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Integrating disciplinary-specific genre structure in discourse strategies to support disciplinary literacy

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Abstract

Classroom discourse plays an important role in shaping how students learn science in the classroom. Past research has examined how content area teachers use a variety of generic discourse strategies to foster classroom interaction and content mastery. However, few have focused on how teachers' discourse strategy can be used in more specific ways to build subject-specialized genres of the discipline, such as scientific explanation. The purpose of this study is to examine how science teachers integrate disciplinary-specific genres in their discourse strategies to engage their students in thinking about the conceptual and epistemic aspects of the discipline. Through a three-year design research, four science teachers learned a genre-based instructional method designed to explicitly teach students how to construct scientific explanations. Lesson observations from these teachers before and after they learned the genre-based instruction were video-recorded and analyzed. It was found that with the incorporation of the genre-based instructional method, a discourse strategy that we call meta-discoursing was employed in new ways to facilitate the teaching of the explanation genre. Using multiple exemplars, we describe the ways in which this discourse strategy was enacted in tandem with the genre-based instructional method to facilitate disciplinary literacy through classroom talk.

Keywords:

Disciplinary literacy; scientific explanation; genre; classroom discourse strategies; metadiscourse; metalanguage

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Introduction

Oral discourse strategy is a crucial component of classroom teaching and interaction in all content areas. A common discourse strategy is the use of questioning to arouse student interest, monitor their understanding, and promote thinking (Wragg & Brown, 2001). Past research on such discourse strategy reveals the predominant use of a triadic Initiate-Response-Evaluate (IRE) dialogue where the teacher *initiates* a question (I), elicits a student's *response* (R), and then *evaluates* (E) the correctness of that response (Mehan, 1979). Because the IRE dialogue is often seen as a didactic and controlling structure (Lemke, 1990), many researchers and teachers have looked for ways to modify this questioning strategy to make classroom talk more engaging (Edwards & Mercer, 1987). One common approach is to make the last move in the triadic exchange less evaluative and more of an extended "follow up" (F) to scaffold students' construction of knowledge (Boyd & Rubin, 2006; Wells, 1993), thus turning the exchange into an IRF or IRF-RF- chain of questioning (Mortimer & Scott, 2003). Building on this approach, several techniques have been identified to make the "follow up" move more dialogic, such as Socratic questioning (Hogan & Pressley, 1997), reflective toss (Van Zee & Minstrell, 1997), revoicing (O'Connor & Michaels, 1993), and constructive challenge (Chin, 2006).

The above-mentioned research has identified many useful techniques teachers can use to improve their pedagogical repertoire. These techniques are not specific to a discipline and, as such, they can be used in all content areas. Although such general techniques are versatile as they can be applied across all academic subjects, the trade-off is that they are limited in facilitating disciplinary-specific talk in the classrooms. In science education for example, specialized genres such as scientific explanation, report, and argument are commonly found in science texts and discourse in the classrooms (Wellington & Osborne, 2001). These genres are also linguistically and epistemologically distinct from other text genres that children are

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more familiar with (Halliday & Martin, 1993). Therefore, they require more specific ways of facilitating students' mastery of disciplinary-specific discourse through classroom talk. In this respect, few studies have focused on disciplinary-specific discourse strategies that can be used to build the specialized genres of the discipline in the classroom.

The purpose of this study is, therefore, to explore how disciplinary-specific genres can be incorporated into classroom discourse so as to support students in developing disciplinary literacy, or the specific ways of talking, reading, writing, and thinking used in a discipline (Moje, 2008). Specifically, through a three-year research partnership with four secondary school science teachers in Singapore, we developed an instructional method called the Premise-Reasoning-Outcome (PRO) to teach students the genre of scientific explanations (Tang, 2015, 2016a). The participating teachers and students learned about the PRO method and incorporated it into their discourse. We then compared video-recorded lesson observations from these participants before and after they learned the PRO method in order to examine their discourse with and without a disciplinary-specific genre structure. From this comparison, we observed the teachers used a new discourse strategy which we call "meta-discoursing," to help their students learn the explanation genre. The focus of this paper is to illustrate this meta-discoursing as the teachers integrated the PRO method into their existing discourse strategies.

Theoretical Perspectives

Disciplinary Literacy

This study is situated within the research on disciplinary literacy. Disciplinary literacy refers to the ability to use the specialized language and practices of a discipline to access and construct knowledge in that discipline (McConachie et al., 2006; Moje, 2007). In recent years, curriculum reforms and standards around the world are putting more emphasis on disciplinary literacy instruction in science (National Research Council, 2014).

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According to Shanahan and Shanahan (2008), there are two research areas that influence the conceptualization and development of disciplinary literacy. The first area comprises studies that examine the cognitive and epistemic practices engaged by experts in a discipline and compare them with those of novices. Informed by the cognitive sciences, initial studies tend to examine the reading and sense-making practices of students vis-à-vis scientists in order to derive implications for the design of disciplinary literacy instruction (e.g., Holliday, Yore, & Alvermann, 1994; Kozma, Chin, Russell, & Marx, 2000). During the period leading to the Common Core Standards and the Next Generation Science Standards in the USA, there was an increasing emphasis on using literacy to support scientific inquiry and practices (Pearson, Moje, & Greenleaf, 2010), notably in the practices of constructing scientific explanation, engaging in evidence-based argumentation, and communicating multimodal information (Tang & Danielsson, 2018).

Within the research in explanation and argumentation, several researchers have developed literacy tools to engage students in the practices of scientific explanation and argumentation (see Duschl & Osborne, 2002). For instance, the Science Writing Heuristic (e.g., Hand, Prain, & Wallace, 2002; Nam, Choi, & Hand, 2011) was developed and used as an epistemological tool to help students understand how scientific claims are made through argumentative investigations and activities. Others have also developed frameworks based on Toulmin's (1958) model of argumentation to scaffold students' writing process in constructing scientific explanations (McNeill & Krajcik, 2008; Sandoval & Millwood, 2005).

The second research area is informed by systemic functional linguistics (SFL), which examines the language processes in knowledge creation and communication within a discipline (Schleppegrell, 2004). SFL is a theory of how people use language to make meanings in specific social contexts (Halliday, 1978). As the language of science is unique (Lemke, 1990), students need explicit teaching about its specialized genres and language

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conventions in order to effectively participate according to scientific norms. In particular, the genre of explanation poses a challenge for many science learners (Halliday & Martin, 1993).

According to Martin (1992), a genre has distinct functional stages that can be identified on the basis of lexical and grammatical shifts in the text. An explanation genre comprises three functional stages called phenomenon identification (what is being explained), implication sequences (series of logical clauses), and closure (Veel, 1997). The implication sequences stage is the defining characteristic of an explanation and it has two prominent linguistic features: a relatively high proportion of action verbs and the use of conjunctions (e.g., because, when, however) to construct logical relations across clauses and sentences (Martin, 1993). Unsworth (2001) attributes the "language of reasoning" in an explanation to the patterns of logical relations formed by conjunctions. Much of the analysis on scientific explanation within SFL focuses on written explanations (e.g., Halliday & Martin, 1993; Unsworth, 2001).

PRO Instructional Method

Based on the above-mentioned areas of research in disciplinary literacy, Tang (2015, 2016a) developed the PRO instructional method to support students in learning one of the epistemic processes of science – the construction of scientific explanations. The method involves identifying and using three components of a scientific explanation: premise (P), reasoning (R), and outcome (O). Informed by Braaten and Windschitl's (2011) work, the *premise* is the basis or "first cause" of an explanation and can comprise well-established laws, theories, or big ideas accepted in the scientific community. The next component of the explanation is the *reasoning* that follows logically from the established knowledge in the premise. Based on work in SFL (e.g., Unsworth, 2001), this reasoning process is built up from successive clauses connected by conjunctions. Eventually, this sequence of reasoning connects to the *outcome*, which is the phenomenon to be explained in the explanation.

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The following example illustrates the PRO structure in a scientific explanation to the question, "why does a solid have a fixed shape and volume?" (Tang, 2015):

Premise (P) There **are attractive and repulsive forces** that hold the molecules in the solid in fixed position. (*This is accepted knowledge commonly taught in most secondary school science curricula*).

Reasoning (R) The strong attractive forces **prevent the molecules from leaving** their positions (*This is a causal effect from the above premise of attractive and repulsive forces*)

<u>while</u> the repulsive forces, which act when they are too close together, **prevent them from collapsing**.

Thus, the molecules can **only vibrate** about their fixed positions

<u>and</u> they are **held together** in a regular pattern

Outcome (O) <u>Therefore</u>**,** a solid **has a fixed shape and volume**.

- <u>*Underline*</u> denotes conjunctions joining independent clauses
- **Bold** denotes main clause consisting of the main process (verb) and participants (noun).

In a previous study, Tang (2016b) examined the impact of the PRO instructional method on student writing in science. Based on a corpus of examination papers collected over two years, it was found that students' written explanations that exhibit a PRO structure were graded better by the teachers, thus suggesting that students who wrote with a PRO structure were able to produce conceptually better explanations.

Scaffolding Classroom Talk through Meta-discoursing

Although there has been some progress in disciplinary literacy on both the epistemological and SFL fronts, much of the research including our previous study (Tang, 2016b) centers on students' writing. There is comparatively less research on fostering disciplinary literacy through talk, particularly on integrating disciplinary ways of talking into

classroom discourse. On the other hand, much research outside disciplinary literacy has considered how science teachers can scaffold classroom talk to create opportunities for students to co-construct content knowledge with the teacher (e.g., Boyd & Rubin, 2006; Mercer, Dawes, Wegerif, & Sams, 2004; Mortimer & Scott, 2003). In this study, our point of departure is that teacher-led talk can be a potential resource for weaving the epistemic and genre requirements of a discipline into classroom instruction. Through this study, we assert that one of the ways teachers can accomplish this is through a discourse strategy that we call "meta-discoursing," which we define as the use of metadiscourse to guide students in learning the discourse of the discipline.

Metadiscourse, also termed meta-talk by Schiffrin (1980), refers to the linguistic resources used for organizing propositional content to construct a discourse, for interpreting, evaluating and developing attitudes toward that discourse, and for helping outsiders or new entrants understand how discourse is constructed within a given discourse community and context for a given purpose (Hyland, 2005; Vande Kopple, 2012). Metadiscourse is characterized by strategies employed by the speaker or writer that illustrate the speaker or writer's reflexivity and intentionality (Hyland, 2005). These strategies operate primarily by means of bracketing the discourse on "a referential, informational plane when it serves as an organizational bracket, and on an expressive, symbolic plane when it serves as an evaluative bracket" (Schiffrin, 1980, p. 231). These two bracketing strategies are called organizational and evaluative metadiscourse. Organizational metadiscourse includes text connectives like "let's *go back* to the experiment *just now*" and "we need to *start from*", while evaluative metadiscourse includes attitude markers like "this is an *important* link" and "I know this is a *difficult* part" (Tang, 2017).

Because it serves to both organize and evaluate propositional content, metadiscourse is an integral part of classroom talk. In particular, it serves as a discursive resource for the

teachers to direct and shape ongoing classroom talk about subject content in accordance with the discourse practices for a given subject. In this study, we noted that metadiscourse occurred quite frequently in the classroom talk. However, with the introduction of the PRO method that highlighted the epistemic structure and genre of a scientific explanation, we noted a qualitative change in how the teachers used metadiscourse to engage the students' thinking. We were thus prompted to investigate this phenomenon further.

Methodology

Research Context

The data for this study were taken from a three-year design research (Collins, Joseph, & Bielaczyc, 2004) aimed at developing disciplinary literacy instruction in science at two secondary schools in Singapore. Four teachers (one physics and one chemistry teacher from each school) took part in the project based on recommendations by their school leaders for their experience and eagerness to improve their teaching repertoire. Both physics teachers were male while the chemistry teachers were female. One class from each teacher was selected for classroom observation. At the start of the study, there were 107 participating students, with 87 students in the 9^{th} grade and 20 students in the 10^{th} grade. The average class size was 29 students. These students were generally motivated and their academic abilities were average and above average, according to results from a national examination taken at the end of 6^{th} grade.

The research project consisted of two phases. The first phase was a baseline observation of the four teachers' teaching practices in physics and chemistry over six months. It was observed that the teachers predominantly delivered content information through an IRE or IRF dialogue with the class (see Tang, 2016b). Although the teachers used several strategies (e.g., Socratic questioning, wait time, think-pair-share) in their oral repertoire, no genre-specific literacy strategy was observed during the first phase of the research. Based on

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this observation, the research team developed the PRO method in order to help the students focused on the genre of scientific explanation.

The second phase was the intervention phase of the design research that involved collaboration with the teachers to co-develop lesson ideas and materials to be enacted over the next two years. It was during this phase that the PRO method (along with a suite of literacy instructions; see Tang & Putra, 2018) were introduced to the teachers, who went on to implement them in their classrooms. Furthermore, the teachers also attended two professional development workshops conducted by the researchers. The first workshop focused on the role of disciplinary literacy for science learning in general, while the second workshop introduced the PRO method and a discussion on how to use it as a writing scaffold. Besides these workshops, there were regular meetings where the researchers and teachers brainstormed lesson ideas and discussed implementation issues for various physics and chemistry topics, such as forces and motion, density, kinetic model of matter, atmosphere, and electrolysis. Part of the discussion revolved around how to explicitly teach the students the structure of a scientific explanation through the language of premise, reasoning, and outcome. However, there was no discussion on meta-discoursing during the workshops and meetings because this analytical focus only emerged after the design intervention was concluded.

Although the teachers learned the PRO method from the research team, they had full ownership and flexibility in incorporating the method in their lesson design and implementation according to their teaching style and the classroom context. Part of the purpose of the research was then to examine how the teachers integrated the PRO method into their existing teaching practices. Therefore, we compared the classroom talk before and after the teachers learned the PRO method in order to examine their discourse prior to and

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after introducing a disciplinary-specific genre structure. Specifically, the research questions that guided this study were:

1. How did the teachers use discourse without and with the PRO method in their classroom talk? What are the key differences?
2. How did the use of PRO method in the teachers' discourse promote (or hinder) their teaching of disciplinary literacy in science?

Data Sources & Analytical Methods

In this study, we used ethnographic methods comprising classroom observation, video recording, field-note taking, and artifact collection, to collect data from the four observed classrooms. The primary data source for the study in this paper was classroom videos (about 124 hours) covering a range of physics and chemistry topics. The videos were recorded by one camera at the back of the classroom focusing on the teacher. Table 1 shows the number of hours observed for each teacher distributed over the baseline and intervention phases.

Table 1. Distribution of video data collected (hours:minutes)

		Baseline	**Intervention**	
		2013	**2014**	**2015**
School 1	Physics (John)	16:42	24:52	5:48
	Chemistry (Anne)	17:03	13:25	-
School 2	Physics (Derrick)	4:43	12:27	-
	Chemistry (Kathryn)	3:04	20:11	5:43
	Total (hrs:mins)	**41:34**	**70:57**	**11:32**

The analysis focused on systematically identifying what was observable in the data and then identifying emerging patterns in the teachers' discourse (Westgate & Hughes, 1997).

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Data analysis was carried out in three distinct phases: (a) segmentation and selection, (b) coding of utterances, and (c) micro-analytical discourse interpretation.

First, we segmented the continuous sequences in a lesson video into meaningful discrete units according to Erickson's (1992) ethnographic microanalysis methods. Each segment was determined by clear boundaries demarcating prominent shifts occurring in the classroom, such as a discernible change in the participants' interaction pattern and spatial orientation. The average duration of a segment was 3 minutes and 14 seconds. Segments that revolved around whole class talk focusing on scientific explanation were then selected and transcribed for further analysis. In addition, the subsequent analysis drew on segments before the introduction of the PRO method and segments where the teachers made deliberate use of the PRO method. The number of video segments and their duration selected for pre-PRO and post-PRO phase was 44 (3 hrs 6 mins) and 41 (3 hrs 42 minutes) respectively.

Second, we coded the utterances from every segment along three aspects of classroom talk focusing on the teacher, namely: (a) type of utterance, (b) purpose of utterance, and (c) metadiscourse. See Table 2 for the descriptions of these codes. We adapted Chin's (2006) codes for identifying the type and purpose of an utterance for our analysis. The type of utterance refers to whether it is a question or statement. The purpose of an utterance refers to the function of the discourse move, which includes probe, focus, accept, extend, justify, clarify, and consolidate from Chin's (2006) study, as well as other categories we identified, such as revoice, organize, connect, and challenge.

Table 2. Coding Scheme

Code	Description

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Type	
Question	A request for information.
Statement	Provision of information.
Purpose	
Probe	To question the scientific mechanism by asking 'why', 'how come', 'so what' and 'and then'.
Focus	To direct students' attention to a specific aspect of the propositional content or metadiscourse.
Organise	To direct students' attention to how thoughts, language and scientific explanation should be structured.
Accept	To affirm a student's answer e.g. 'yes', 'good'.
Revoice	To repeat and paraphrase a student's initial answer so as to introduce more precise subject language or greater specificity in the propositional content or metadiscourse.
Extend	To provide greater specificity in the description of the scientific mechanism.
Connect	To connect what is being said to what was said or learnt previously.
Challenge	To get students to re-consider their answer so as to arrive at correct and precisely described propositional content.
Justify	To provide a rationale for a decision or practice or answer.
Clarify	To highlight and address common misconceptions, confusion or wrong language use.
Consolidate	To summarise key points/considerations.

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Metadiscourse	
Text connective	To connect one part of a conversation to another using past and future signposting, sequencer and topicalizer.
Knowledge connective	To connect participants' prior knowledge or a known idea to current conversation.
Activity connective	To connect conversation to ongoing or external activities participants are or would be engaged in.
Attitude marker	To signal one's or participants' stance, such as importance, challenge, excitement, boredom, toward the propositional content
Epistemology marker	To reflect one's or participants' stance towards evidential status of propositional content
Interpretative marker	To direct participants to grasp or construct the appropriate interpretation

For metadiscourse, we used a typology developed by Tang (2017) consisting of six major categories of organizational and evaluative metadiscourse commonly used in science classroom discourse. The organizational metadiscourse comprises text connective, knowledge connective, and activity connective, while evaluative metadiscourse comprises attitude marker, epistemology marker, and interpretative marker (see Table 2 for code description, Tang 2017 for an example of each code). For example, the most common category of organizational metadiscourse observed was *text connective*, which was frequently used by the teachers to connect different ideas in an ongoing explanation together in a coherent manner. These text connectives include *prior conversation* (e.g. "what did I say just now?"), *future conversation* (e.g., "I will explain later"), *sequencer* (e.g., "first", "and then"), and *topicalizer* (e.g., "for scenario 1… for scenario 2"). The most common type of evaluative metadiscourse was attitude marker, which signalled the teacher's stance toward the propositional content, such as importance (e.g., "this is an important link"), challenge (e.g., "let's move on to the difficult part"), or affect (e.g., "wow, looks pretty cool huh?").

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Both authors were involved in the coding process. We began by viewing the video segments individually and analyzing them with tentative codes from Chin (2006) and Tang (2017). We met regularly to discuss and refine the codes iteratively with our emergent assertions. These codes and assertions were also tested with other video segments to check for confirming and disconfirming evidence. Disagreement between the authors was discussed jointly until a common interpretation was established.

The final phase was discourse analysis that involved interpreting key segments in greater detail and paying attention to the participants' moment-by-moment meaning-making and interactions as mediated by the teachers' discourse strategies. We compared the segments of classroom talk prior to and after the introduction of the PRO method to address RQ 1. This comparison was followed by a report on how the teachers' inclusion of the PRO method in their discourse facilitated their teaching of disciplinary literacy in science, which we used to address RQ 2.

Results

In this section, we report the key differences in the teachers' discourse prior to and after the introduction of the PRO method, with a particular attention to the use of metadiscourse. Particularly, we point out new ways of meta-discoursing that were observed with the integration of the PRO method. Such meta-discoursing:

1. Delineated the epistemic relationship between parts of a scientific explanation according to their genre structure
2. Served as conceptual and navigational markers to support non-linear development of a scientific explanation
3. Facilitated understanding and evaluation of the propositional content within an explanation genre

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In what follows, we illustrate with representative examples the key differences in the way metadiscourse was used before and after the PRO method was introduced, first for organizational metadiscourse and later for evaluative metadiscourse.

Teacher Discourse featuring Organizational Metadiscourse without PRO

Prior to the introduction of PRO, we observed that the teachers employed organizational metadiscourse mostly to signpost the propositional content being discussed. We observed this practice in IRF exchanges where the teachers had asked the initial question and followed up with more contextual information to supplement the question. In these "follow-up" moves, metadiscourse was typically used to: (i) signal the sequential order in which the propositional content should be developed and (ii) highlight the keywords to be incorporated in the explanation. Examples are drawn from Excerpt 1 below where a physics teacher, John, provided more information after he had asked the initial question, which was "How do we explain pressure of a gas using kinetic model of matter?"

Excerpt 1

Utterance	**Type**	**Purpose**	**Metadiscourse**
T: ***First, we'll have, we will start with*** air particles inside the balloon.	Statement	Focus	***Text connective – sequencer***
T: Okay, ***let's start with*** *a balloon then****.*** *(T erases the statement 'when air is blown inside' and leaves the statement '<u>more air particles</u> inside balloon' on the board)*	Statement	Focus	***Text connective – sequencer***
T: *How does gas inside the balloon exert a pressure?*	Question	Probe	
T: ***Let's use bubble then.***	Statement		***Activity Connective – ongoing activity***
T: *Obviously there is* ***one more chain of answer*** *here.* ***And then one chain of answer****. (Below the statement,* ***T draws 2 boxes with arrows to show sequence on the***	Statement		***Text Connective – sequencer***

Utterance	Type	Purpose	Metadiscourse
board*; See Figure 1)*			
T: …***So let's see what are the important keywords that you need to make use of.***	Statement	Focus	***Attitude marker – importance***
T: ***We want to use 'force', we want to make use of 'particles', we want to use 'area' because we want to talk about pressure. And we want use them 'continuously', 'randomly', and then maybe… 'collision'.*** *(T writes the keywords on the board)*	Statement	Focus	***Text connective – topicalizers***

Signaling the development of the explanation sequentially. In Excerpt 1, John marked out how he expected the explanation to be developed when he said "we will start with" and "let's start with." He identified this starting point as the scientific phenomenon of "air particles inside the balloon." John also highlighted the appropriate sequencing of propositional content through the use of an ordinal series with the word "first" and drew two boxes (see Figure 1) to reflect the chronological sequence. This example shows how teachers typically used text connectives at the beginning of an explanation (right after the question was asked) to signal some expectations or anticipation of how the explanation should be developed or linkages to a past conversation. At the same time, such text connectives were also frequently found in the developing and closing stages of the explanation when teachers used conjunctions like "and then," "next," and "now" to highlight the sequential order of the explanation.

[INSERT FIGURE 1 ABOUT HERE]

Facilitating development of explanation through reference to topicalizers. A common use of organizational metadiscourse in the teachers' discourse was to underscore the role of language in constructing an explanation by signaling keywords. This is similar to a topicalizer that calls attention to how bits of information are connected to one another (Vande

Kopple, 1997). For instance, in Excerpt 1, John made repeated references to the "use" of keywords and the need to "talk about" the keywords This illustrates how language was deployed in metadiscourse as topicalizers serving as conceptual markers to help students identify, organize, and expand on the requisite propositional content. The two instances of John using attitude markers, the word "important" and the clause "we want to," reflect the importance he attached to what he was saying concerning the use of keywords.

Prior to the introduction of the PRO method, it was observed that the teachers' metadiscourse was targeted at the word or phrase level in a chronological development of the explanation. However, with the incorporation of the PRO method, new ways in which the teachers employed metadiscourse to facilitate learning of an explanation genre were observed. These are discussed in the next section.

Teacher Discourse featuring Organizational Metadiscourse with PRO

The inclusion of the PRO method made qualitative differences to the teachers' organizational metadiscourse. In addition to the use of metadiscourse to direct the students' focus toward vocabulary and chronological steps (as discussed earlier), a new type of text connective highlighting the genre elements of an explanation text was observed when the PRO method was used. This text connective became one of the most frequently occurring type of metadiscourse. Organizational metadiscourse now encompassed (i) using PRO to delineate the relationship between the epistemic parts of an explanation and (ii) flexibly adapting PRO as conceptual and navigational markers for organizing propositional content to facilitate the writing of an explanation text.

One year after Excerpt 1 was recorded, John addressed the same question on kinetic model of matter with another class. The following excerpt, Excerpt 2, from one of his lessons is illustrative of how teachers used organizational metadiscourse with PRO to make

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distinctions and label various propositional content of a question according to their epistemic function.

Excerpt 2

Utterance	Type	Purpose	Metadiscourse
T: … explain using the kinetic model of matter, why gas, or air, sorry, air, blow into a balloon inflates it. *(T writes question on the board)*	Statement	Focus	
T: Notice***, it's again an explain question***. Now, yup, sorry, you were saying?	Statement	Focus	***Text connective-genre***
S: PRO			
T: ***so now***, ***since you say PRO…*** ***what's my P then?***	Question	Probe	***Text connective – genre***
S: Due to kinematic model of matter.			
(T writes "Due to kinematic model of matter")			
T: ***What's my outcome?***	Question	Probe	***Text connective – genre***
S: Balloon inflated			
T: So, or as, or so, the balloon is inflated.	Statement	Revoice	

Delineating the epistemic relationship between parts of an explanation. John employed PRO to illustrate to his students how the different parts of the question, namely, "kinetic model of matter" and "air blown into the balloon inflates it" were epistemically related to one another—the former was the scientific law (premise) that accounted for the occurrence of the latter phenomenon (outcome). The relationship of these different components of the question would, otherwise, have remained implicit. By having a linguistic moniker for scientific law, phenomenon and mechanisms, John was able to make explicit how these different pieces of information served different epistemic functions in an explanation text. With the introduction of the PRO method, the teachers and students began to develop a shared meta-language for naming the genre elements of an explanation. This

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shared meta-language enabled the teachers and students to delineate the epistemic relationship between different parts of an explanation according to their genre structure (i.e., premise, reasoning, outcome). Notice in this excerpt, it was a student who initiated using the PRO method.

Using conceptual and navigational markers to support non-linear development of explanation. Prior to the introduction of the PRO method, we saw earlier how the teachers' discourse was limited to signaling the sequential order of an explanation in a chronological manner. With the shared meta-language from the PRO method, the P, R, and O were used as conceptual and navigational markers to help teachers and students develop the explanation in a non-linear way.

In the following example, John flexibly adapted the PRO method in his organizational metadiscourse to facilitate the writing of an explanation for the 'dancing raisins' phenomenon. First, the students observed that when raisins were dropped into a beaker of carbonated water, they would sink and float repeatedly. Subsequently, John wrote a series of P, R and O vertically on the whiteboard (see Figure 2) and used these markers to guide his whole-class questioning.

[INSERT FIGURE 2 ABOUT HERE]

In excerpt 3 below, John's utterances and written texts on the whiteboard began with the premise for the explanation. This was the formula for average density (i.e., density equals mass per unit volume) that the class had previously explored as a plausible premise for the 'dancing raisins' phenomenon. John then shifted repeatedly between different outcomes and their associated reasoning to account for the raisins rising, sinking and rising again based on the premise of density formula.

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Excerpt 3

Utterance	**Type**	**Purpose**	**Metadiscourse**
(Teacher writes "Due to density is mass per unit volume" next to P on the board)			***Text connective – genre***
T: ***What did you first observe?***	Question	Probe	***Text connective – genre***
T: ***Let's write down the observation.***	Statement	Focus	***Activity connective – indicating start process***
T: The raisin the moment you put it in, actually most of them actually?	Question	Probe	
S: Sink			
T: Sink. ***So outcome is*** *the raisin sink****.(T writes "the raisins sink" on the board next to the first O)***	Statement	Revoice	***Text connective – genre***
T: So why do you think the raisin will sink?	Question	Probe	
S: Due to fact that they are more dense than water			
T: Correct. So the density of raisin is higher ***(T writes "the density of raisins is higher than water"on the board next to the first R)…***	Statement	Accept Revoice	***Text connective – genre***
T: After that, what do you observe?	Question	Probe	***Text connective- genre***
S: (inaudible)			
T: The raisins *actually*?	Question	Probe	
S: float			
T: Why did the raisins float?	Question	Probe	
S: Carbon dioxide …			
T: Now what actually happens to the carbon dioxide gas bubbles?	Question	Probe	
S: Attach itself to the raisins			
T: Yes, it attach itself to the raisins.	Statement	Accept Revoice	

T: The gas bubbles attached themselves to the raisins. ***(T writes these words on the board next to the second R)***	Statement	Revoice	***Text connective- genre*** ***Text connective- genre***
T: And when it attach to the rasin, what happen to it? What increases? What thing increases first?	Question	Probe	
S: Volume			
T: The volume increases ***(T writes adds these words to the second R on the board).***	Statement	Revoice	***Text connective-genre***
T: So what happen when the volume increases?	Question	Probe	
S: average density decrease			
T. The average density decreases. ***(T adds these words to the second R on the board)***	Statement	Revoice	
T: ***So, so what's the outcome?*** The raisin with the air bubble?	Question	Probe	
S: Floats			

By combining his chain of questioning (shown in excerpt 3) with a visual representation of the P-R-O-R-O-R-O structure of the explanation text, John could direct his students' attention to the specific component they were developing, and organize their responses using these markers. He shifted from P to the first O to the first R, and then on to the second O and R and back to the second O again, and so on, in order to account for the "dancing raisins" phenomenon. This flexibility enabled him to employ their responses as the basis for systematically developing the outcome and reasoning components of the genre.

As a comparison, another teacher Sally also integrated the PRO method in her organizational metadiscourse to help her students develop the reasoning needed to address a common Chemistry question. In the following task shown in Excerpt 4, the students had to

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observe a video on electrolysis of molten lead (II) bromide, and predict and explain the products that were formed from the electrolysis.

Excerpt 4

Utterance	Type	Purpose	Metadiscourse
…..			
T: ***Right now, we will move on to the R, the reasoning***... T: After Pb two plus is being attracted to the cathode, Br minus attracted to the anode, what happen? ...	Statement	Focus	***Activity connective- ongoing activity***
T: ***How would you explain it such that it will lead us to outcome? Do you remember our outcome?***	Question Question	Probe Focus	***Text connective- genre***
S: Bromine and gas			
T: Ok, very good... In this case, lead and bromine gas will be formed.	Statement	Accept Revoice	
T: ***That is our outcome.***	Statement	Focus	***Text connective- genre***
T: ***Before we can come to the outcome, how do we explain it?***	Question	Probe	***Text connective- genre***
T: ***Because right now, until here at this point of time,*** we could only say that the ions are only attracted to the respective electrode.	Statement	Connect	***Text connective- earlier conversation***
T: ***So what causes a particular phenomenon to happen such that we will get our outcome?...***	Question	Probe	***Text connective- genre***
T: ***Going back to what we first know.***	Statement	Connect	***Text connective- earlier conversation***
T: It is a redox involving, involving the gain or loss of electrons.	Statement	Connect	
T: I heard S saying something. Oxidized and?	Question	Revoice	
S: Reduced			
T: Reduced.	Statement	Revoice	
T: ***So right now under the reasoning, remember I start you off at the anode, what happen?***	Question	Connect	***Text connective- earlier conversation, genre***

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Utterance	Type	Purpose	Metadiscourse
OK, so at the anode, what happens to the Br minus, to the Br ions, such that they form Br two gas?	Question	Probe	

First, Sally tried to get her students to build on what they already knew to develop the reasoning component of the explanation genre. When she did not get a response, she employed the text connective for genre by asking them to think about a process that would lead to the outcome ("How would you explain it such that it will lead us to outcome?") and then elicited from them the outcome to remind them about what they already knew ("Do you remember our outcome?"). Using a student's answer, she reverted to her earlier question on reasoning that would lead to the outcome identified (So what causes a particular phenomenon to happen such that we will get our outcome?). Using the text connective for earlier conversations, she reminded her students a couple of times about the information they already had ("Going back to what we first know" and "So right now under the reasoning, remember I start you off at the anode, what happen?"). Sally appears to have taken a circuitous route but she was moving flexibly across R and O in order to help her students recall what they already knew and to employ this knowledge as the basis for systematically developing the reasoning component of the genre with her students.

Teacher Discourse featuring Evaluative Metadiscourse without PRO

The teachers' evaluative metadiscourse to address the quality of an explanation was frequently used whenever they rejected, substituted, rephrased and/or reiterated (Schiffrin, 1980) content put forth by students for the explanation. As Schiffrin (1980, p. 218) suggests, the evaluative metadiscourse also encompassed requests for contextualization and a fuller

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description. In this study, the teachers' evaluative metadiscourse prior to their use of PRO focused on identifying and evaluating gaps in their students' explanation in a linear fashion.

This is exemplified in excerpt 5 below where, in relation to the question, "Why is carbon monoxide poisonous?", Kathryn pointed out that there was something "missing from the answer" and sought her students' input on what was missing before moving on with the development of the explanation. Kathryn's evaluative metadiscourse was seen from her use of attitude markers (of importance) at the end of the excerpt: "the how is important" and "I also need the how."

Excerpt 5

Utterance	**Type**	**Purpose**	**Metadiscourse**
T: ...students will just write down here *(T points to the screen using cursor)* 'carbon monoxide combines with haemoglobin in the blood' full stop. ***I cannot award this student the full credit. Why not?***	Statement Question	Challenge Probe	***Activity connective – connecting to activities outside class***
T: Tell me something that's missing from the answer. ...	Statement	Focus	
S: how is it (inaudible)			
T: Yah. How. ***You're*** *(students in general)* ***not answering to the question.***	Statement	Accept Revoice	***Activity connective – connecting to activities outside class***
T: ***You're just telling me what*** it does. It binds to the haemoglobin ***but you're not telling me how*** is it poisonous.	Statement	Focus	***Text connective – topicalizers***
T: So ***the how*** is ***important.***	Statement	Focus	***Attitude marker – importance***
T: Alright, apart from this part here, ***I also need the how***, which is preventing it from transporting oxygen to the rest of the body, okay.	Statement	Extend	***Attitude marker – importance***

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Identifying and evaluating gaps in the explanation in a linear fashion. Kathryn elicited the component frequently missing in their explanation by using text connectives in the form of topicalizers to shift students' explanation from the "what" to the "how" in order to propel the development of the explanation forward. The parallel structure reflected in the sentences "You're just telling me what… but you're not telling me how…" juxtaposed what students did and did not do with the propositional content. It highlighted to her students their tendency to focus on the initial effect carbon monoxide had on the body and their failure to describe the subsequent processes that would lead to poisoning. The topicalizer thus set up a contrast that facilitated Kathryn's expansion of the explanation (Vande Kopple, 1997) to make it a more complete response to the question. Kathryn also repeatedly used a nominalized form of an interrogative, "the how," to label the frequently missing component in her students' explanation. In doing so, she provided students a linguistic moniker for discussing and monitoring the presence of this component in their explanation. She also included a subordinate clause describing "the how" ("which is preventing it from transporting oxygen to the rest of the body") to help her students identify the processes leading to this specific outcome.

These comments on the gap in the students' explanation were evaluated and marked as "important" by Kathryn's subsequent use of attitude markers in two instances. One was the use of the word "important" and the other was reflected in the clause, "I also need," Both these attitude markers were used in relation to "the how" to underscore the importance of students providing a thorough explanation in response to an examination question.

Teacher Discourse featuring Evaluative Metadiscourse with PRO

The inclusion of PRO in the teachers' discourse paved the way for the teachers to incorporate evaluative metadiscourse to achieve the additional function of facilitating

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students' understanding and evaluation of the propositional content in relation to an explanation genre.

Excerpt 6 below provides an example of how another physics teacher, Derrick, employed evaluative metadiscourse in his questioning to help his students distinguish between the principle and the reasoning in their explanation for the following question: "The sound from a radio speaker can be heard by everyone in the room. Describe how the sound from the radio reaches all parts of the room." Derrick showed a number of written statements on the screen and asked his students to state which of these statements were the principle[1], reasoning, and outcome of the explanation.

Excerpt 6

Utterance	**Type**	**Purpose**	**Metadiscourse**
T: ***So what is the outcome?***	Question	Probe	***Text connective – genre***
T: S, eh ***this is the easiest one to answer.***	Statement	Focus	***Attitude marker – ease/challenge***
T: ***What is the outcome?***	Question	Probe	***Text connective – genre***
S: Sound reaches all parts of the room			
T: Sound reaches all parts of the room.	Statement	Revoice	
T: ***That is the outcome.***	Statement	Focus	***Text connective – genre***
T: Alright so, ***you want to now try to reason okay why it reaches all parts of the room***.	Statement	Focus	***Text connective-sequencer, genre***
T: What do you think is ***the first possible reasoning***?	Question	Probe	***Text connective – sequencer, genre***
T: Or maybe ***I give you a hint first*** lah okay.	Statement	Focus	***Interpretive marker – signalling a way to interpret text***
T: ***Would you think this is a suitable reasoning when you say to answer this outcome? Would it link directly to this part?***	Question	Probe	***Text connective – genre***
S: No			
T: ***No, is this more a principle or a reasoning?***	Question	Probe	***Text connective – genre***

[1] The teacher used the term "Principle" instead of "Premise" for the "P" in the P-R-O because it was felt that students would have had difficulty understanding the word "Premise".

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Utterance	**Type**	**Purpose**	**Metadiscourse**
S: Principle (very softly)			
T: ***So it is more of a principle right?***	Statement	Accept	***Text connective – genre***
T: ***You wouldn't be able to*** state this and ***say that oh that's why*** everyone, every part of the room can be heard.	Statement	Clarify	***Interpretive marker – signalling a way to interpret text***
T: ***But you may start this as a principle***, ok, **sound travels by means as a sound wave** and…then you say sound wave travel in the…***ok so you can use it as a start.***	Statement	Clarify	***Text connective – genre*** ***Text connective – sequencer***

Facilitating understanding and evaluation of propositional content in relation to genre. In this excerpt, instead of developing the scientific explanation in a linear way, Derrick wanted his students to understand the logic of the explanation and identify its epistemic components. Besides using organizational metadiscourse (specifically genre text connective) in a similar manner we saw earlier (see excerpt 2), Derrick also used interpretive markers to signal a way to interpret the propositional content in relation to the explanation genre. In particular, he signaled how the statement "sound travels by means as a sound wave" could not constitute the reasoning and had to be the principle. This is an interpretive marker as he was evaluating the epistemic function of the statement. He used the contrasting clause structures, "You wouldn't be able to…say that oh that's why…" and "But you may start this as a principle" to highlight the semantic and logical gap in saying that "every part of the room can be heard" because "sound travels by means as a sound wave."

In another illustration shown in excerpt 7, Kathryn highlighted and evaluated the gaps in her students' explanation based on its overall structure (as mediated by the PRO metalanguage) as opposed to pointing out individual piece-wise gaps in a linear way over the course of developing an explanation. In response to the Chemistry question, "Explain why potassium chloride cannot conduct electricity in solid state but in molten state," Kathryn's

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questioning and comments addressed the relationship of the different parts of the explanation text in order to develop a complete explanation. Using text connectives for sequence and genre, Kathryn pointed out the relationship between a two-part parallel structure in the reasoning process (R) and the two-part parallel structure in the conclusion (O). She also used an interpretative marker in the phrase "there's always a double why for reason" to signal to the students the requirement in the reasoning involved. In doing so, she guided her students to see how this divergence in the reasoning process led to the differing conclusions or outcomes of electricity being conducted or not being conducted.

Excerpt 7

Utterance	**Type**	**Purpose**	**Metadiscourse**
T: ***What about P, what is the R?***	Question	Focus	***Text connective-genre***
T: ***R is reason, okay?*** ***So what is the reason for a solid not being able to conduct electricity?***	Statement Question	Clarify Probe	***Text connective-genre***
S: no free moving ions.			
T: Good. There is no free moving ions.	Statement	Accept Revoice	
T: ***But you got to explain a little bit more. Why? Okay?*** ***There's always a double why for reason.***	Statement	Focus	***Attitude marker – importance*** ***Interpretive marker – signalling a way to interpret text***
T: Okay? ***Now, moving on to*** molten, while we look at molten, ***first of all, the reason being,*** the forces of attraction has been overcome**,** okay?	Statement	Extend	***Text connective-sequence*** ***Text connective-genre***
T: ***So these are the various reasons for*** whether it can conduct electricity or cannot conduct electricity.	Statement	Consolidate	***Text connective-genre***
T: And ***finally, when you come to the last part… when you mention about the outcomes or the observations that you see?...*** You say there is no free mobile	Statement	Organize	***Text connectives-sequence*** ***Text connective-genre***

Utterance	**Type**	**Purpose**	**Metadiscourse**
ions right?			
T: ***So what is the conclusion?...***	Question	Probe	***Text connective-genre***
S: Cannot conduct electricity.			
T: Cannot conduct electricity.	Statement	Revoice	

Teacher Discourse with PRO and the Development of Disciplinary Literacy in Science

The findings suggest that teacher discourse for directing and scaffolding students' learning of the discourse practices of the discipline often resides within the metadiscourse. The key pedagogical practices for teacher discourse that support the development of literacy in science appear contingent upon the type and function of metadiscourse. Metadiscourse that centers on integrating and making explicit reference to the key elements of the genre, in particular, are critical in facilitating students' production of genre-specific texts within a discipline.

As we have seen in the examples, the metadiscourse prior to the introduction of PRO was often embedded in the teachers' discourse to raise students' awareness of the key vocabulary and processes they needed to include in their explanation. However, such discourse was not entirely in tandem with developing disciplinary literacy in science. This is because the pedagogical practices with respect to the teachers' discourse did not always make explicit the nature of the specialized genres to facilitate students' access to and participation in the disciplinary norms. Prior to the intervention, while explanation texts were systematically constructed during classroom talk, the scaffolding provided by the teacher generally occurred in a linear and seemingly piecemeal fashion. Students were also not given insights on the type of text (i.e. explanation genre) they had to write. In such an approach, the use of metadiscourse by the teachers was largely toward ensuring an explanation text had all the necessary content, as determined on the basis of keywords, so as to fully address the

question rather than toward building an understanding of what constitutes an explanation within the discourse of science.

Without a genre-based structure, the metadiscourse in the teachers' discourse was thus confined to the word or phrase levels articulated in a sequential manner and did not address the overarching structure of the explanation. The teacher on his or her end knew where his/her word/phrase level-questioning was heading toward because he/she already had the entire explanation worked out in his/her mind. However, the students were engaged in discussions about propositional content without being able to perceive the explanation in its entirety and were unable to take a step back to think about how the propositional content was being woven together into a coherent whole. Moreover, as it stands during the discourse, the teacher employed metadiscourse to model and evaluate language use at the word/phrase level but was unable to model and evaluate the construction of an explanation text.

With the inclusion of the PRO method, the teachers' use of metadiscourse was accompanied by a shift from a disproportionate focus on propositional content, linear sequencing of propositional content, and precise use of key vocabulary and phrases toward new ways of employing metadiscourse to facilitate students learning specific ways of developing explanation texts in the context of science education. Specifically, the PRO method was used as a pedagogical resource for teachers to help students open the black box of constructing explanation texts, making explicit the overall structure of the explanation text, the intra-textual relations of propositional content and how the different genre components and their associated propositional content could be flexibly woven together to form a coherent whole. At a more micro level, it was also a pedagogical resource used in the discourse to flexibly signpost genre elements when discussing propositional content with respect to the explanation text. It enabled the teachers to direct students' focus and help them systematically identify and organize the propositional content. The PRO method thus gave

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greater clarity to the structure of the explanation text and the function of the propositional content in relation to this structure. In essence, it may be argued that the PRO method constitutes one of the 'pedagogical practices for teaching content alongside the linguistic, cognitive, and cultural text-based practices and processes associated with a discipline' (Moje, 2007, p. 10).

The PRO method employed during the teachers' discourse was a key instrument in the meaning-making process as teachers used it to help their students make sense of and evaluate the propositional content through meta-discoursing. Teacher discourse employing PRO focused on helping students distinguish the characteristics of the premise, reasoning and outcome and assess the relevance of the propositional content to these genre elements. Teachers guided students to work their way logically through the propositional content using reasoning in order to connect the premise with the outcome. They were also able to monitor and/or help their students monitor their own understanding of the premise, the reasoning and the outcome, the substance and function of the propositional content in relation to these genre elements and how these should be woven together. By incorporating PRO into their discourse for the purpose of jointly crafting an explanation text, teachers were able to model to their students some of the thinking and writing practices within the discipline of science education as well as informally assess their students' participation in and adherence to the conventional and disciplinary-specific ways of using language associated with the explanation text (Lemke, 1989).

Limitations & Future Research

The data in this study were drawn from four teachers and are illustrative of their specific pedagogical practices in their discourse prior to and after the introduction of the PRO method. This paper has highlighted how the incorporation of genre elements in the form of PRO has transformed the teachers' discourse strategies, specifically in the way they used

metadiscourse, in ways that provide more scaffolding for students learning how to develop explanations in science. Thus, our key findings where metadiscourse was used to facilitate student understanding and construction of a scientific explanation genre were observed in all the four teachers. However, not all of them used metadiscourse in the same way. Some teachers (particularly John) used metadiscourse more frequently and in more varied ways compared to the others. While this paper highlights the changes in the four teachers' use of metadiscourse, it cannot claim to provide evidence that such changes in metadiscourse would similarly emerge across all classroom and cultural contexts, genres, disciplines and individual teacher discourse strategies. Hence, it warrants a broader or closer examination of metadiscourse in teacher discourse.

It would be useful to replicate this study on a larger scale and/or vary aspects of its implementation; a larger number of teachers in different classroom settings, different genres and/or different disciplines to determine whether the integration of a genre-based structure in teacher discourse strategies would yield similar findings. Such research may also provide an opportunity to document more varied ways in which a genre-based structure may be deployed in teacher-led classroom talk to facilitate the writing of texts within various disciplines. The extension to other disciplines by including other genre-based structure salient to a specific discipline could potentially provide a basis for comparing the various ways in which teacher discourse strategies incorporating a genre-based focus for a specific discipline are enacted. Their findings would facilitate a more nuanced understanding of the sometimes overlapping yet distinct practices of the various disciplines.

Moreover, given that explanation construction is a highly complex task (Gilbert, Boulter, & Rutherford, 2000), other context-specific factors impacting teacher discourse strategies to facilitate explanation construction, such as content matter, students' conceptual knowledge and language ability and teachers' knowledge and experience should be explored

in future. Such investigations would enable researchers to develop a more comprehensive understanding of how all these factors are mutually constitutive and how a configuration of these factors could impact the extent to which the integration of a genre-based approach in teacher discourse strategies facilitates explanation construction.

A criticism often leveled at the proponents of genre-based pedagogies is that a genre-based approach may be too prescriptive, resulting in reification and formulaic reproductions rather than socially-situated meaning-making (Dixon, 1987; Freedman & Medway, 1994; Raimes, 1991). Another criticism is that the approach of teaching genre is hegemonic as conventional notions of what constitutes legitimate science discourse become entrenched and the community of users becomes less open to diverging views (Luke, 1996). This criticism implies a resultant unquestioning adherence to the discourse practices of a community and a shallow understanding of these practices.

However, if students do not learn how to engage in academic literacy practices at the secondary school level, they would be ill-equipped to engage in similar practices at the college level (Bilkstad-Balas, 2012; Ivanic, 2009). Moreover, contrary to the aforementioned claims, by making explicit the genre elements and delineating the relationship among the epistemic parts of an explanation and employing these elements as conceptual and navigational markers to guide students to write explanation texts, we found that the teachers provided their students with the means to think, speak, write about, and organize the propositional content. They became not the passive recipients but active interpreters and producers of a science text as they used the genre elements to make meaning out of and assess the relevance of the propositional content. In accordance with the New London Group's (1996) principles of multiliteracies, the PRO genre structure provides the "overt instruction" to equip students with the means to unpack the discourse practices of science, before they can critically evaluate them.

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While the genre approach is limiting in that it equips students to organize and evaluate the propositional content only in relation to what has been pre-determined as important in the genre, we contend that these are important precursors to evaluating the discourse at a more advanced level. Awareness of the constructed nature of the discourse and fluency with the discourse are needed before students can begin to interrogate and transform it (Hammond & Macken-Horarik, 1999). Therefore, there are two areas that warrant further investigation. The first area is to explore opportunities for engaging in dialogic and exploratory talk amongst peers (Boyd & Rubin, 2006; Mercer et al., 2004) to support students' efforts to master, interrogate and transform the discourse. The second area is to examine how dominant literacy practices in the form of genre-based strategies initiated by the teacher interact with the vernacular literacy practices generated by students in the form of a hybrid "third space" (e.g., Ciechanowski, 2012; Tang, 2011), and how teachers work with, incorporate and/or build on these vernacular literacy practices. In both areas, there is potential for this study to provide a starting point along those directions.

Implications & Conclusion

This paper illustrates how teachers explicitly teach and incorporate genre elements into their metadiscourse when engaging in oral discourse to support students in constructing scientific explanations in oral and written form. The findings are in line with the goal of developing students' literacy in science, and have several theoretical and curricular implications.

The first implication is a theoretical consideration of the salient genre elements in various disciplines that can and should be incorporated into curriculum design. In this study, we focused on the genre of scientific explanation with the PRO method that was conceived from and built on the theoretical work from science education (e.g., Braaten & Windschitl, 2011) and linguistic studies (e.g., Unsworth, 2001, Veel, 1997). However, the theoretical

work on genre has yet to be as thoroughly elucidated in other disciplines. This gap needs addressing before similar research incorporating a genre-based strategy can be undertaken within these disciplines. Nevertheless, even with an established theoretical base, the central concern amongst educators would be the basis they should use to identify the genre elements. Should these be based on research literature salient to a specific genre? Should such research be situated within the relevant discipline? Alternatively, should these be drawn from model texts written by experts in the field or crafted as answers written in response to an examination question? These questions need to be addressed before any intervention can be designed and implemented. Moreover, differences in discourse practices across disciplines make it difficult to extrapolate what has been learnt from more established research in some disciplines to others.

In terms of curricular implication, there is a need to rethink the pedagogical support required when teachers aim to develop literacy in a discipline. One way teachers employ such support is to adopt a questioning framework or approach to facilitate classroom talk. Although there have been many existing non-genre specific questioning frameworks (e.g., Chin, 2006; Mortimer & Scott, 2003), such frameworks might be of greater benefit to teachers and students when they are enacted in relation to a specific genre. A combination of questioning framework and a genre-based strategy would both lend structure and method to teacher questioning. While a questioning framework on its own focuses on the question types and/or the teacher's immediate intent in asking a question, a genre-based strategy focuses on the eventual goal of the questioning, that is, to facilitate students becoming competent producers of disciplinary texts. This combination of questioning framework with a genre-based approach might become an important pedagogical resource for developing students' disciplinary literacy.

Lastly, the focus in the professional development of content subject teachers has been primarily on the propositional content given the emphasis placed on content knowledge (Shulman, 1987). Less often discussed is the function and importance of metadiscourse in teacher discourse strategies where content knowledge is not foregrounded. We contend that the skillful use of metadiscourse in teacher discourse strategies (in this case relating to the PRO method) constitutes a form of pedagogical content knowledge (Shulman, 1987) essential to teachers' professional development. Having said that, what teachers need is not a more eclectic range of strategies to add to an already wide repertoire of content literacy strategies but a more deliberate, systematic and focused intervention that is simple to grasp yet closely aligned with the discourse of science. Teacher discourse, when supported with a genre-based structure, facilitates the intersection of content knowledge, pedagogical content knowledge and the discourse practices of a community. Hence, there is a need in teachers' professional development to move beyond the focus on content learning or upgrading to address teachers' grasp of pedagogical practices for discourse strategies purposed for guiding students to read, write, talk, and think like an expert within that discipline.

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