students. These concurrent developments reflect the complex nature of language of HTRAs as semantic decisions (e.g., Halliday, 1977, 1978) based upon pedagogical language goals (e.g., Bunch, 2013) of engaging in discussion related to historical thinking (Wineburg, 2001) as part of the academic register (Schleppegrell, 2012) of the read-aloud experience.

9.6 Conclusion

In conclusion, this chapter offers an illustration of how understanding of language corresponded with read-alouds with a social studies content focus, but more work is needed to help all stakeholders understand the relationship between language and learning. Standards that guide curriculum require proficiency with literacy and disciplines, but at the current time, it is up to individual teachers and teacher educators to frame their instruction with critical discourse in mind. Future researchers should consider how teacher knowledge of language might inform critical discourse in other disciplines. This study was conducted with historical thinking in mind, but elementary students should also be aware of critical narratives in civics, science, mathematics, and other areas. Additionally, examining the impact of a series of HTRAs on elementary students' disciplinary knowledge and critical discourse would inform the dual fields of social studies and literacy.

HTRAs help PSTs learn how to integrate, and this way of teaching privileges language as a foundational part of learning. Moreover, HTRAs offers a potential space where language, content knowledge, and critical evaluations of systemic power meet (see Wrenn & Gallagher, 2021). While we continue our practice as teacher educators, the HTRA will remain a vital part of helping our PSTs learn to operate in the hybridity (e.g., Hinchman & O'Brien, 2019) of social studies and literacy. We encourage other teacher educators and practitioners to embrace this approach and join us in working toward developing critical discourse as a normal part of pedagogical instruction targeted toward enacting language in elementary spaces.

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Chapter 10
The Underground Railroad Doesn't Run Underground: Tackling Metaphors in the Social Studies Classroom

Lillian Ardell and Paul J. Yoder

Abstract This chapter details findings from a study on one teacher's Missed Linguistic Opportunities (MLOs) to address figurative language with emergent bilingual learners in the social studies classroom. The study provides insights on teacher practice rooted in a Pedagogical Language Knowledge (PLK) framework that allows us to examine how the teacher (mis)managed the instruction of abstract concepts in his linguistically diverse fifth-grade classroom. A form-function analysis of two terms highlights alternative pedagogical pathways to elicit a deeper understanding of both content and language knowledge with learners. The findings endorse the development of a PLK-noticing apparatus that can bolster teacher PLK and the associated instructional moves to anchor student understandings of abstract concepts in the social studies classroom.

10.1 Introduction

Was the Cold War only fought during winter? Did the underground railroad run through a tunnel? If you're reading this chapter, then you know the premise behind these questions is to get you thinking about the use of metaphor in social studies language. But have you ever posed these questions to a group of teachers, and wondered how they managed a response? We wouldn't be surprised if an emergent bilingual learner (EB) silently wondered these thoughts during a unit on Soviet Russia or the Civil War.

With these questions in mind, we share findings from a study on one fifth-grade teacher's Missed Linguistic Opportunities (MLOs) to address figurative language with EBs in the social studies classroom. The study provides insights on teacher

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practice rooted in a Pedagogical Language Knowledge (PLK) framework that allows us to examine how Mr. Stanley (mis)managed the instruction of abstract concepts in his culturally and linguistically diverse fifth-grade classroom. In the pages that follow, we explore how a form-function analysis of two terms (plate tectonics, underground railroad) foregrounds the role of metaphor as a salient feature of social studies register (Mahood, 1987; Schall-Leckrone, 2017) that elicits deeper understandings of both content and language knowledge when discussed with EBs. The findings endorse the development of a PLK-noticing apparatus that can bolster a teacher's knowledge of language and associated instructional moves to facilitate engagement with abstract disciplinary concepts.

10.2 Literature Review

To anchor the present study within scholarship on teachers' language-related knowledge in a social studies context, this section includes scholarship from a range of disciplines. First, we operationally define PLK and summarize empirical efforts to codify its meaning and purpose in the TESOL community. Next, we describe emerging notions of culturally and linguistically responsive social studies pedagogy, with a concluding review of what we know about the language of social studies. This review of literature helps situate the findings of the present study as relevant across both content (social studies) and language (TESOL/bilingual) educational contexts.

10.2.1 Pedagogical Language Knowledge (PLK)

Building on the work of Galguera (2011) and Bunch (2013), PLK (Stevens, 2020) is the understanding of language and pedagogy that a teacher brings to their instructional practice with students in the service of subject area teaching. As depicted in Table 10.1, PLK in our study encompasses four strands of language knowledge: (1) knowledge of second language acquisition (Ellis, 2015); (2) academic language use (Schleppegrell, 2004), (3) sociolinguistic knowledge (Cazden, 2001), and (4) critical language awareness (Paris & Alim, 2017).

PLK is deployed by teachers through metalinguistic interactions, or moments when language becomes the object of study to resolve discrepancies in meaning, in order to notice, analyze, and interpret encoded meanings of subject area topics and texts as well as support students' development of academic registers. Scholars (Bunch, 2013; Turkan et al., 2014; Wong Fillmore & Snow, 2018) suggested sustained exposure to the four PLK strands listed above should be required for all teachers of EBs, especially for content area teachers who routinely express concern about effectively supporting their language learning students (International Literacy Association, 2020).

Table 10.1 Pedagogical language knowledge

Pedagogical language knowledge	
Second language acquisition knowledge	The trajectories and behaviors associated with new language development includes concepts like comprehensible input (Krashen, 1982), language transfer (Cummins, 1981), and the mode continuum (Martin, 1984)
Academic language use	The "language of schooling" accounts for the lexical, sentence-, and discourse-level features that connote disciplinary literacy (Schleppegrell, 2004)
Sociolinguistic knowledge	How children are socialized into using language (e.g., Heath, 1983) and how classroom discourse norms influence learning (Cazden, 2001). This includes an awareness of register variety and the attitudes attached to standard vs. non-standard forms
Critical language awareness	An awareness of how language-minoritized speakers are positioned in mainstream learning contexts is accompanied by a critical approach to pedagogy that seeks to challenge dominant forms of language use (Paris & Alim, 2017)

Although the PLK construct accounts for four categories of language knowledge, the extant literature has focused on second language acquisition and academic language. Lucero's (2013) study found that among early elementary teachers, the participating bilingual teacher showed most instances of language scaffolding that nudged her students along the "mode continuum" from oral/spoken to more written/academic sounding registers of output (Gibbons, 2007). Bigelow and Ranney (2005) supported content teachers' engagement with the writing of form-function language objectives. Findings after a semester-long treatment suggested teachers expanded their knowledge about language but their practices remained rooted in traditional vocabulary-based approaches. Stevens' (2020) study on teacher PLK found that in the absence of sustained support on the language of schooling (Schleppegrell, 2004), teachers reported low efficacy to enact changes to their pedagogy. One fifth-grade teacher admitted that although figurative language remained a challenge for her EBs' reading comprehension, she felt unprepared to examine non-literal forms in the social studies classroom. Other scholarship has reported the trend of language-focused interventions to succeed in expanding a teacher's PLK with limited success in applying new knowledge of language into classroom practice (Brisk & Zisselsberger, 2011; Tigert & Peercy, 2018). Our study aims to address these MLOs on the basis of teacher PLK by offering teacher educators a practical framework to build figurative-language acumen in a reflection-based exercise.

10.2.2 *The Language of Social Studies as Culturally and Linguistically Responsive*

Culturally and linguistically responsive teaching pairs nicely with the PLK framework above. The pedagogy centers EBs' background experiences in an effort to enlist their cultural and linguistic resources in the social studies classroom (Dong, 2017; Jaffee, 2016, 2018; Jaffee & Yoder, 2019; Yoder et al., 2016). Based on a study of high school newcomer social studies classes, Jaffee (2016) addressed the role of bilingual discourse and translanguaging in disciplinary skills while also foregrounding the role of linguistically responsive teaching (e.g., Franquiz & Salinas, 2013; Lucas et al., 2008; Schleppegrell, 2004). Jaffee's findings support research by Lucas and Villegas, who asserted that teachers "need knowledge of language forms and functions and the ability to conduct basic linguistic analysis of oral and written texts in particular disciplines," (2010, p. 305). In sum, linguistically responsive social studies instruction draws out the linguistic demands of instructional tasks and engages students in the disciplinary skills at the heart of the curriculum (Jaffee, 2018; Jaffee & Yoder, 2019; Lucas & Villegas, 2010; Yoder & van Hover, 2018).

Exposure to the linguistic characteristics of social studies content is among the first steps toward building the PLK needed for culturally and linguistically responsive instruction (Schall-Leckrone & McQuillan, 2012). Such exposure assists learners in building metalinguistic awareness, defined as the ability to consciously reflect on the structures and design of language to assist in academic meaning-making (Bialystock, 2007). This perspective is evident in the reflections of a newcomer TESOL teacher who began teaching US history and recalled "realizing that language is still enormously necessary [for students] to be successful," (Yoder & van Hover, 2018, p. 57). At the same time, social studies teachers reported feeling a tension in how to introduce metalinguistic analysis,[1] questioning whether to introduce academic linguistic terminology or "more familiar grammatical terms" with K-12 students (Schall-Leckrone & McQuillan, 2012, p. 255). Such considerations are particularly relevant due to the dense phrases, frequent nominalization, and passive verb use that marks the language of social studies content (e.g., de Oliveira, 2010; Schall-Leckrone, 2017; Schleppegrell & de Oliveira, 2006; Schleppegrell et al., 2008). These linguistic markers create barriers for the academic achievement of EBs (Miller, 2018; Zhang, 2017).

In order to make the complex language of social studies accessible to EBs, scholars have advocated for teachers to engage students in analyzing social studies text features (Schleppegrell & de Oliveira, 2006; Zhang, 2017). Scholarship on the language of social studies has also highlighted the importance of vocabulary instruction that harnesses "the synergy that comes from integrating language and social studies practices in classroom instruction" (Yoder et al., 2016, p. 33). An analysis of individual content terms can provide students with an entry point for thematic exploration, such as through defining and reflecting on the word "revolution" at

[1] Some examples include: how the passive voice construes a particular perspective in historical register, analysis of word choice in depictions of war and triumph.

the beginning of a unit on the Haitian or American Revolution (Jaffee & Yoder, 2019). While the literature on social studies education addresses the role of academic language (Salinas et al., 2017), there remains little empirical analysis of how content vocabulary figures into building up a teacher's PLK. The role of metaphor in social studies register has received little analysis, with the exception of Mahood (1987) who examined contemporary historical terms (i.e., Iron Curtain, Cold War) to illustrate how metaphors can serve a pedagogical function through inviting analysis of the concrete to abstract transformation of meaning. A high school teacher in Fránquiz and Salinas' study (2013) used questions to draw the attention of her newcomer EBs to the meaning of several "idiomatic expressions" while inviting students to consider whether the Cold War meant "the war was cold" or "if it was actually a war" (p. 352). While the aforementioned studies considered the role of vocabulary in the context of historical register, few have addressed the role of figurative language, much less metaphor, as a feature worthy of explicit instruction in the social studies classroom.

10.2.3 Systemic Functional Linguistics and Teacher Noticing

The present study brings together insights from Systemic Functional Linguistics (SFL; Halliday, 1993; Schleppegrell, 2004) and a noticing framework to build teacher language awareness (Svalberg, 2007) in pursuit of attention to and reflection on Missed Linguistic Opportunities in the social studies classroom. MLOs are defined as either planned or impromptu moments in the classroom talk when the teacher *misses an opportunity* to focus on how language construes meaning in a particular (disciplinary) way. Although scholarship has identified instances of missed learning opportunities in the language classroom (Evans et al., 2011; Mayo & Zeitler, 2017), this is the first study to operationally define and analyze MLOs using tools provided by systemic functional linguistics. SFL scholars have shown how certain expressions construe everyday words in incongruent ways (Halliday, 1993; Schleppegrell, 2004). Comprehension of non-literal expressions in historical registers (e.g., plate tectonics, underground railroad) becomes a challenge for EBs which has implications for a teacher's instructional decisions. Accordingly, students may remain fixed on a literal "what you see is what you get" interpretation if a teacher enlists a business-as-usual vocabulary-based approach (e.g., provides a definition without further exploration of the term's form-function relationship). Discussions about how familiar words build new meanings in academic spaces offer EBs an entry point to expand their linguistic repertoires and to learn concepts about language through sustained metalinguistic engagement with disciplinary concepts (Schleppegrell, 2016). To achieve this goal, a form of teacher noticing of the form-function relationship that characterizes historical registers is needed.

Noticing, or the endeavor to raise consciousness and knowledge around particular forms in the target language (Schmidt, 1990), reflects a cognitivist stance from second language instructional contexts (Ellis, 2005). Borg (2003) and Svalberg (2007) reviewed studies that promote a noticing orientation toward building a teacher's language awareness, and in turn, an awareness in their EBs. Several functional grammar interventions (Accurso, 2020; Schall-Leckrone & McQuillan, 2012; Schleppegrell et al., 2008) have apprenticed teachers through noticing activities to build their metalinguistic awareness. A goal of such interventions has been to arm teachers with this comprehension skill to notice and engage EB's analysis of figurative forms in disciplinary texts (Christie, 2012).

Analytically, we offer a language-noticing scheme meant to engage teachers of EBs with a robust examination of these specialized forms. We argue that the development of a PLK-noticing apparatus will support teachers to recognize metaphorical terms as worthy of (and in need of) metalinguistic examinations. When language-focused prompts (e.g., do any terms in this era of history use everyday terms in specialized ways?) arise in teacher planning sessions, the teacher will be better prepared to build metalinguistic conversations into discussions with EBs. In this way, the application of this apparatus can support the expansion of a learner's meaning-making resources within and across disciplinary texts (e.g., plate tectonics in geology, underground railroad in history). In professional development spaces, analysis of historical texts and the provision of feedback on lessons taught can expand teacher PLK so that Halliday's vision of EBs learning language, learning *through* language, and learning *about* language (1993) may become a reality.

10.3 Methodology

The data come from a larger comparative teacher case study on upper-elementary teacher PLK in the social studies classroom (Stevens, 2020). Case study approaches (Yin, 2009) allow for a systematic analysis of how participants experience the phenomena in question. As this method reflects a qualitative epistemology, the use of observational and elicitation methods offers complementary sources of data to triangulate findings in pursuit of authenticity (Miles, Huberman, & Saldaña, 2014). Steps were taken in the design to allow for a teacher's emic articulations of his decision-making processes to unfold over time. These ideas are traced alongside observational data to present a fuller picture of how teacher PLK manifests across classroom discourse and elicitation data. The participant was purposively selected from one of the two approved school sites in a northeastern city in the USA according to the following criteria: have at least 33% of their roster as classified EBs and teach social studies.

Mr. Stanley (all names are pseudonyms) is an early career, elementary school (fifth-grade) teacher in a mixed-ability classroom, working under his Special Education license. He works in an ethnically and linguistically diverse K-5 school in a densely populated northeastern city in the USA. He expressed a love of history and human behavior as a young learner himself, opting to study geography in higher education before pursuing a career in education. He also worked closely with the

English as a New Language (ENL) provider[2] to address gaps in his own understandings of how to modify instruction for emergent bilingual learners. Social studies is taught as a stand-alone subject three to four times a week at the end of the day. During the 45 min period, Mr. Stanley will give a brief lesson before assigning students to rotate through two stations: some of which have computers, others scattered with maps, coloring utensils, and textbooks. He prefers a more "free form" instructional design to increase student engagement with the themes at the end of the school day (interview 9/27/17).

Data collection occurred in two phases. In phase one, the first author conducted 11 observations during the fall and collected four post-observation interviews to probe Mr. Stanley's decision-making behind certain pedagogical moves (Thornton, 1991). Two formal interviews took place: the first probed Mr. Stanley's background as a learner and his exposure to language-focused instruction, and the second gave him an opportunity to reflect on a language-related episode (Swain & Lapkin, 1998) with two EBs immediately after the incident occurred. In phase two, the first author returned at the end of the school year to conduct a member-check interview.

Data analysis unfolded in three consecutive stages. During field observations, the first author would note instances in Mr. Stanley's teaching practice where she anticipated a discussion of language might emerge, reflecting the influence of her own PLK as a noticing apparatus to guide her researcher's gaze. These instances were coded in the observational data for further analysis and exploration of trends (e.g., were their instances when language was addressed versus not?) Then, she reviewed the data set to identify any MLOs that coalesced around a particular feature of academic vocabulary (in this case, metaphorically used terms). Next, a description of the instructional moment was provided, highlighting the teacher's engagement with the focal terms and how the EBs responded to the instruction. Last, our analysis adopts a functional language perspective to unpack the form and function relationships in historical register. We wondered: What metalinguistic explanations *could* Mr. Stanley have offered his EBs in pursuit of conceptual and linguistic understandings? A functional grammar lens provides a framework to unpack how language forms construe meanings within a discipline, arming analysts (and teacher educators alike) with the conceptual understandings to describe and explain the MLO as well as help teachers arrive at alternative approaches to instruction in a post-observation setting (which is where we anticipate this type of work to be addressed).

[2] Ms. Coraline was the upper-grade ENL provider. She and Mr. Stanley had a friendly working relationship where they routinely co-planned social studies lessons with linguistic supports. Three days a week, Ms. Coraline was observed leading a small group of beginner-level EBs in vocabulary previews and close-readings of historical texts.

10.4 Findings

This section explores two language-related episodes (Swain & Lapkin, 1998), wherein Mr. Stanley attempted to explain abstract concepts embedded in the curriculum to a group of EBs in either small or whole group structures. A description of each moment includes the interactions and instructional resources enlisted to support EBs' engagement with particular disciplinary concepts. Our goal is to highlight how each moment revealed *missed* opportunities to examine a feature of academic register (the metaphorical function that construes the meaning and interpretation of everyday language) as a means to acquire new understandings.

10.4.1 Missed Linguistic Opportunities

10.4.1.1 Plate Tectonics

The first MLO occurred at the beginning of the year, during a culminating activity for the Pangaea Continental Drift unit (Field Notes 9/23/17). Students were homogeneously grouped with assigned tasks commensurate to their perceived academic abilities. Dante and Julio (two EBs of Mexican heritage with intermediate English proficiencies) were at the Vocabulary Center, where the task was to look up definitions in a children's dictionary and write them "in your own words." For two consecutive 45 min class periods, the first author observed Dante and Julio struggle to obtain a definition of the geological term plate tectonics on their own. When Dante found the term /plate/, Mr. Stanley encouraged him to read through each of the five definitions to determine which was the best match. The dictionary contained five options: (1) a thin flat disk, (2) something served on a thin flat dish, (3) a thin flat piece of metal, (4) home base, and (5) metal that is covered with a thin layer of gold or silver (DK Children, 2016).

Since /tectonics/ didn't figure into any of the provided definitions, Mr. Stanley retrieved a visual resource: a color map of world tectonic plates with arrows representing tectonic shifts. Dante counted how many plates there were and then turned to his teacher with confidence, "I think I get it now." Dante reasoned that countries need something "to live on" so plates "are like an island." Building on Dante's confidence, Mr. Stanley scaffolded the meaning of the resource through the use of geological terms (i.e., continents, drifting, earth, crust, thin). "Remember that word *thin* from plate?" referring back to the dictionary definitions. Then, the students extended the geologically attuned dialogue, including words (i.e., mantel, dirt, core) that the ESL teacher prompted the students to recall from their prior knowledge during an earlier discussion. As the exchange concluded, Dante offered this verbal definition "it's a giant piece of crust that floats…all around the world," which got revised in his notebook to: "a giant piece of rock that's all around the world."

In brief, this language-related episode prompted Mr. Stanley to support two EBs' engagement with a highly specialized scientific term. However, he missed an opportunity to convey a linguistic fact of academic register: that geologists borrow "everyday" words in order to convey an abstract concept. This is achieved through use of a metaphor (plate). While Dante, with some help from Julio, relied on prior knowledge and a visual resource to compose a workable definition of "plate tectonics," a crucial linguistic opportunity to study the metaphorical use of plate was overlooked.

10.4.1.2 Underground Railroad

A second MLO occurred while Mr. Stanley was launching a unit on the American Civil War and specifically about the underground railroad (URR). Students were prompted to "notice, think, and wonder" about an image of Harriet Tubman leading escaped slaves while Mr. Stanley collected their ideas in a semantic web. As they offered ideas, Mr. Stanley inquired whether anyone knows "how [the URR] works." Julissa (an intermediate EB of Dominican heritage) raised her hand, "The underground railroad means …a path that you go through underground." Julissa's comment gave Mr. Stanley pause, as there seemed to be lingering confusion about the meaning of "underground," So, by way of example, he correlated the familiar image of a subway system as being "a secret," followed by some perplexing twists and turns.

Mr. Stanley: The word underground, in *this* case it does *not* mean *under* the earth… when you think of something being underground like, say you're *flying* over New York City. Can you see the subway?
Student 1: No… because…. it's too far away to see?
Mr. Stanley: Say you're flying into NYC and you're close enough to see the ground, but you don't see the subway. (1 s) why can't you see it? Brittney.
Student 2: cuz it's underground?
Mr. Stanley: (quietly) it's underground, meaning that it's a *secret*. Sort of like you wouldn't know it's there if you *didn't* know it was *there*. In other words, the *underground* part means….[turns to write on the board] *secret*.

As we see in Mr. Stanley's ambiguous and circular explanation of /underground/, Mr. Stanley's limited awareness of the word's polysemy does not allow him to successfully unpack its meaning with EBs. In other words, he has some *language* knowledge about metaphors without sufficient *pedagogical* knowledge to explain their alternative meanings. Hence, Mr. Stanley missed the opportunity to help his EBs see how metaphor construes the meaning in the following ways. The term is best described as a conceptual metaphor (Lakoff & Johnson, 1980) where /underground/ functions as an adjective to modify the noun /railroad/. Lakoff and Johnson described metaphorical analysis in terms of the domain in which the metaphor exists or invokes in the reader. In this case, the domain is /journey/, highlighting the intercontinental network of escaped slaves. It bears repeating that Mr. Stanley was not prepared to address a broader linguistic fact of academic register: that the abstract

Table 10.2 From the MLO to the Metalinguistic Conversation

Find the MLO	Plate tectonics	Underground railroad
(1) Identify figurative language	Metaphorical use of /plate/ to construe an abstract, geological concept	Metaphorical use of /underground/ to express the illicit nature of escaped slaves. Use of /railroad/ as a visual metaphor of the intercontinental pathways and safe houses along the way to the north
(2) Explore form-function meanings in the language	*Plate* functions as a metaphorical adjective to modify the noun /tectonic/. *Tectonics* describes a geological concept of slowly shifting disks on the Earth's surface	*Railroad* invokes journey imagery and the intercontinental aspect of the phenomena. Note how the term is used similarly in "underground hip-hop" to portray a hidden or secret form of music
(3) Summarize	Reveals how language encodes the scientific meaning through a metaphorical transformation of the everyday use of /plate/ to confer a specialized series of thin, flat disks	Escaped slaves could only arrive safely to the north by way of secret (underground) pathways of abolitionist supporters throughout the south (the railroad)

use of everyday words is confusing if students don't realize *when* and *how* words are used metaphorically in the language of human history.

10.4.2 Application to Practice

While noticing the MLO is the first step, a potential expansion of teacher PLK can take root through guided reflection on practice with the goal of applying new language knowledge for future lessons. We offer the three-columned chart below (Table 10.2) as a model to assist teacher educators and staff developers in the identification of figurative terms, an exploration of meaning as a move away from the literal to the abstract, and sample summary statements for teacher output. The table begins with the PLK-noticing apparatus (when the observer identifies the MLO) and follows up with prompted reflections on what *could have been* explicitly explored through metalinguistic discussions of figurative language forms.

10.4.2.1 Plate Tectonics

First, the students have to recognize that only /plate/ is used figuratively. Mr. Stanley could begin by reviewing each of the five definitions to home in on the most general option, "a thin, flat disk." Selection of this definition requires both a process-awareness of dictionary usage and the knowledge that reference texts (e.g., dictionaries and atlases) are helpful resources for semantic problem solving during social studies.

For /tectonics/, two linguistic features require attention. The first is that plate functions as a classifier[3] to modify the head noun "tectonics." The second is the term's meaning as "large-scale processes affecting the structure of the earth's crust." In the term plate tectonics, the word plate is used metaphorically and would require an examination of how geological concepts are encoded through language based on a meta-metaphor of plates and disks. Such a discussion at the onset of the unit can foreground the abstract to concrete relationship for EBs, therefore giving Dante and Julio the working conceptual and linguistic knowledge to successfully "write [the term] in their own words." In summary, a functional analysis of plate tectonics reveals how language encodes the scientific meaning through a metaphorical transformation of the everyday use of /plate/ to confer a specialized series of thin, flat disks.

10.4.2.2 Underground Railroad

First, the students have to be taught that both words in the expression are used figuratively. For /underground/, an examination of potential dictionary definitions would render the following: "a group or movement organized secretly to work against an existing regime." Moreover, there is a false image equivalency between the specialized and literal meanings of the word. A T-chart to compare both word meanings would support this endeavor. For /railroad/**,** an examination of its use as a conceptual metaphor (Lakoff & Johnson, 1980) warrants attention. To highlight the term's shared meaning of /journey/, Mr. Stanley could explain, "when we think of railroads, we think of *journeys* that take place over very long distances." Then, he would need to present the two words as a semantic unit through explication of each word's form-function relationship. Labeling of each word's parts-of-speech would help students to see how /underground/ acts as a classifier of /railroad/.

Building on the lexical investigation of each word's figurative meaning, the students need to situate underground railroad in the context of their developing knowledge of the American Civil War, in particular the horrific phenomenon of human enslavement. To achieve this goal, Mr. Stanley can rely on arresting visuals (e.g., the Tubman portrait, videos that recreate dramatic escapes) and map resources. By now, students can connect the lexical information to its relevant context of use. At this point, Mr. Stanley would need Julissa to review her original (literal) interpretation and, through scaffolded interactions, arrive at some version of the following phrase: "a secretive network of people and houses across many states that slaves used to escape their owners."

[3] In SFL, the term classifier refers to an adjective that indicates a particular subclass of the head noun in a nominal group.

Lastly, the students have to recognize that this term functions to create a certain kind of narrative about slavery and abolitionists within the American Civil War. The courageous act of a slave escaping their owners was framed by abolitionists as illicit. The word /underground/ confers a rebellious or defiant type of actor who put her life at risk to become free. Per the field notes (5/25/18), students grappled mightily with the notion of a "free person," having limited experiential context to make sense of humans-as-property through a twenty-first-century lens.

10.5 Implications

Through analyzing Mr. Stanley's MLOs in the context of a fifth-grade social studies classroom, our discussion highlights the ways metaphors can provide an important opportunity for social studies teachers to not only promote better understanding of historical concepts but also to facilitate metalinguistic practice among EBs. The findings contribute to the existing scholarship on PLK for teaching social studies (e.g., Bunch, 2013; Schall-Leckrone, 2017; Stevens, 2020), particularly building on attention to figurative language in the teaching of social studies (e.g., Fránquiz & Salinas, 2013; Schall-Leckrone & McQuillan, 2012). The analysis provides evidence of the potential of noticing and interrogating the role of metaphors in social studies as an important element of a teacher's language-related knowledge and a tool for promoting culturally and linguistically responsive social studies instruction (Jaffee, 2016, 2018; Jaffee & Yoder, 2019).

The PLK-noticing apparatus described in this chapter is a practical tool for scaffolding and building the PLK of content teachers. We recommend that social studies teachers who are writing language objectives as part of using the Sheltered Instruction Observation Protocol (Short et al., 2011) or a similar lesson planning tool not only focus on social studies skills such as interpreting slogans or analyzing documents (Yoder & van Hover, 2018), but also build and operationalize linguistic knowledge. For example, social studies teachers may wish to identify and summarize metaphors (i.e., Cold War, Iron Curtain) as a form-function-oriented language objective that can guide the planning and instruction processes. Conversely, social studies teachers can engage in noticing and addressing MLOs in real time or retrospectively as they continue to develop and practice their own PLK. For example, Mr. Stanley introduced a visual resource when he realized that the available definitions for plates did not describe tectonic plates. Further discussion rooted in a functional grammar stance may result in Mr. Stanley sharpening his noticing apparatus to identify forthcoming terms to plan language objectives that address the layered meanings of the metaphorical terms as noted in the social studies curriculum. We contend that the combination of post-observation conferences about MLOs between a staff developer and a teacher can build up their noticing-lens to ultimately replace MLOs with Planned Linguistic Opportunities (PLOs) in the linguistically diverse classroom.

Finally, research suggests that social studies teachers who seek to develop their PLK will face competing priorities (e.g., Stevens, 2020; Yoder & van Hover, 2018) and likely realize that their own metalinguistic knowledge is stretched thin (e.g., Schall-Leckrone, 2017). As such, social studies teachers can and should develop the PLK needed to support EBs and that metaphors provide an accessible starting point for these conversations. Toward this end, we offer the three steps of the PLK-noticing apparatus described in Table 10.2 as a starting point. Based on our analysis in the present chapter, we recommend that social studies teachers identify figurative language, explore form-function meanings in the language, and then summarize that analysis in student-friendly language. In this way, social studies teachers may consider implementing this approach in collaboration with TESOL colleagues or instructional coaches (Jaffee & Yoder, 2019; Zhang, 2017). This work is most fruitful when teacher educators engage social studies teachers in such reflection and analysis as a means of developing their PLK.

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Chapter 11
Thinking and Talking Like a Geographer: Teachers' Use of Dialogic Talk for Engaging Students with Multimodal Data in the Geography Classroom

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Abstract Geographical inquiry is an approach to learning that acknowledges the constructivist view of knowledge and prioritises the need for students to make sense of what they are learning for themselves. Alexander (2003; 2008) advanced dialogic teaching as a strategy for eliciting students' understanding and engaging students in using language as a tool for constructing knowledge. This suggests that the successful use of geographical inquiry as a pedagogy entails learning how to think and talk like a geographer. Geography teachers in Singapore are encouraged to use inquiry-based pedagogies in order to help students understand the nature of disciplinary work in geography and as the main route to knowledge construction (CPDD, 2013; 2014). This chapter draws on a study that examines geography teachers' language knowledge for content teaching (Morton, 2018) through the use of dialogic talk to guide multimodal data analysis, interpretation, and knowledge construction in geography. Using examples of teachers' enactment of knowledge in the classroom, we suggest how geography teachers can help students make sense of geographical data through greater attention to language use. We further argue that exploring the qualitative dimension of using dialogic talk as a pedagogic strategy addresses a gap in geography education and contributes to the growing body of work on disciplinary literacy.

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11.1 Introduction

Geographical education embraces a constructivist view of knowledge and prioritises the need for students to make sense of the world for themselves. Geographical inquiry is widely acknowledged as a key aspect of geography teachers' pedagogy. For example, in the UK, the Geographical Association has advocated for students to play an active role in discovering and constructing knowledge about the world around them, on the grounds that inquiry is quintessential to the discipline both epistemologically and pedagogically (Geographical Association, 2009). An inquiry approach has also been recommended in the National Geography Standards in the USA since 1994 (Geography Education Standards Project, 1994). Roberts (2013) argued that learning geography is "framed by the questions and imaginations that geographers bring to the task" (p. 18) and that "geographers have developed particular ways of looking at the world and understanding it" (p. 95).

In Singapore, an inquiry approach has been strongly advocated by the Ministry of Education (MOE) for teaching and learning geography since 2012. Acquiring skills relevant to how geographers see, think about, and interpret multimodal data (Jackson, 2006) is critical to the discipline. This includes developing competencies in comprehending, extracting, applying, and interpreting geographical data to patterns and deduce relationships, which are emphasised in secondary geography syllabuses by MOE (CPDD, 2013, 2014). Empirical research by Seow et al. (2019) yielded broad evidence that Singapore teachers' pedagogical content knowledge is strongly informed by geographical inquiry. However, the authors also noted that teachers' enactment of geographical inquiry can be impeded by teachers' content knowledge gaps. In this chapter, we extend the analysis to teachers' knowledge about language, a key component of language-related knowledge base for content teaching, as outlined in this book (see Seah, Silver & Baildon, this volume). In particular, we study geography teachers' language awareness involved in developing students' disciplinary competences, specifically the ways in which teachers frame their questions when analysing and discussing multimodal data in the geography classroom. We believe our study addresses calls for explicit instruction (Brown & Ryoo, 2008) to develop disciplinary literacy within distinctive subject areas (Schleppegrell, 2004; Shanahan et al., 2011).

11.1.1 Disciplinary Literacy and Knowledge Construction

In recent years, there has been increasing interest in how content learning is tied to developing disciplinary literacy. Moje (2008), for instance, argued that disciplinary literacy inducts students into an understanding of how disciplinary practitioners construct knowledge in the disciplines (Shanahan & Shanahan, 2008; Shanahan et al., 2011), and how this is shaped by the practices of a social context (Cook-Gumperz, 1986). Literacy, in specific disciplines serving distinct purposes, extends beyond an understanding of vocabulary and grammar to a type of socialisation where members of a discourse community successfully participate in knowledge construction through discipline-specific oral and written language (Quinn et al., 2012). This implies that geography teachers need to tap on their knowledge about language in employing strategies that develop students' ability to use language appropriately, meaningfully, and precisely. As Walshe (2017) argued, these strategies can lead to both "significant improvements in students' literacy" and to "their geographical understanding" (p. 199).

Scholars have also noted the multimodal nature of geographical knowledge construction (Goin, 2001). Lukinbeal (2014) emphasised the importance of multiple literacies, "the ability to locate, evaluate, effectively use, and produce geographic information" (p. 41), in geographical knowledge construction. Geographers acknowledge the plethora of multimodal texts they rely on to produce, interpret, and disseminate knowledge. Studies in processing multimodal texts suggest that encouraging students to read, investigate, explain, talk, and write about the concepts following teacher's modelling (McConachie et al., 2006) is crucial to subject matter understanding (Graesser et al., 2007; Perfetti et al., 1999; Wiley et al., 2009).

Following Seow et al. 's (2019) observation that some teachers have gaps in their subject matter knowledge that impede their practice of geographical inquiry, the question arises as to how language-aware teachers are in their content teaching (Morton, 2018). Teacher language awareness (TLA) is "the knowledge that teachers have of the underlying systems of the language that enables them to teach effectively" (Thornbury, 1997, p. x). TLA in content teaching takes into account students' exposure to inputs, interactions, and outputs in a target language (Lo, 2019). Earlier research (Seow, 2015) suggests that geography teachers face challenges in guiding their students in analysing multimodal data. This is further compounded by students' lack of precision in the use of geographical content vocabulary and a failure to understand what specific language features mean in context (Ho et al., 2017). This makes it important to understand how geography teachers use language to increase students' output in their classroom (Xu & Harfitt, 2019) and to provide TLA-filtered classroom inputs for students. TLA filters function as a form of mediation that ensures students' output is precise, meaningful, structurally accurate, functionally appropriate, and generalisable for other students (Andrews, 2001).

TLA mediation is a conscious, ongoing effort that contextualises and makes explicit the language features to students during real-time classroom interaction (Andrews, 2001), rather than a stand-alone component of a lesson. Moje (2008) noted that non-English language teachers often perceive time spent on disciplinary literacy as an additional teaching task imposed on them and a drain on their content teaching time. This chapter therefore pays careful attention to how geography teachers can mediate classroom inputs for students and create more space for students' output to maximise learning through strategic teacher talk.

11.1.2 Dialogic Talk and Knowledge Construction

Hodgkinson and Mercer (2008) argued that “classroom talk is not merely a conduit for the sharing of information… it is the most important educational tool for guiding the development of understanding and for jointly constructing knowledge” (p. xi). However, the extant literature suggests that teachers’ questioning in the classroom tends towards asymmetry, with the teacher predominantly asking a significant number of closed-ended questions (Alexander, 2008; Barnes, 2008; Hogan et al., 2012; Mercer & Dawes, 2008). Such question–answer routines position the teachers as the sole legitimate source and disseminator of knowledge. This implies that students may not have sufficient opportunities to actively participate or lead in the thinking and talking routines related to knowledge construction in the disciplines.

Alexander’s (2003, 2008) seminal work on classroom talk advanced the concept of dialogic teaching with the focus on teacher–student and student–student interactions. Through a repertoire of strategies, teachers can engage students in using language as a tool for constructing knowledge. The key to dialogic talk is teachers’ prompts intended to draw out students’ own thinking, “encourage them to elaborate on their previous answers and ideas, and help them construct their own knowledge” (Chin, 2007, p. 4). These prompts also encourage students to become aware of the importance of reflection, fostering a capacity to interrogate their own reasoning and that of their peers (Dawes, 2004; Kawalkar & Vijapurkar, 2013). Through dialogic teaching, therefore, “students and teachers work together to clarify the meaning and ideas, offer and explain reasons, invite and discuss alternative perspectives and solutions, make connections and establish conceptual relationships, justify beliefs, frame and reframe arguments…” (Hogan et al., 2012, p. 180).

Dialogic questioning is an effective way to promote deep student learning through encouraging active participation (Wells & Arauz, 2006), but it requires a critical shift from teacher-fronted teaching to one where teachers steer classroom talk to achieve educational goals (Alexander, 2008). Michaels and O’Connor (2012) outlined four goals for productive discussion: help individual students share, expand, and clarify their own thoughts; help students listen carefully to one another; help students deepen their reasoning; and help students engage with others’ reasoning. Each goal can be achieved by a set of teachers’ strategic talk moves “designed to open up the conversation and support student participation, explication, and reasoning” (Michaels & O’Connor, 2012, p. 7).

Building on the work of Alexander (2003, 2008), Michaels and O’Connor (2012), and Zwiers and Crawford (2011), the English Language Institute of Singapore (ELIS) adapted talk moves (see Table 11.2) for use in Singapore classrooms. These talk moves, “strategic ways of asking questions and inviting participation in classroom conversations” (Chapin et al., 2013, p. 11) to facilitate productive academic discussion have been employed by researchers to analyse and improve teachers’ talk in biology (Ho et al., 2019), mathematics (Vijayakumar et al., 2015), and geography (Vijayakumar et al., 2015) classrooms. In general, these studies suggest that teachers have become more self-aware in their use of talk moves to support students' knowledge construction.

In this chapter, we draw on our study of teachers' strategic application of talk moves to multimodal analysis and interpretation for knowledge construction in geography classrooms. Using data from lesson observations of two teachers participating in the study, we highlight the strengths of the dialogic talk strategies used by the teachers and suggest ways in which geography teachers can refine their questioning and language use for multimodal data analysis, interpretation, and meaning-making. We argue that paying close attention to dialogic talk in classroom discussions around multimodal data can strengthen TLA and lead to improvements in both students' disciplinary literacy and geographical understanding.

11.2 Research Context and Methodology

We examined data from our collaboration with two geography teachers in a mainstream secondary school in Singapore, who had twenty and nine years of teaching under their belts, respectively, and who also had prior experience of participating in the Whole School Approach to Effective Communication in English (WSA-EC) which was active at the time of the study. This was a strategic initiative by MOE, which had as its goal the development of teachers' ability to communicate disciplinary knowledge to better support students' learning (ELIS, 2011). Earlier research by (Ho et al., 2017) indicated that teachers and students faced challenges due to students' imprecise use of geographical content vocabulary as well as their lack of understanding of specific language features in context. Seow (2015) observed that geography teachers faced challenges in guiding their students in analysing multimodal data. As this project sought to determine how geography teachers' classroom talk could be sharpened when working with multimodal geographical data, and to identify areas that needed refinement, the experiences these teachers had put them in a better position to reflect on the application of the talk moves when engaging with multimodal data in geography.

Together with history, literature, and social studies, geography is considered a humanities subject in Singapore. It is a compulsory subject at lower secondary level (ages 12–14 years) and is an optional subject at upper secondary level (ages 14–16 years) where it is taken either as a "pure geography" subject or as a "geography elective" subject taught in combination with social studies. Interpreting and evaluating multimodal data at both the upper and lower secondary levels are important assessment objectives, specified in the MOE syllabuses as the ability to:

1. "Comprehend and extract relevant information from geographical data (numerical, diagrammatic, pictorial and graphical forms)" (CPDD, 2013, p. 41, 2014, p. 34);

2. "Use and apply geographical knowledge and understanding to interpret geographical data in graphs, maps, photographs, sketches, tables, numerical figures and texts/quotes" (CPDD, 2013, p. 42, 2014, p. 34); and
3. "Recognise patterns in geographical data and deduce relationships" (CPDD, 2013, p. 41, 2014, p. 34).

The majority of the students from the school were from middle to lower income socio-economic groups with average academic ability. The lower secondary class had started studying geography as a subject in the year we began our study, while the upper secondary students were in their third year of formal geography education at the start of the project. Each class was observed six times over the data collection period between July 2018 and August 2019. Table 11.1 provides more information on the classes involved in the study:

The study involved close collaboration between the researchers and teachers to support students' engagement with multimodal data through teachers using talk moves, that is, "strategic ways of asking questions and inviting participation in classroom conversations" (Chapin et al., 2013, p. 11), examples of which are provided in Table 11.2. In general, the prompts focused on helping students to voice and clarify their ideas, listen closely to other students, deepen their own and engage with others' reasoning, and consolidate discussions.

Table 11.1 Biographical data of classes involved

Participants	Grade (age) of class	Total no. of students	No. of female students	No. of male students
Teacher 1/class 1	Lower secondary (12–14 years old)	31	18	13
Teacher 2/class 2	Upper secondary (14–16 years old)	24	13	11

Table 11.2 Examples of talk moves used by teachers

	Talk move	Frames for prompting
Focus area 1: Voice and clarify a student's ideas	Seek clarification	What do you mean by…? Specifically, can you please tell me…?
Focus area 2: Listen closely to another student	Ask a student to restate another students' contribution	What do you think X was saying? Can you phrase it in your own words for us what student X just told us?
Focus area 3: Deepen a student's reasoning	Probe for reasoning or evidence	Why do you think that…? What's your evidence for that?

Adapted from Michaels and O'Connor (2012) and Zwiers and Crawford (2011) by English Language Institute of Singapore

The primary source of data reported in this chapter is multimodal transcripts of classroom discourse from video-recorded lessons. Episodes that featured discussion around multimodal data (e.g. graphs, maps, statistical tables, photographs, sketches, satellite images, and videos) were studied. Each episode started with a teacher's verbal signal to draw students' attention to the data and ended with the teacher's brief summary of the discussion before moving on to the next activity. We examined the teacher's intended purpose for each prompt and coded the prompts, drawing on ELIS's adaptation from Michaels and O'Connor (2012) and Zwiers and Crawford (2011), in conjunction with the geographical inquiry skills (identification, location, description, prediction, explanation, and evaluation) and language features (geographical vocabulary and specialised geographical language) outlined by Dolan (2019).

The focus of the transcript analysis was to identify and categorise the range of talk moves (see Table 11.2) used by teachers when guiding their students to analyse geographical data. We also sought to determine the extent to which the question prompts enabled students to analyse and interpret the data sources. The identification and categorisation were carried out independently by the researchers who then cross-checked with one another for consistency in interpretation and classification. In addition, teachers' and students' perspectives were elicited through teacher interviews and student focus group discussions, given our interest in examining the impact of the use of talk moves and teacher questioning on teaching and learning.

11.3 Findings and Implications for Pedagogy

The following sections highlight the main points that emerged from the examination of our data. We found that when applied to *multimodal data in geography*, the categories of talk moves used at the start of the project could not adequately meet the needs of geography teachers and students and would require refinement. In this segment, we identified two important categories of talk moves used by the geography teachers: *decode* and *recast*. In addition, we noted that teachers often used prompts that did not develop students' thinking routines around geographical data, for instance in categories like *decode* and *specify*. In general, however, we found that teachers and students were appreciative of the value of talk moves in engaging students in analysing multimodal data and creating opportunities to draw on one another's ideas.

11.3.1 Building Routines for Decoding Multimodal Data

Teachers spent a substantial amount of time helping students to understand the given multimodal data used in geography lessons. Extract 1 shows how Teacher 1 unpacked

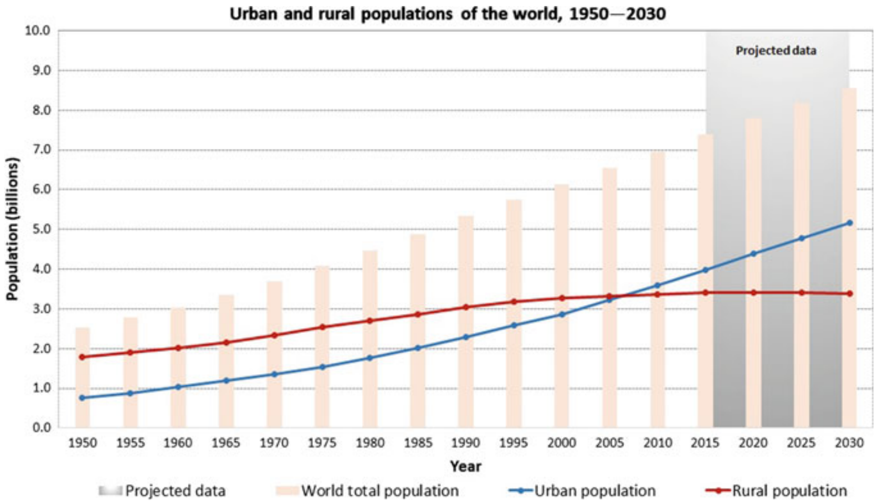

Fig. 11.1 Line and bar graph on urban and rural population of the world, 1950–2030 (reproduced from United Nations, Department of Economic and Social Affairs, Population Division, 2018)

the line and bar graphs depicted in Fig. 11.1 with the students. This type of interaction was frequently observed in lessons that involved the use of such data.

Extract 1

Turn	Speaker	Classroom talk
40	T1	Now what about the vertical axis?
41	S4	Population
42	T1	It shows population. Specifically, S5, can you tell me, population, are we talking about thousands? Or are we talking about hundreds?
43	S5	Billions
44	T1	Yes, we are talking about billions. Billions. Ok. So we are talking about billions of them and population of what? We are talking about…? What kind of population?
45	S4	World
46	S5	World population
47	T1	World population and this is represented by…? Wait, hold on. So there are two things. The vertical axis refers to population, so it actually shows the world population, the world total population by the bar graphs. Alright, the beige bar graphs. And then you also have got the blue line and the red line. So the blue line and the red line actually… S6, what does the red line represent? It shows population but what kind of population?
48	S6	Rural
49	T1	Yes, it's talking about rural population. And then what about the blue line?
50	T5	Urban

T Teacher, *S* Student

In the extract above, Teacher 1 asked a number of questions that prompted students to work towards *decoding* the population data depicted in Fig. 11.1. This involved getting the students to state what the data representations (bars, lines, and axes) meant in the given source (total, urban and rural population growth, in billions, from 1950 to 2030). For instance in Turn 40, the teacher directed attention to the vertical axis and asked students to note the unit of measurement (Turn 42). In subsequent turns (44, 47 and 49), she dissected how different categories of population were represented in the graph (world population in the beige bar graphs, urban and rural populations in the blue and red lines, respectively). Based on the lessons observed, we argue that talk moves for decoding data in geography would be an important refinement to the model.

However, we also noted that in this instance, the moves made by the teacher essentially meant that she carried out the thinking and decoding work herself. Her questions often only required students to read off the data as directed. For example, she asked students "Now what about the vertical axis?" (Turn 40) and specified "can you tell me, population, are we talking about thousands? Or are we talking about hundreds?" (Turn 42). These questions were crafted such that they only elicited one word answers. Moreover, students were not prompted in a way that enabled them to internalise the process of decoding the data for themselves.

Instead, in Turn 42, rather than asking students a direct question about the unit of measurement ("are we talking about thousands? Or are we talking about hundreds?"), the teacher could have asked an open-ended question that encouraged students to decode the information in the vertical axis for themselves. She could have asked instead, "Is there more information on the vertical axis?", which would have directed students' attention to the unit of measurement. Noting and understanding what is represented in the axes and the unit of measurements used is a fundamental step in making sense of graphical data, and students would have benefited from a question prompt that steered them towards approaching the graph in a way that built their competency in decoding the data for themselves. Similarly, in Turn 47, Teacher 1 not only decoded the way in which the world population was represented ("the beige bar graphs"), but she also explicitly instructed students to decode how rural population was represented ("what does the red line represent? It shows population but what kind of population?"). Again, Teacher 1 could have asked a more open-ended question that prompted students to decode data for themselves. For instance, she could have responded in Turn 47 with "How are these data represented?", followed by "What other population categories do you see?".

In this section, we observed that Teacher 1 was explicitly demonstrating to students the ways in which geographers read, think, and talk about line and bar graphs. This reinforces what research has shown: in developing students' multi-modal literacy (McConachie et al., 2006) and geographical thinking (Kitson, 2016), teacher modelling in talking about the information is key. However, we also noted that the teacher's efforts were stymied by the *type of questions* being asked even as she attempted to model how to decode data. Mercer and Dawes (2008) observed that interaction structures in which the teacher asks "closed questions and children provide brief answers on which the teacher makes evaluative comments… represents an unsatisfactory, limited use of the powerful educational tool of language" (p. 57). There is, therefore, a need to develop open-ended question prompts around decoding data for geography classrooms. This could help teachers become more aware of their language use for content teaching in this stage of working with multimodal data, thereby increasing their knowledge about language and their language-related content base for teaching.

11.3.2 *Building Routines for Independent Specification of Evidence from Data*

The ability to extract evidence from data in order to support claims about phenomena is crucial in constructing understandings about the world we live in. In our study, we observed the importance that the geography teachers placed on getting students to support their claims with specific evidence from the data. Extract 2 demonstrates how Teacher 1 prompted students to specify data to support claims that the world population was increasing, again using Fig. 11.1.

Extract 2

Turn	Speaker	Classroom talk
78	T1	I asked you from which part of the graph that shows that the population is increasing?
79	S9	Go higher
80	T1	The bar graph goes higher and higher. Ok, are you able to tell me what is the world total population in, say, 1950?
81	S10	2.4 billion
82	T1	Yes, S10. 2.? 2.4 billion. Ok, close. That is the first graph
83	S11	2.5
84	T1	Ok, S11 said it's 2.5. Close. Alright, so it's about 2.5 billion that you have in 19…
85	S4	50
86	T1	Ok, yes. 2.5 billion in 1950. [writes: 2.5 million, 1950] But then when we look at 2030…
87	S4	8.4
88	S7	8.5
89	T1	It is close to 8.4 billion. [writes: 8.4 million] Eh, sorry billion. [writes: 8.4 billion, 2030]
90	S4	2.5 million also wrong

(continued)

(continued)

Turn	Speaker	Classroom talk
91	T1	[changes to: 2.5 billion, 1950] Thank you. It shows that you are very alert today. Thank you. Ok, so you have 2.5 billions and 8.4 billions by the end of 2030. So that is why S8 said that it is increasing

T Teacher, *S* Student

In Turn 78, Teacher 1 explicitly used a talk move that probed for students' reasoning by specifying what and where exactly students were to focus on in examining the graphical data ("I asked you from which part of the graph that shows that the population is increasing?"), to which the S9 responded "Go higher" (Turn 79). Having reached that point, Teacher 1 proceeded to build the evidence to support that claim by leading students to refer to specific data points by indicating the period of focus in Turns 80 ("what is the world total population in, say, 1950?") and 86 ("But then when we look at 2030…").

Here we notice that Teacher 1 was familiar with talk moves that probed students' reasoning and encouraged them to specify evidence (see Table 11.2). However, we also noted she was less familiar with how to prompt students to use specific data to justify or support the phenomena under discussion *for themselves*. Similar to the point on decoding data above, we argue that helping teachers to become more aware of the specific question prompts that build students' skills in extracting relevant multimodal data to support their reasoning would be useful. For instance, prompts like "Which data point(s) on the graph would you choose to support this increase?" followed by "Why did you choose this/these data point(s)" would put the onus on students to think about and justify the evidence they select and develop the thinking routines required to use data effectively in geographical discourse.

11.3.3 Recasting Data to Construct Geographical Explanations

Extract 3 is part of a longer discussion where Teacher 2 worked with her class to examine and explain the relationships among relief, distance from the sea, and rainfall amounts experienced at different locations (see Fig. 11.2). Across the lessons, we noted that the geography teachers and students typically constructed explanations by referencing a process or concept learned earlier, with the teachers encouraging students to apply these to the data in the geographical resource under discussion. Here, the class is discussing the influence of relief (the Rocky Mountains) on rainfall patterns.

Extract 3

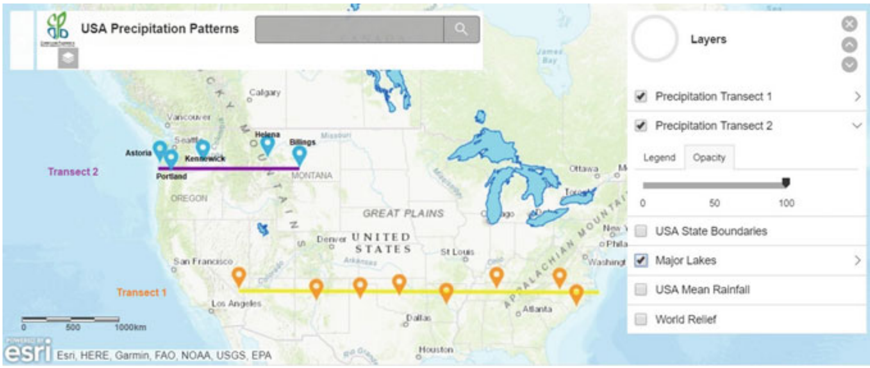

Fig. 11.2 GIS map showing precipitation levels across two transects in the USA (reproduced from Esri, ArcGIS Online)

Turn	Speaker	Classroom talk
179	T2	S10, what do you recall from relief rain?
180	S10	The mountain lah
181	T2	The mountain lah. Remember I don't like one word or few words. The mountain, what about it?
182	S10	Leeward and the don't know what, don't know what
183	T2	Ok. The don't know what, don't know what. Ok. S11, relief rain. So can you help what S10 was saying, he said "leeward" then "don't know what, don't know what." Can you phrase it?
184	S11	There are two sides of the mountain, then…
185	T2	Two sides of the mountain. A bit louder, so this side can hear you
186	S11	Two sides of the mountain, a windward side and leeward side
187	T2	Ok. So? How does this lead to what we are talking about in terms of rainfall?
188	S11	Because the place with higher altitude then the…
189	T2	Ok. I help you a little bit. Just now you mentioned there is two sides of the mountain, the windward side and leeward side. Link back. What happens?

T Teacher, *S* Student

In this segment, Teacher 2 prompted the students to recall the concept of relief rain (Turn 179), before guiding them towards developing an explanation by linking the presence of the mountain range in the map to the formation of relief rain in Turn 181 ("The mountain, what about it?"), Turn 187 ("How does this lead to what we are talking about in terms of rainfall?", and Turn 189 ("Link back. What happens?"). Alongside these moves, Teacher 2 consistently encouraged her students to rephrase their responses in more appropriate geographical language. Love (2009) argued that teachers' emphasis on and encouragement to use specialised, technical discourse helped students differentiate academic language from everyday language and modified how they expressed their reasoning to a form that was valued in the discipline.

In this case, Teacher 2 was consistent in mediating students' output by encouraging them to talk like a geographer. In response to the student's answers "The mountain." and "the don't know what, don't know what", the teacher pushed the students to use geographical terms by asking "Remember I don't like one word or few words." (Turn 181) and "Can you phrase it?" (Turn 182). Such filtered output served as inputs (Andrews, 2001) that demonstrated the appropriate way to describe a geographical phenomenon to other students. It enabled the teacher to elicit and draw students' attention to the geographical terms "windward side" and "leeward side".

We also observed that this recasting effort often occurred as a collaborative effort, supported through teachers' use of a talk move that invited students to restate other students' contributions (see Table 11.2). In this instance, Teacher 2 invited another student to expand on, complete, and modify S10's answer in Turn 182 ("Leeward and the don't know what, don't know what.") to "There is two sides of the mountain, a windward side and leeward side." (Turn 186). In such interactions, each student's contribution had the potential to serve as a resource for a whole-class learning experience (Dawes et al., 2010).

These observations led us to believe that it would be important to add the talk move *recast* to the range of prompts that geography teachers could use in their classrooms. For instance, prompts like "How might we make this a more geographical answer?" or "Could you phrase this in a geographical manner?"—used with existing talk moves that encouraged students to engage with each other's responses—would be of value to geography teachers. This could help to address students' imprecise use of geographical content vocabulary noted by Ho et al. (2017), and with practice, could lead students to extend their own utterances and improve their ability to produce talk that is acceptable or appropriate to disciplinary-specific norms (Boyd & Rubin, 2006).

11.3.4 Increased Engagement and Student Input

Overall, a key finding in the study was the perception among teachers and students that the use of talk moves that invited students to engage with their own reasoning and build on one another's ideas had led to more active participation in class discussions by students. For instance, Teacher 1 stated:

> Yeah, I find that they're more active. I think if you watch the video again, I think they are more participative. And there's really discussion, yeah. (Post-project interview)

Teacher 2 also noted that students were more interested in participating in class.

> …if you talk in terms of appreciating the subject a little bit more, I think so. After the exams when we were doing *Tourism*…I thought they were more enthusiastic, and thought they were a bit more responsive also… Maybe that aspect is obvious. (Mid-project interview)

Student focus group discussion data similarly pointed to a perception that the increased participation helped them to construct geographical knowledge with the help of their peers, which improved their learning.

> So, I feel that when we are sharing and learning together, we can get to know each other's answers, so at the same time, if let's say I know my friend's answer, there's a mistake in it, I can guide her and as well she can guide me. So, we can actually learn [sic] our mistakes together and know how to prevent it and then our answers, we can combine to form a perfect answer I guess, and then it helps us understand much better. (Class 2 post-project FGD)

In addition, both teachers reported becoming more self-aware in the ways that they asked questions in class. For instance, Teachers 1 and 2 both discussed the usefulness of using talk moves to help them think through the purpose of the questions used in class in order to provide focus to class discussions.

> So, these different focus areas… let me know why do I ask that question, what is my purpose of asking that question. So, it's beneficial to me in a way that now I know, if it is just, if I want them to have response for the discussion then I would need them, I need to ask, focus on certain area of questioning. (Teacher 1, Post-project interview)

> Of course, we must be willing to… to… like you said in this case, willing to really think, okay, what kind of questions I want to ask, how do I wanna ask, and then when they respond, and then what else do I respond... (Teacher 2, Post-project interview)

Through the explicit use of talk moves, the two teachers in the study were able to draw on students' own thinking, prompt them to elaborate on their own answers, and help them to construct geographical knowledge (Chin, 2007). This supported the inquiry-based pedagogies used by the teachers, where the discussions around multimodal data allowed students to co-construct geographical knowledge in a manner similar to disciplinary practitioners (Burke & Welsch, 2018).

11.4 Conclusion

In this chapter, we highlighted a number of key points relating to geography teachers' language knowledge for content teaching. Firstly, we highlighted the importance of teachers' talk moves, as a pedagogic strategy, to engage students with multimodal data, (in this case graphical data and a map), to construct content knowledge. Geography teachers' skilful use of talk moves contributes to a dialogic teaching context that supports students in making sense of geographical discourse. This resonates with the observation by Xu and Harfitt (2019) that language-aware teachers tend to encourage students' self-scaffolding and probe for the expansion of the class learning space through their strategic questioning. The TLA mediation helps teachers to achieve a linguistic shift from a situation where the teacher supplies students with correct answers to students recasting their own answers.

In addition to the talk moves that promoted productive classroom discussion adapted by ELIS that the teachers were already using at the start of the study, we highlighted specific moves that were relevant for analysing and interpreting multimodal data in the context of geography. This included moves that helped students to *decode* data, *specify* evidence from the data, and *recast* their reasoning in precise language that is relevant to the discipline. However, we also noted that in decoding or specifying data, there was often a tendency for teachers to tell the students where to look, rather than prompt students with questions that helped them routinise these important skills for themselves. Chin (2006) suggested that in constructivist, inquiry-oriented classrooms, "questioning is used to diagnose and extend students' ideas and to scaffold students' thinking" (p. 1319). In our study, we note, therefore, the need for question prompts that help students to engage in the *thinking routines* that disciplinary practitioners use when analysing new data themselves. We have provided examples of such prompts in Findings 2 and 3 above. This study expands the TLA framework by including productive talk moves that help build a dialogic classroom environment for both content teaching and language learning in geography and pays attention to the role of explicit instruction in mastering disciplinary literacy skills (Brown & Ryoo, 2008) across distinctive subjects (Schleppegrell, 2004; Shanahan et al., 2011).

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Chapter 12
Commentary: What Do We Mean by "Language"? And Other Key Questions Related to Building a Language-Related Knowledge Base for Teachers

George C. Bunch

As this volume compellingly demonstrates, it is not only language teachers who need to know something about language. *All* teachers—through their own language use, their understandings and ideologies surrounding their students' language, and the opportunities they do (or do not) create for students to use and develop language—play a central role in the language of the classroom. And so it is important to explore, as this volume does, what teachers across the content areas know about language, what they need to know, and how we (researchers and teacher educators focusing on issues related to language for teachers) can best support teachers to develop that knowledge. This exploration is particularly urgent as we attempt to challenge educational policies and practices around the world that have resulted in disproportionately low access to high-quality disciplinary instruction—including opportunities to engage in the linguistic and disciplinary practices of those disciplines—for students from marginalized backgrounds.

Yet, as the current volume also illustrates, articulating *what* knowledge about language that teachers need to have, not to mention how best to prepare them with this knowledge, is no simple task. So I appreciate the invitation to comment on this important collection of chapters, which outlines work done by researchers and teacher educators across three different continents and a wide variety of contexts. Reading the chapters helped me both clarify and complicate my own thinking about what Galguera (2011) originally called Pedagogical Language Knowledge (PLK), a notion that I subsequently adapted (almost a decade ago) and used to explore literature addressing the preparation of content-area teachers with language knowledge (Bunch, 2013). Since that time, the term PLK has appeared frequently in work on language-related preparation for teachers, as have other important constructs, including Disciplinary

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Linguistic Knowledge (Turkan et al., 2014); Literacy Pedagogical Content Knowledge (Love, 2009); Teacher Language Awareness (Andrews & Lin, 2017; Lindahl, 2019); Content and Language Knowledge for Teaching (Morton, 2016); Linguistically Responsive Teachers (Lucas & Villegas, 2010); and Educational Linguistics for teachers (Fillmore & Snow, 2002).

Drawing on the notion of Pedagogical Content Knowledge (Shulman, 1987) and arguing that canonical wisdom from the fields of linguistics and second language acquisition did not adequately describe the language-related understandings needed by content-area teachers, I defined Pedagogical Language Knowledge as "knowledge of language *directly related to disciplinary teaching and learning and situated in the particular (and multiple) contexts in which teaching and learning take place*" (Bunch, 2013, p. 307). So it was a pleasure to see all the authors in the current volume firmly position their language work with teachers in the *disciplinary* contexts of content-area classrooms.

Reflecting on the variety of approaches represented in the chapters, I am convinced more than ever of the need for clarity on questions such as what we mean by language, what specifically it is that we want teachers to be able to help their students do (and in what contexts), and how our ambitions as linguists line up with available resources such as time and expertise available in different teacher preparation contexts, at different scales. I would like, therefore, to raise a number of questions that might be productive to ask about *any* endeavor (past, current, or future) aimed at building a language-related knowledge base for teachers.

12.1 What is the Primary Goal of a Language-Related Knowledge Base for Content Teaching?

Although no grouping is perfect, it could be argued that the range of initiatives portrayed in this volume coalesce into three broad categories of goals for working with teachers on language. Although not mutually exclusive, each of these goals does reveal different priorities, and it is worth considering the differences among them.

12.1.1 Teach Teachers to Analyze Functional Grammar with Their Students

The majority of chapters in this volume advocate for teaching teachers a set of linguistic features associated with the language conventions of particular subject areas and encouraging teachers to highlight these features explicitly with their students during the course of disciplinary instruction. Most describe efforts to introduce teachers to tools developed by educational linguists influenced by the systemic functional linguistics (SFL) of British linguist Halliday (1994). SFL focuses on "lexico-grammar," conceptualized as linguistic choices at the clause level that simultaneously represent the topic of an utterance, the relationship between speaker (or writer) and interlocutor (or reader), and the mode in which the communication is taking place. Two of the SFL-inspired chapters in this volume describe initiatives designed to encourage teachers to analyze the features of student writing in disciplinary contexts. Focusing on science education, Seah and Silver (Chap. 2) asked primary and secondary teachers in Singapore to bring to professional development sessions student writing that teachers found problematic from a language perspective. The authors introduced "new perspectives" to the teachers based on functional language in order to interpret their students' language challenges, and they asked teachers to develop lesson plans that explicitly called to attention those particular language structures. Meanwhile, Adams and Lin (Chap. 3) introduced secondary science teachers, also in Singapore, to a "functional literacy" approach. Their initiative focused on preparing teachers to engage in "joint construction" of texts with their students, after highlighting linguistic structures associated with a particular genre. The authors modeled this method of joint construction and then asked teachers to plan, conduct, and evaluate the effectiveness of lessons taught based on this approach.

Two chapters describe initiatives that began by introducing teachers to functional grammar related to subject-area textbooks, with the goal for teachers to introduce the same type of metalinguistic knowledge to their students. Patrick and Fang (Chap. 4) began their professional development with high school science teachers in Florida by introducing SFL constructs associated with science textbooks (*technicality*, *abstraction*, *density*, and *genre*) and encouraged them to focus explicitly on those features in the classroom. For example, teachers were taught methods to help students to break down words to identify roots and affixes, focus on nominalization, and look for and deconstruct noun phrases. Focusing on history, and also operating from an SFL perspective, Fitzgerald (Chap. 8) argues that teachers should understand the wide variety of ways that the historical notion of *cause* is represented grammatically in secondary history textbooks, and that they should share this knowledge with their students.

Also using SFL, Accurso and Levassuer (Chap. 5) present a six-year case study of one secondary chemistry teacher in a long-term initiative in Massachusetts designed to prepare teachers to both to understand the linguistic challenges facing students in science classes and to highlight what knowledge of genres and registers is relevant to science learning that students already possess. Rounding out the chapters focusing on preparing teachers with a knowledge of functional linguistics, Ardell and Yoder (Chap. 10) observed fifth-grade teachers in the Northeastern USA and looked for instances in which the authors believed that teachers should have provided a more explicit focus on the nature of figurative language in social studies classrooms. Ardell and Yoder propose a process for teachers to identify figurative language such as metaphors for their students, make explicit how "form-function meanings" are represented, and summarize the meaning of the figurative language and its significance for the lesson at hand.

12.1.2 Encourage Teachers to Foster Dialogic Student Discussion

In contrast to the chapters advocating for focusing teachers primarily on the linguistic features of disciplinary language, other chapters explore working with teachers on how language is used more broadly as a discursive and interactive classroom resource for engaging their students in disciplinary learning. In Chap. 11, Seow, Ho, and Lin, working with geography teachers in Singapore, report on preparing teachers to create and guide opportunities for their students to engage in the kind of inquiry that is central to geographical epistemology and pedagogy. They introduced "talk moves" that teachers can use to promote student inquiry, for example *seeking clarification*, *asking a student to restate another students' contribution*, and *probing for reasoning or evidence*. Teachers' language knowledge in this case includes their awareness of their own questioning practices, the extent to which their questions instantiate disciplinary practices, and the kinds of dialogic interactions in which they expect their students to be able to engage. Similarly, working with undergraduate pre-service elementary teachers in the Southeastern USA, Wrenn and Stanley (Chap. 9) focus on the role of teachers' "pedagogical and dialogic language knowledge" in using talk moves to promote historical and critical discourse in teacher "read-alouds" designed to promote historical thinking.

12.1.3 Prepare Teachers to Engage Students in Interpreting and Producing Multimodal Representations

Finally, two chapters focus on the importance of teachers' understanding that *various* representational modes, including but transcending language, are critical for disciplinary meaning-making and communication. In Chap. 6, Yeo and Tan report on demonstrating to primary grades teachers in Singapore an "image-to-writing" approach. This method leads students through a progression of scientific meaning-making that values students' everyday language resources, engagement with multimodal forms of scientific representation, and the comprehension and production of scientific language. For example, in a sixth-grade lesson on pollination, teachers guide students in discussing an animated video, sequencing a set of still images from the video, writing a description of each image using the active voice they are familiar with, transforming that writing to the passive voice commonly used in scientific discourse, and finally writing a definition of pollination. In this case, teachers (and subsequently, their students) learn that scientific inquiry begins with engagement in ideas, and that *different* linguistic choices may be useful at different stages of scientific meaning-making. Teachers also learn that students' own "everyday" language resources are valuable for their scientific communication, and that scientific communication relies on more than language alone.

Prain, in Chap. 7, also focuses on teachers' understandings of various kinds of *representation* in science education. Focusing on secondary science teachers in Australia, he positions the value of teachers' language-related knowledge in terms of the extent to which it allows them to foster students' own scientific inquiry, as well as students' ability to create, critique, and refine multimodal representations of their own thinking and the thinking of others. In what he calls a Representation Construction Approach, teachers focus on students' own vernacular language as a "main resource" for disciplinary learning, as well as on the symbolic meaning-making potential of multiple representations (graphs, diagrams, tables, flowcharts, mathematical symbols) for scientific reasoning and communication. Prain outlines a process whereby teachers elicit students' own verbal responses to an inquiry question, ask them to make claims about the phenomena, and lead them through a "comparative review and evaluation" of the effectiveness of their representations. Throughout this process, students learn how different representations serve different purposes in scientific discourse and how *multiple* representations are often needed (emphasis added). To pull off all of the above, Prain argues that teachers themselves need a deep understanding of the nature and role of various representations in the concepts and processes of the topics they are teaching, including but not limited to "specialist content language," and how the various modes work together to make justifiable claims.

12.2 What Do We Mean by "Language"?

In reflecting on the different goals and approaches for their language-related work with teachers, it is clear that the authors of the various chapters base their initiatives on different conceptions of language—or at least on different ideas for what aspects of language should be prioritized in the often-limited time we have with teachers for such work. Obviously, a notion as complex as language can be defined and theorized in a multitude of ways (Cook, 2010). A full discussion of the differences is beyond the scope of this brief commentary. As van Lier (2004) has argued, "one single-all-encompassing" theory may be impossible for a construct as vast and elaborate as language, and most theories attempt to deal with only selected *aspects* of language (van Lier, p. 23).

But it is important to acknowledge that, whether the connection is made explicitly or not, decisions about language-related teacher development approaches are ultimately decisions about which aspects of language are most important for learning and teaching in content-area classrooms. Valdés et al. (2014) have linked different foundational theories of second language development (formal, cognitive, functional, and sociocultural) with their corresponding teaching practices, emphasizing the need for teachers (and teacher educators and researchers) to understand that different approaches to working with "language" in the classroom are linked to different theories of language and language development. Whether teachers know about the different scholarly theories or not, they are tapping into assumptions about language and how it is learned as they choose among various options: whether to focus explicitly on the meaning that grammatical structures makes in content-area texts, ask students to complete more generalized grammatical accuracy exercises, provide of large amounts of "comprehensible input," teach students cognitive language learning strategies, or focus on apprenticeship into language practices associated with different disciplines through engagement, interaction, and scaffolding (Valdés et al., 2014). It may be the case, of course, that teachers tap into more than one of these perspectives on language to use more than one teaching approach. But our goal is to help teachers (and teacher educators) move beyond simply selecting *a la carte* from a language pedagogy menu without understanding the assumptions about language and language learning underneath their choices.

Here again, the current volume is helpful, in that the chapters highlight a range of different options, situated in different visions of language knowledge important for teachers. In their introductory chapter, editors Seah, Silver, and Baildon allude to the importance of a range of perspectives on language and language development relevant to preparing teachers, including those variously derived from the "linguistic turn" and the "interactional turn" in educational research, the notion of "voice," different ways that texts are read in different disciplines, and the construct of "socialization" into academic discourse communities.

Seah, Silver, and Baildon, however, are also clear in terms of which view of language they themselves privilege, quoting Thornbury's definition of Teacher Language Awareness as "the knowledge that teachers have of the underlying *systems of the language* that enables them to teach effectively." The editors explain that, in their own model, "knowledge of language" represents the implicit "linguistic competence" of a teacher (p. 4). Meanwhile, "knowledge *about* language," according to the editors, includes "the explicit, conscious (i.e. declarative) knowledge of the language," including "metalingual knowledge" to "label and describe the linguistic features, categories, functions, and conventions" (p. 4). Most chapter authors in this volume similarly emphasize the importance of teachers' understanding of language as a linguistic system and the importance of preparing teachers to use systemic functional linguistics in particular to explain to their students how different lexico-grammatical "choices" convey disciplinary meaning.

Other chapters, such as Seow, Ho, and Lin's on talk moves in geography classrooms and Wrenn and Stanley's on historical thinking read-alouds, take a different approach, emphasizing teachers' knowledge of the role of language in *structures of participation* in classroom discourse, more than *linguistic structures* themselves. The role of talk and discourse in classroom learning has, in fact, been the focus on considerable research over the years (see Resnick et al., 2015), suggesting a number of different language-related understandings important for teachers in disciplinary classrooms. Some language and teacher education scholars have focused on language as part of an apprenticeship process that socializes learners into disciplinary practices (Lee et al., 2013), such as those predicated on a sociocultural view of "meanings and understandings constructed not in individual heads, but as between humans engaged in specific situated social interaction" (Hawkins, 2004, p. 15). These approaches educate teachers about the nature of language as a social practice, and its role in facilitating students' access to disciplinary communities of practice, engagement in joint activity, scaffolds for learning, and classroom participant structures that facilitate language development and use for disciplinary learning (Galguera, 2011; Walqui & Bunch, 2019; Walqui, 2006, 2011). Such approaches do not deny the importance of an explicit focus on the linguistic structures of language, but rather situate that focus in the larger social context of participation in disciplinary practices.

The chapters by Yeo and Tan and by Prain, focusing on the importance of interpreting and producing multimodal texts in disciplinary settings, suggest that the notion of *language* itself may be too narrow a construct for understanding the semiotic resources, challenges, and opportunities present in content-area classrooms and what teachers need to know about them. This is consistent with calls from van Lier (2004) and others to expand our lenses of "what counts" in meaning-making, rather than limiting our focus to "some inner formal core of words and sentence patterns" (p. 43). van Lier (2004) argues that language cannot be "boiled down" to component parts such as grammar or meaning and that we must pay attention to how "verbal and non-verbal signs, as well as allusions to physical and social properties of the world, interface in intricate ways to create interpretations" (p. 43). Language, therefore, is inextricably linked to *action* (van Lier, 2004, p. 53; see also van Lier & Walqui, 2012).

In a similar vein, Haneda (2014) has argued that "academic communication" may be more appropriate than "academic language" for capturing "the multi-modal dynamics of learning and teaching as it occurs in classrooms" (p. 126). For example, Haneda points out that ethnographers studying scientists at work have observed that, "contrary to the logical and coherent process that is described in science textbooks and scientific papers as the Scientific Method, actual scientific practice involves collaborative creative work, including tool-mediated action, imagination, and scientific reasoning" (Haneda, 2014, p. 129). To be clear, shifting the lens from academic language to academic communication does not deny the importance of teachers' knowledge of language for understanding, developing, and expressing disciplinary content, but rather suggests that it may be important to help teachers contextualize language within a range of resources important for engaging in disciplinary practice wider than a finite set of linguistic features predetermined to constitute disciplinary language.

At the same time, Haneda (2014) reminds us that the development of academic communication is not "an end itself." Drawing on Freire and Macedo (1987), Haneda points out that the goal should be for schools to help students "not only... 'read the word' but also to develop the capacity to 'read the world'" (p. 130). Another important aspect of teachers' knowledge of language, therefore, is how language replicates or challenges relations of power. This focus includes interrogating the role of language in ideological constructions of linguistically minoritized and racialized subjects and perceptions of their language use (Flores & Rosa, 2015). In this volume, for example, Wrenn and Stanley include "critical disciplinary literacy," "critical talk moves," and text selection challenging dominant narratives among the language-related aspects important to prepare teachers to implement in history classrooms. Bartolomé (1994) years ago argued for the importance of "political clarity" for teachers, with a number of language-related implications. More recently, scholars and teacher educators have used SFL as a tool to help teachers understand the ways that relationships of power are instantiated in linguistic choices and to challenge these power dynamics (see Accurso & Gebhard, 2020). Others have focused on how teachers can recognize and capitalize upon their students' use of home languages or stigmatized varieties of English for engaging in disciplinarily valued practices, in ways often overlooked by teachers (Lee, 2001; Moschkovich, 2007a). And some have critiqued the ontological and epistemological bases of various disciplines themselves as being rooted in oppressive and violent histories, with implications for teachers' understanding of the language used in those disciplines (Medin & Bang, 2014).

My point in this commentary is not to argue for the superiority of any of the particular approaches to language described above. Clearly, they all capture different truths about language. Nor am I suggesting that each perspective is mutually exclusive, or that language-related work with teachers cannot incorporate more than one of them. Rather, I am pointing out that choices made about how we spend limited language-related time and resources with content-area teachers should be based on clarity regarding how we view language and which aspects of language we consider to be most important for teachers to be knowledgeable about.

12.3 What Do We Know About the Subject Areas that We Are Focusing on, and What Sources Are We Using to Understand the Nature of Language in Each Discipline?

As language specialists (myself included) increasingly work in disciplinary contexts in primary and secondary schools, it is helpful to ask ourselves a number of questions. First, how much do we actually know about the disciplinary practices in the content areas we are engaging with, and what do we know about how language can be used to engage in those practices? And how do we learn more? Some scholars and teacher educators leading language-related work with teachers have a background themselves in the relevant disciplines. More often, however, we are "language experts," trying to learn as we go about the subject-area contexts of the teachers we are working with. Content-area teachers themselves, of course, can be valuable sources in this endeavor. But we must also understand that subject-matter teachers, for a wide variety of reasons, may have had limited background in the actual disciplinary practices of their fields. It is necessary, therefore, for us "language people" to consult research, scholarship, and national and state policy guidance surrounding goals and pedagogical approaches in the different disciplines. It is also necessary to ascertain the extent to which standards and frameworks are consistent with what experts in content-area education in each field have to say. We need reliable content-area colleagues to help us sort this all out. Especially valuable are collaborations with those disciplinary scholars who have already taken it upon themselves to think deeply about the role of language and literacy in their content areas, or who are willing to engage with language scholars to do so.

A related question is what sources we use as instantiations of the language of the disciplines. We could, given my discussion earlier, say that the answer to this question depends on what we mean by language, but my point here is a different one. No matter which orientation to language is being taken in our work with teachers, there is almost always a claim (explicit or implicit) regarding the nature of the "language of __________" (insert *science*, *mathematics*, *history*, and so forth). It is worth asking, however, "according to whom or to what?" and "in what particular context(s)"? Is the "language of science" the same in middle school textbooks as it is in peer-reviewed academic journals? What about professionals engaging with colleagues in a laboratory meeting? Professors giving a lecture in higher education? High school teachers leading a whole-class discussion? Fifth-grade students engaged in group work? Articles in the *New York Times* or *Scientific American*? As Moschkovich (2007b) has pointed out in the case of mathematics, there is not a single language of mathematics, but rather *multiple* mathematical discourse practices, each characterized by different uses of language. Academic mathematicians in higher education use language differently than do statisticians working in the government. The language practices of both of those fields differ from the language of mathematics used in the many communities and homes, and even math teachers use language differently based on which grade they are teaching and whether they are teaching in settings influenced more by traditional or reform-oriented mathematics teaching.

In our work with teachers, therefore, it is important to be clear about *which* discourses we are referring to when we speak about the language of a discipline and to take care to not inappropriately extrapolate features of language from one of those contexts, assuming that it is required or even appropriate for another. Ultimately, as Moschkovich (2007b) points out, it is true that some common practices are valued across settings in a particular discipline (e.g., in mathematics: abstracting, generalizing, making claims, and searching for certainty). But, as pointed out in other disciplinary contexts by several of the chapter authors in this volume, students can show conceptual understanding in a wide variety of ways, including through "everyday" language and multimodal resources, even as they work to expand their repertoire to include other disciplinary language forms and practices (see also Moschkovich, 2012).

The question of the extent to which textbooks should be used as a source of knowledge about the language of the disciplines is a particularly fraught one. In some classrooms, they are an important source of access to subject-matter content, while in others, they sit gathering dust as teachers choose other means of engaging their students in the disciplines. It is hard to argue that the ability to comprehend the language and content of textbooks will not serve students well across the grade spans. But I am concerned about teachers coming to believe that the language of school textbooks is *the* "language of the discipline." There are, in my mind, at least two problems with relying too heavily on textbooks as instantiations of disciplinary language (not necessarily made by the authors in this volume, but something I worry about when thinking about wider application with teachers). First, the language used in school textbooks may actually be poor representations of the language and practices valued in the relevant disciplines. For example, history textbooks, at least in the USA, are often characterized by oversimplified narratives, missing footnotes and citations, invisible authors, and lack of clear causal language—thus actually *violating* practices valued by historians rather than representing them (Bunch & Martin, 2020, p. 7). Second, even if particular textbooks do feature good examples of writing in particular disciplines, teachers must understand that the goal is not necessarily to get students to mimic that language in all phases of their disciplinary engagement. Instead, as cogently illustrated in several of the chapters in this volume, the goal is to recognize the ways that *different* kinds of language play *different* roles as students engage in disciplinary practices, access various oral and written texts (and other representations), grapple with meaning in consultation with their teacher and classmates, and communicate their understandings and arguments (in various modes) to others.

12.4 Who Are Our Students, and What Are They Already Able to Do with Their Linguistic (and Other Semiotic) Resources?

One of the mantras of education, across a variety of traditions, is *start with the students*, and this could serve as sage advice for thinking about approaches to developing teachers' language knowledge. Although perhaps I should have begun this commentary with this question, I will instead honor its importance by concluding with it. Each chapter in this volume focuses on teachers of students from widely different backgrounds. Some focus on teachers of general or "mainstream" students, often linguistically and culturally diverse themselves, and others focus on learners of the dominant language of instruction (English, in all the chapters in this volume) as an additional language. Approaches to language with teachers will naturally be different in each of these contexts. Even within a single one of these student populations, there is possibly extreme variation. For example, among "English Learners," there may be significant differences in English language proficiency levels, economic status, formal educational background, and racial and ethnic backgrounds, all of which of course intersect with how students—and their language practices—are positioned by their teachers, their classmates, and themselves.

It is encouraging, therefore, to see "Knowledge of Students" as one of the central features of the language-related knowledge base for content teaching model presented by Seah, Silver, and Baildon in their introductory chapter. Importantly, such knowledge about students transcends understanding the extent to which they are familiar with language used in the different disciplines. As the editors point out, the chapters in this volume to at least some degree view language and learning as "socially, historically, and culturally situated," with culture in this context understood to involve "systems of meaning... linked to notions of practice" (p. 10). Thus, Seah et al. argue, knowing students involve knowing something about how they interact with the world in various contexts, including how their communicative practices and learning are immersed in ideologies and relations of power: "As learners encounter multiple discourse communities in their everyday lives, there is also a need to consider how these discourses, or uses of language, are legitimated, and disseminated in various communities" (p. 11).

It follows that encouraging teachers to learn more about their students, and providing teachers with the tools to recognize the multiple, often undervalued, linguistic resources that *all* students bring with them, is a crucial part of teachers' language education (Lucas & Villegas, 2010; Valdés et al., 2005). Teachers need to know how students can use a wide variety of linguistic and other semiotic resources to effectively learn, demonstrate their learning, and engage in disciplinary practices. In places where English is the dominant societal language of education, for example, valuable resources that students bring with them include home languages other than English, non-dominant varieties of English, "everyday" language, and multimodality of various forms (Lang, 2021; Martínez & Mejia, 2020). As suggested in various places throughout this volume, recognizing students' existing forms of meaning-making, not as impediments to disciplinary learning, but as its most important first step, may be the most productive starting point for developing a language-related knowledge base for teachers across the curriculum.

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