EDUCATION RESEARCH FUNDING PROGRAMME

PROJECT CLOSURE REPORT

Fostering science teachers' language awareness: Exploring the impact on teachers' oral interactions with students to support science writing

By

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IMPORTANT TO NOTE

i. PROOFREADING

As your Final Report will be read by MOE Directors, reviewers and other non-specialists, PIs are strongly encouraged to ensure that the Final Report is properly formatted and written in a clear and concise manner. PIs should anonymise their Project Closure Report to ensure that all schools and research participants are not identifiable. The reports should also be proofread for spelling, punctuation and grammatical errors as well as formatting and style inconsistencies.

ii. DECLARATION: ANONYMISE PROJECT CLOSURE REPORT

Project Closure Report will be read by MOE Directors, reviewers and other non-specialists. PIs should anonymise their reports to ensure that all schools and research participants are not identifiable.

☒ Yes, I **agree to anonymise** my Project Closure Report.

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EXECUTIVE SUMMARY (NO MORE THAN 5 PAGES)

INTRODUCTION/BACKGROUND

The role of language in science learning and teaching has been a focus of science education research for over three decades. This rich body of research has led to the insight that learning the language of science is constitutive of learning science: simultaneously with participating in classroom activities and conversations, describing observations and constructing conceptual understanding, students must begin to appropriate the language of science.

STATEMENT OF PROBLEMS

One crucial insight from two earlier research projects (OER 65/12 SLH and OER 16/14 SLH) is that teachers who are better able to enact language-based strategies to support students' science learning appeared to have more knowledge about their students' language use and the associated challenges students face (Seah, 2018). This observation suggests that raising teacher language awareness (TLA) may better equip teachers in their science instruction, especially in enabling them to pre-empt the kinds of challenges that their students are likely to encounter. Studies on science teachers' knowledge required for teaching the language and literacy of science (the representational dimension) are relatively rare. The findings from this study serve to address this research gap.

PURPOSE OF STUDY

This study is guided by the following research questions:

1. How do science teachers use oral interactions with students to support science writing?
2. What aspects of TLA are invoked by science teachers during the inquiry process and in their oral interactions with students?

3. What other impacts on teachers are reported by them over the course of the inquiry process?

PARTICIPANTS

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. These are mainstream schools which serve mainly their immediate neighbourhood and hence comprise students of a wide range of academic and language abilities.

METHODOLOGY / DESIGN

This project adopted a case study approach (Stake, 1995) to study the inquiry process undertaken by individual teachers (in collaboration with researchers) and their oral interactions with students to develop science writing. Analyses of the data were first conducted at the individual level where the focus was on illuminating the knowledge and discursive strategies/moves that the teachers possessed and required to analyse and support science writing. Subsequently, the analysis focused on identifying patterns and themes that cut across the cases to generate findings that can address the individual RQs.

To develop the TLA, the participating teachers underwent iterative cycles of inquiry (Timperley, Wilson, Barr & Fung, 2007). In each cycle, teachers would examine student-written artefacts of their selection, plan and enact lessons and finally reflect on the lessons enacted. Videos collected from the inquiry sessions and lessons were transcribed, and the transcripts served as data for this study. The research team served as external experts during the inquiry and provided support in the forms of thinking prompts to facilitate analysis of the artefacts and lessons, metalanguage to talk about various aspects of language and the issues that warranted instructional attention as well as possible resources and instructional strategies to address surfaced issues.

FINDINGS / RESULTS

Research question 1

Similarities across teachers. The teachers made deliberate attempts to explicate the representational demands of science writing in addition to the conceptual demands when scaffolding the construction of scientific explanations. In addition, they probed their students to elaborate when they verbalised a scientific answer without taking their responses at face value. The teachers also provided students with feedback that did not merely identify the inaccurate concepts adopted in the students' explanations (conceptual perspective) but also how the language used was not able to represent meanings that are aligned with the scientific perspective (representational perspective).

Diversity of discursive strategies. The range of discursive strategies adopted by the teachers to support student writing was diverse. A multi-dimensional and multi-component framework was developed from the discourse data to unpack and understand this diversity.

Roles of metalanguage. The teachers made extensive use of metalanguage in their oral interactions with the students. Four types of metalanguage were used either in isolation or in various combination in a single utterance by the teachers. The different roles played by the teachers' utterances in which metalanguage appeared in were also characterised.

Differences among the teachers. While all the teachers used metalanguage at some point in their oral interactions with students, the extent to which they used them varies in terms of frequency and variety of types. Consequently, the degree of explicitness and emphasis by which the language issues were targeted during the lessons also vary among the teachers.

Research question 2

The TLA of the teachers were unpacked in two dimensions: a declarative dimension which emphasizes the knowledge that a teacher needs (such as knowledge about language and about students) and a procedural dimension which emphasizes the use that the teacher makes of such knowledge.

Knowledge about (scientific) language (KAL) and Knowledge about students (KS). A total of twelve KAL components and seven KS components were identified. These components span three levels: system, text and lexicogrammatical-sentence.

Procedural dimension of TLA (pTLA). Six pTLA components were observable in the lessons, which demonstrate the multiple approaches that the science teachers made use of the various KAL and KS components. These are: (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.

Research question 3

In addition to their language awareness and teaching practices, the inquiry cycles have also benefited the teachers in terms of a shift in their: (i) beliefs on the role of language in science teaching and learning, and (ii) assessment practices.

Beliefs on the role of language in science teaching. At least three teachers indicated that their beliefs about the role of language in science learning had changed.

Changes in assessment practices. Nearly all the teachers reported how their assessment practices were affected with greater language awareness. Two teachers appeared to become more critical about the way they set assessment tasks.

Contributions

Teaching. The findings suggest that raising TLA through the inquiry cycles can have an impact on how teachers use oral interactions to support students in science writing. Each teacher was able to interpret the language challenges encountered by their students as discussed during the inquiry and addressed them in the lessons by integrating their new knowledge about language and about students with their existing pedagogical knowledge.

Teacher learning. The dimensions and components of the discursive strategies framework and the TLA framework can also be used to inform the professional learning content for developing the capacities of science teachers to support student writing.

Assessment tools. In our attempts to analyse the student artefacts to guide the teachers during the inquiry sessions, we have also developed a framework that teachers could use to evaluate their student writing.

Policy. Science teacher preparation programmes could include a course on TLA that seeks to raise teachers' competencies in understanding and supporting students' learning in science. Examples of learning experiences from resources (e.g. CPDD Teaching and Learning Guide and student activity books) can be included in the course to provide opportunities for participants to understand and raise their TLA in various topics and contexts.

CONCLUSION

This study has demonstrated that enhancing TLA can be an effective way of building teachers' capacity to support students in science writing. Serving as a proof-of-concept, it validated our assumption that teachers can provide more explicit instruction on disciplinary literacy if they are more aware of the language features and demands of science.

ACKNOWLEDGEMENTS

This study was funded by the Education Research Funding Programme, National Institute of Education (NIE), Nanyang Technological University, Singapore, project no. OER 16/16 SLH. The views expressed in this paper are the author's and do not necessarily represent the views of NIE. We are also grateful to the schools, teachers and students who participated in this project, without their support and commitment, we would not be able to complete this report.

KEYWORDS

Teacher language awareness; Disciplinary literacy; Science learning; Metalangauge

FORMAT OF FINAL CLOSURE REPORT

For Tier 1 and Tier 2 projects, the recommended page limit of the Project Closure Report is of no more than 25 pages and no more than 30 pages for Tier 3, A4 typewritten (excluding references and appendices) – full-sized type font (not Arial Narrow), font size 10-12, double-spaced, with a margin of at least 2 cm on all sides. There is a maximum allowance of 4 additional pages for tables or diagrams which can either appear in-text or be included as appendices. It is the prerogative of the review committee to reject reports that do not meet the page limit.

Fostering science teachers' language awareness: Exploring impact on teachers' oral interactions with students to support science writing

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INTRODUCTION

The role of language in science learning and teaching has been a focus of science education research for over three decades (see for example, Lemke, 1990, Wellington & Osborne, 2001). This rich body of research has led to the insight that learning the language of science is constitutive of learning science: simultaneously with participating in classroom activities and conversations, describing observations and constructing conceptual understanding, students must begin to appropriate the language of science. One of the reasons that language has been viewed as a "barrier" can be attributed to the many language features that are distinctive to science (including its unique lexicon, grammar, text structures and semantics), which constitute the language demands that this study refers to.

STATEMENT OF PROBLEMS

A study of nine science teachers in a local primary school (as part of the research project SGD 24/12 SLH) has revealed a tendency among the teachers to attribute students' language-related challenges in science mainly to the use of technical terms (Seah, 2015). While scientific language is no doubt a highly technical language, there are a number of inherent grammatical features that could also pose significant difficulties to students (Fang, 2005). In fact, Halliday and Martin (1993, p. 71) argued that a strong emphasis on vocabulary can be limiting, since 'the difficulty [with scientific writing] lies more with the grammar than with the vocabulary' as 'the problems with technical terminology usually arise not from the technical terms themselves but from the complex relationships they have with one another'.

One crucial insight from two other research projects (OER 65/12 SLG and OER 16/14 SLH) is that teachers who are better able to enact the language-based strategies to support science learning appeared to have more knowledge about their students' language use and the associated challenges students face (Seah, 2018). This observation suggests that raising teacher language awareness (TLA) may better equip teachers in their science instruction, especially in enabling them to pre-empt the kinds of challenges that their students are likely to encounter. TLA denotes 'the knowledge that teachers have of the underlying systems of the language that enables them to teach effectively' (Thornbury, 1997, p. x), which is assumed to be important for empowering teachers with the necessary capacity to address the language demands and literacy practices of content classrooms (Andrews & Lin, 2017). This study is an attempt to test and validate this assumption. One obvious indicator of TLA that can have a direct impact on students is teachers' oral interactions to support students' writings, an important aspect of scientific literacy especially in the local educational context where students are still being assessed primarily through the use of written assessments.

Studies on science teachers' knowledge required for teaching the language and literacy of science (the representational dimension) are relatively rare. The findings from this study serve to address this research gap.

PURPOSE OF STUDY

This study is guided by the following research questions:

1. How do science teachers use oral interactions with students to support science writing?
2. What aspects of TLA are invoked by science teachers during the inquiry process and in their oral interactions with students?
3. What other impacts on teachers are reported by them over the course of the inquiry process?

PARTICIPANTS

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 ([1]Preston Primary School, PPS, and Westin Primary School, WPS) and two secondary schools (Pearl Secondary School, PSS and Yarra Secondary School, YSS). These are mainstream schools which serve mainly their immediate neighbourhood and hence comprise students of a wide range of academic and language abilities. Please refer to Appendix A for the table illustrating the number of teachers and students from these schools who participated in this study.

METHODOLOGY/DESIGN

To develop the TLA, the participating teachers underwent iterative cycles of inquiry (Timperley, Wilson, Barr & Fung, 2007). In each cycle, teachers would examine student-

[1] Pseudonyms are used to represent the schools and all research participants.

written artefacts of their selection, plan and enact lessons and finally reflect on the lessons enacted. Videos collected from the inquiry sessions and lessons were transcribed, and the transcripts served as data for this study. The research team served as external experts during the inquiry and provided support in the forms of thinking prompts to facilitate analysis of the artefacts and lessons, metalanguage to talk about various aspects of language and the issues that warranted instructional attention as well as possible resources and instructional strategies to address surfaced issues. Teachers undertook the task of developing their lesson plans to address the issues surfaced following the discussion with the research team. A post-lesson reflection dialogue was conducted at the end of a cycle for both the researchers and teachers to extract the learning points, which provided the foundation for embarking on deeper inquiry in subsequent cycles.

This project adopted a case study approach (Stake, 1995) to study the inquiry process undertaken by individual teachers (in collaboration with researchers) and their oral interactions with students to develop science writing. Analyses of the data were first conducted at the individual level where the focus is on illuminating the knowledge and discursive strategies/moves that the teachers possess and require to analyse and support science writing. Subsequently, the analysis focused on identifying patterns and themes that cut across the cases to generate findings that can address the individual RQs.

FINDINGS

RQ1 [How do science teachers use oral interactions with students to support science writing?]

This research question will be addressed in three ways. First, we highlight some of the similarities that cut across the six teachers' oral interactions. Next, we unpack and characterised two features of the oral interactions to provide an in-depth analysis of how the teachers, at a collective level, supported students in science writing. Finally, we identify several differences among the teachers to provide a more comprehensive view of the diverse impacts of the inquiry on the teachers.

Similarities across teachers

Our lesson observations and analysis of the lesson transcripts reveal that the [2]teachers made deliberate attempts to explicate the representational demands of science writing in addition to the conceptual demands when scaffolding the construction of scientific explanations. This was evident particularly in the use of diverse discursive strategies to highlight, explicate and illustrate the language demands when the teachers were scaffolding the process of constructing scientific explanations. Such scaffolding process made transparent to the students the representational knowledge and thinking that are required to construct a scientifically accurate and clear explanation, the requisite conceptual knowledge notwithstanding. A second similarity among the teachers was the more detailed and concrete feedback given to their students on their use of language that incorporated both the representational and conceptual perspectives. In other words, the feedback did not merely identify the inaccurate concepts adopted in the students' explanations (conceptual perspective) but also how the language used was not able to represent meanings that are aligned with the scientific perspective (representational perspective). Examples include how linguistic resources (e.g. conjunctions, prepositions, pronouns) employed were inappropriate or sufficiently specific to the context of use. A third similarity was the tendency of the teachers to probe students to elaborate on what they meant when they verbalised a scientific answer without taking their responses at face value. When the students provided ambiguous answers, the teachers did not jump to the conclusion that the answers were due to a lack of

[2] Main claims of the analysis are identified in purple font.

scientific understanding. The teachers would request the students instead to explain or justify their answers. By probing students to do so, the teachers enhanced the likelihood of assessing whether the ambiguity in the students' answers could be attributed to a lack of conceptual understanding (misconception) or rather an unsophisticated use of language to represent intended meaning (misrepresentation).

Diversity of discursive strategies

As a whole, the range of discursive strategies adopted by the teachers to support student writing was very diverse. To unpack and understand this diversity, a multi-dimensional and multi-component framework was developed from the discourse data (see Figure 1 below for a diagrammatic representation of the framework).

These discursive strategies can be unpacked along two dimensions: the "what" (i.e. aspects of the language attended to) and the "how" (i.e. the discursive means by which the aspects of language are addressed). The discursive means can, in turn, be decomposed into two components: (I) the interactional goals (the instructional purpose of the teacher's talk) and (II) the language resource (the nature of the talk content which can originate from either the teacher or student/s).

The aspects of language that the teachers attended to cut across four levels: (i) *lexicogrammatical resources (word/phrase) level* [e.g. form (e.g. spelling), meaning and type (e.g. adjective, noun) of words; word list (e.g. graph descriptors)] (ii) *sentence-level* [e.g. word choice in their context-of-use, word choice of specific word type (e.g. pronouns, connectors, comparatives) in their context-of-use, phrasing]; (iii) *text level* [e.g. quality of texts, components of various text-types (e.g. description of graphs, explanations, definitions), sequencing of the text components, relationships between text components (e.g. link between cause and effect)]; and (iv) *semantics level* [e.g. conventions and norms of language use: relevance, accuracy, specificity, appropriateness].

There are at least 15 distinct interactional goals identified thus far which can be broadly classified into five categories: (Ia) attentive, (Ib) deconstructive, (Ic) demonstrative, (Id) constructive, (Ie) evaluative, and (f) student-directed. The attentive discursive means include those discursive strategies adopted by the teachers to [3]***focus*** or ***highlight*** particular language resource through their oral interactions with students. The deconstructive discursive means comprise talks when the teacher ***interpreted***, ***identified, defined*** and ***rationalised*** the aspects of the language of concerns. Demonstrative discursive means occurred when the teachers ***illustrated*** an aspect of language that students needed to pay attention to for example by modelling how certain language criteria could be used to evaluate students' language use. The teachers engaged in constructive discursive means when they ***extended*** or ***recast*** students' language or ***proposed*** alternative language. There were also discursive means which were evaluative in nature when the teachers ***accepted*** or ***graded*** students' language use. Finally, the last category identifies discursive means with which the teachers imbued students with the agency to talk about the language resource by ***questioning***, ***seeking*** or ***cueing*** them.

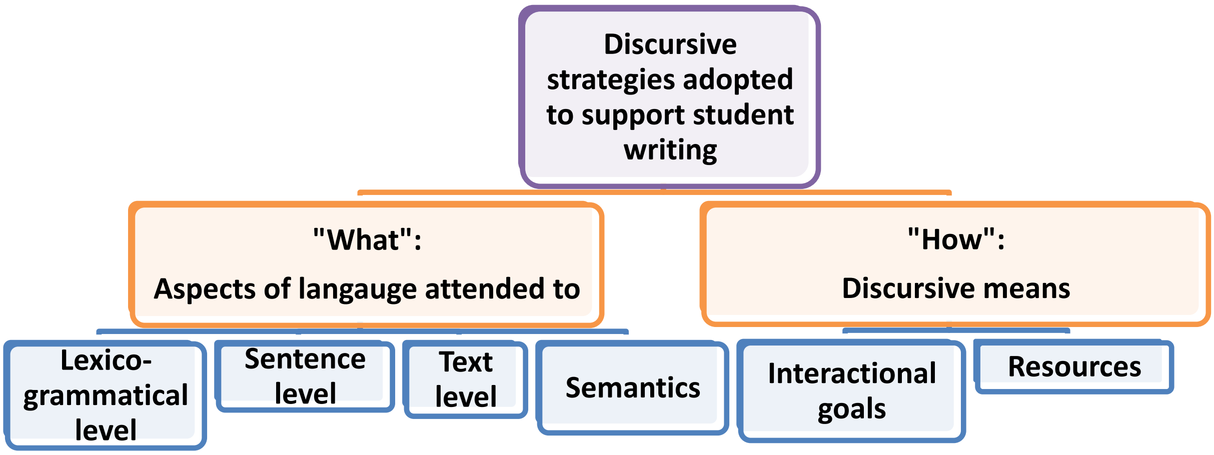
The resource components of the discursive means identify the nature of the content being talked about. There are also five broad types: (IIa) student language, (IIb) language errors, (IIIc) scientific language, (IId) language dimensions and features and (IIe) student feedback. These resource components are distinct from the aspects of language that the discursive strategies seek to address. With the resource component of the discursive means, we are merely referring to the language resources that the teachers refer to and from which they explicate the aspects of language. This is in contrast to the aspects of

[3] The 15 different types of discursive means are bold and italicized.

language which refer to the particular features of language that the teachers seek to make explicit so that the students are made aware of the language demands of science writing.

Appendix B contains an episode of a teacher's talk, which is used to illustrate the various discursive strategies employed to support students in their science writing. In that episode, the teacher did not only highlight the content inadequacy of the student's response (what science teachers would typically do), he also skilfully related this inadequacy to the language choice made by the student. In doing so, the teacher not only alerted students to the need for critical evaluation of the language choices made in construing their meaning but also illuminated the language conventions and norms valued in scientific writing. Such language-content connections are important if students are to appreciate the role of language in science learning and communication.

Figure 1. ***Diagrammatic representation of the discursive strategies framework***



Roles of metalanguage

Another 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 analyse 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). However, limited research has examined the role of metalanguage in science education even though engaging in scientific practices such as explanation and argumentation is widely acknowledged to be language intensive (Jung, 2019). By its very nature, metalanguage identifies particular aspects of language being talked about and hence allows teachers to be explicit about the representational demands of science writing.

From the lesson transcripts collected, we managed to identify several roles played by the teachers' utterances in which metalanguage appeared in. Metalanguage has been found to enable the teachers to:

1) Unpack question demands for students
   - By deconstructing what the question is asking from students
   - By outlining the expectations of the responses to the question (e.g. explanation, observation, description)
2) Illuminate the [4]conventions and norms of scientific writing for students
3) Support the use of language in science
   - By unpacking, elaborating and/or rationalizing how and why language is used in a particular way in science
   - By scaffolding the construction of science texts
4) Critique the use of language by students

[4] By conventions and norms of language, we refer to the needs for language to be relevant, accurate, specific and appropriateness for the particular context of the science tasks and problems. This is not to be confused with the rigid and arbitrary demands for particular "keywords" without consideration of the contextual requirements.

- By evaluating, unpacking and critiquing students' use of language (feedback)
- By facilitating self/peer evaluation and critique of student explanations

5) Stimulate deeper thinking into content with students

The metalanguage found in the oral interactions varied in nature and could be grouped into four categories. The first type is the grammar metalanguage, which identifies the various linguistic components that constitute a sentence in science writing. There are two sub-types according to the different traditions from which they are derived from: those that come from the traditional grammar such as 'noun', 'verb', prepositional phrase'; and those that come from Michael Halliday's functional grammar perspective (Halliday & Matthiessen, 2001) such as 'participant', 'process', 'circumstance'. The second type of metalanguage is the language convention metalanguage, which identifies the values and norms of language use in science, examples include 'accuracy', 'specificity', 'relevance', 'appropriateness'. The third type of metalanguage is the science content metalanguage which many science teachers would be familiar with. This metalanguage type identifies the nature or ontology of the science content that made up a scientific text such as 'biological parts', 'cause', 'effect'. The final type of metalanguage is what we labelled as science practice metalanguage, which identifies the textual products generated from scientific practices engaged by science students such as 'explanation', 'description', 'comparison'. In certain traditions such as the functional grammar perspective, these practices would be considered as different text genres but we have labelled them as such as we believe that this would have greater traction with science teachers who tend to be more familiar with these terms as science practices rather than as text genres. These four types of metalanguage were used either in isolation or in various combination in a single utterance by the teachers to perform the various roles identified above. These four types of metalanguage, in illuminating the multiple dimensions (i.e. the form, meaning, norms and function/product) of the language of science, allowed the teachers to make transparent the connections between language and disciplinary content cum practices. Appendix C contains an illustration of the use of metalanguage using the same episode illustrating the discursive strategies framework.

Differences among the teachers

While all the teachers used metalanguage at some point in their oral interactions with students, the extent to which they used them varies in terms of frequency and variety of types. The teachers appeared to demonstrate varying degree of familiarity with the differnt types of metalanguage and willingness to use them in the classrooms. Some teachers professed uncertainty with the meaning of certain metalanguage terms and explained their reluctance on their use based on this uncertainty. As metalanguage specifies the aspects of language being addressed, the extent of its use can indicate to a certain extent the degree of explicitness in which language issues were discussed and unpacked during science instruction. The lack of use of metalanguage may suggest that the language issues are being discussed implicitly or not at all.

A related difference across the teachers' oral interactions was the extent of emphasis on the language issues that have been highlighted to students. In other words, how sustained the language issues were being highlighted across lessons and over time. To some degree, this difference could be related to the use of metalanguage. Metalanguage not only specifies the aspects of language being targeted but also serves as a referent with which the teachers can quickly recall the language issue discussed before and remind students of its importance. An example is how Aaida directed her students' attention to the problematic use of pronouns by students. The metalanguage 'pronouns' allowed the teacher to identify the grammatical resource that the students need to be watchful of. But once the issue with its use has been discussed, the metalanguage also enabled the teacher to quickly remind students of its problematic use by simply asking them to recall what they have learnt about pronouns. The use of metalanguage thus enabled teachers to repeatedly emphasize the importance of particular aspects of the language across lessons and reinforce the learning whenever similar opportunities arise. By contrast, the lack of use of metalanguage would make it harder for teachers to do so and increase the likelihood of students making similar errors in other content topics where students might not see the relevance of how the same language issue may apply.

The third difference among the teachers was the preferred approach by which the teachers addressed the language demands of science writing. While some teachers preferred a more discursive approach to highlighting and discussing the language issues by engaging students in oral interactions, others preferred a more activity/task-based approach. The latter often involved the teachers designing activities and tasks to engage students in pair/group discussion on the language issues. The former approach tended to be more teacher-driven while the latter tended to imbue students with greater agency. More details on the approaches by which the teachers addressed the language demands of science writing are presented below with respect to RQ2.

In summary, while the teachers demonstrated an enhanced focus on the representational demands of science writing as evident by the use of diverse discursive strategies and metalanguage in their oral interactions with students, they differed in the extent of use in terms of frequency and variety. Consequently, the degree of explicitness and emphasis by which the language issues were targeted during the lessons also vary among the teachers.

***RQ2** [What aspects of TLA are invoked by science teachers during the inquiry process and in their oral interactions with students?]*

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. Within the declarative dimension, there are three components: knowledge of language (KL), knowledge about language (KAL) and knowledge about students in terms of their language knowledge and abilities (KS) (Andrews, 2008). As the project assumes that the teachers have sufficient proficiency in scientific language, KL is excluded from this analysis. We focus mainly on unpacking KAL and KS components of TLA and its procedural dimension in the following subsections.

Knowledge about (scientific) language (KAL)

In this study, KAL denotes the conscious and explicit knowledge of the nature and features of scientific language that was invoked either during the inquiry cycles or the classroom lessons conducted. Given its nature, KAL as with the other components of TLA, can only be inferred from the data, rather than be directly observed, primarily from the content of talk (either between teacher/s and researcher/s or during class). Based on the aspects of language that were the subject of the talk, the components of KAL were identified. These components need not always be initiated by the teachers but could be introduced by the researchers and became subsequently part of the knowledge base applied by the teachers in their analysis of student writing, their oral interactions or even design of lessons. A total of 12 KAL components were identified, which span three levels: system, text and lexicogrammatical-sentence (refer to Table 1 below for the components). System-level KAL components refer to the broad understanding teachers have of the scientific language as a system rather than of particular texts. Text-level KAL components refers to the knowledge about particular text-types, while Lexicogrammatical-sentence-level KAL components cover the spectrum of knowledge that relates to the meaning, feature and function of individual words (both lexicons/vocabulary and grammatical resources such as pronoun, preposition and conjunction) to their use in sentence making.

Knowledge about students' language (KS)

The knowledge about students (KS) is closely related to KAL as some KS components indicated the specific challenges that the students faced that were related to the various KAL components. A total of seven KS components were identified, which can be classified into the three levels as KAL (i.e. system, text and lexicogrammatical-sentence) (refer to Table 1 below for the components). Though the focus of KS in this study is from the language perspective, the "inextricably intertwined" relationships between content and language (Fang & Coatnam, 2018, p. X) means that the aspects of KS identified here are related to students' conceptual understanding as much as their use of language. More components were identified at the lexicogrammatical-sentence-level than the other two. The KS invoked at this level was particularly prominent in the primary science classes given that the students at these grade levels tended to be learning basic and disciplinary literacies concurrently. These seven KAS components constitute the knowledge base about students' language use with which the researchers and teachers co-construct as we analysed the student writing and sought to better understand the language challenges student face. Descriptions of the individual components of KAL and KS can be found in Appendix D.

Table 1. ***KAL and KS components***

Level	KAL	KS
System level	1) Differences between everyday and scientific language 2) Knowledge required to construct scientific texts 3) Differences between oral language and written language (e.g. use of pronouns, active vs passive voice)	1) Students' language can indicate misconception or misrepresentation 2) Challenges in comprehending questions and the requirements
Text level	4) Differences between text-types (e.g. description vs explanation,	3) Confusing between the various types of texts (e.g. explanatory,

	description of features vs description of function) 5) Textual components required of various text-types (e.g. explanations, relational statements, definitions, data-based description and explanation) 6) Ordering/sequencing of text components (e.g. when making comparisons, when describing and explaining data)	comparative, descriptive, relational) and knowing the structural components and sequencing 4) Missing structural components
LG-sentence level	7) Morphemes: parts of words: prefixes, roots, suffixes 8) Role of grammatical resources (e.g. preposition, noun, verb, adjective) 9) Role and nature of nominalisations (function of grammatical metaphors) 10) Expectations of command word (e.g. describe, explain) as in assessment questions 11) Condition/context of use of technical terms 12) Sentence construction	5) Excessive lengthy sentences that lacked coherence and clarity (e.g. using too many 'and') 6) Converting active voice to passive voice (reversing the actor and the entity being acted upon) 7) Conventions:) (ir)relevance, (in)accuracy, (non-)specificity and (in)appropriateness of particular vocabulary and grammatical resources

Procedural dimension of TLA (pTLA)

This dimension of TLA (henceforth pTLA) denotes how teachers apply the various aspects of KAL and KS in their teaching. Six pTLA components were observable in the lessons, which demonstrate the multiple approaches that the science teachers made use of the declarative dimension of TLA. These are: (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. The first component has been described in RQ1. 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, teachers would be less likely to pay attention to or possess the vocabulary to talk about them explicitly during science lessons.

The more KAL and KS they had, the more metalanguage the science teachers were likely to acquire, apply and adapt in their oral interactions with students.

The teachers also showed innovativeness in designing activities for students that foregrounded the role of language. An instance is 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 and which students would need 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 pronoun used in sentences can be replaced, and activated not only their language knowledge but 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 in which the sentences were intended for. This particular activity would relate particularly to Component 8 of KAL and Component 7 of KS (refer to Table 1 for the various KAL and KS components).

The teachers designed and employed a range of scaffolds for students to support their completion of a task (task scaffolds). Examples of such scaffolds include sentence starter, helping words, sentence/text construction tables to more elaborate support such as rubrics for students to practice peer evaluation and a glossary list with the terms provided organised into categories that reflect the key ideas in the topic. These scaffolds reflected an awareness the teachers have towards the potential challenges that their students might face in completing the task and the teachers' abilities to integrate their pedagogical knowledge with their KAL and KS.

The fourth pTLA component involved the ability of the science teachers to leverage on student writing as resources to highlight, illustrate, critique and model how language was used and ought to be used by students. Through the use of these resources, teachers were able to make explicit the language-content connections by relating the language features and resources employed to the meaning realised. The teachers made use of these resources in multiple ways: as board notes for discussion (when students wrote their answers on the board), as group activity for peer discussion (when the teacher collated student writing as resources for students to discuss and critique) and as individual activity for self- and peer evaluation (when students were expected to critique their peers' explanations with the rubrics given). The KS of the teachers were especially relevant here as the use of the student writing could be best optimized if the teachers have a clear understanding of the challenges that their students exhibited in their writing and how these challenges can be leveraged on to help students be aware of and overcome them.

Visual aids had also been employed to support students in their acquisition of the language skills needed to construct scientific texts (Component 5 of pTLA). A particularly vivid example was when Hana used laminated magnetic coloured cards containing words representing the various states of water (e.g. water, water vapour, water droplets), processes of change of state (e.g. evaporate, condense) and other associated words of the water cycle (e.g. sea, cloud). These cards were coloured coded according to whether they are noun or verb and can 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), making students aware of the need to match the right noun with the right verb is crucial. 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 matching. 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 where to place 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.

Lastly, the teachers also applied their KAL and KS to provide more specific and elaborated feedback to students (Component 6 of pTLA). Feedback included both oral and written form. The oral feedback, amply described in RQ1, overlaps with Component 1 and 4 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. 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". As with the discursive strategies adopted among the teachers, the TLA invoked by each teacher also vary in terms of both extent and quality.

RQ3 [What other impacts on teachers are reported by them over the course of the inquiry process?]

In addition to their language awareness and teaching practices, the inquiry cycles have also benefited the teachers in terms of a shift in their: (i) beliefs on the role of language in science teaching and learning, and (ii) assessment practices. Below are the teachers' quotes during the interviews that illustrate these impacts. The teachers' quotations have been edited slightly to aid reading while retaining their intended meaning.

Beliefs on the role of language in science teaching

As a consequence of their increase in language awareness, at least three teachers indicated that their beliefs about the role of language in science learning had changed. Aaida admitted to focusing mainly on 'just delivering the science content' previously, but her view has changed over the course of the inquiry: 'Now I realise it's not just the content. Sometimes they have the content, they can verbalise but then they have difficulty writing because they do not have any scaffolding to guide them to write the right way.' Similarly, Tasha talked about how she perceived her students' challenges differently: 'Even to myself, I wouldn't think where the student went wrong. I just know student never study hard enough. Because the phrase is all wrong. But now I think that maybe it's not because the student did not study. The student studied but because of whatever language issues they have, when they write it out, it's not coming out in the same way as we want it to come out.' Yiling also realized that what was easy for teachers may not be so for students: 'I would not take that extra effort to really explain in greater details as to how they should be answering a question like this because to us it's so simple. It's so easy. But to them, it is so difficult.' She attributed her previous stance to 'our language proficiency is better than the students, [hence] when we write sometimes we forget [the demands], and that is how the students sometimes struggle.' Such changes in belief are significant as research has shown that one critical obstacle preventing content teachers from providing students with language learning opportunities is their beliefs, particularly their role as a content teacher (viz a viz a language teacher) (Tan, 2011).

The narrowing of students' opportunities may also extend beyond language learning. Tasha admitted that she used to discourage her science students (presumably those in secondary two) from taking up biology in upper grade levels if their language is weak. However, she seemed to have a change of heart after going through the inquiry cycles: ‘But now, if I think that there are ways where we can boost their language capability, then maybe these students who are very passionate about the subject will be able to take [Biology].... So at least we know that okay teaching of these language components or issues can be part of my teaching of the subject...Because it will definitely help them understand better and help them perform better.’ Going by Tasha’s experience, there is potential for science teachers to better support their students in learning science topics/subjects that are more language intensive through gaining greater skills and confidence through the inquiry process, despite their reservations about their students’ language proficiency.

Changes in assessment practices

Nearly all the teachers reported how their assessment practices were affected with greater language awareness. Not surprisingly, the increase in language awareness heightened teachers' sensitivity to language issues when marking their student work. For example, Aaida reported being 'more alert and sharp’ when she marked. Similarly, the increased capacities of teachers to discuss students' language issues through whole-class instruction were also translated into more specific written feedback when marking student work. Tasha elaborated on how her written feedback was different from the past: ‘I think the feedback we give definitely is richer now ... normally we just put … the mountain symbol, it just means that you need to say more… Or we will just say that it’s not specific or … “poor phrasing”. When I [marked the] prelim paper...I never write a single poor phrasing... They know that it's poor but what is wrong?... So now .. I can say that this is an inaccurate representation or this information is irrelevant... we are clearer in identifying their errors and we are able to point out to them.’

It appears from the quote above that Tasha not only realised that her feedback given in the past was not sufficient or useful to students, but she also felt better equipped in providing more precise feedback that could support students in thinking more critically about their language use in science. Another teacher, Baofei, related an incident when he was helping his student one-to-one after school. He was able to deconstruct the explanation, identify the missing element in the student's explanation and advised his student accordingly. He concluded that 'So at least I'm now able to suggest an alternative method, rather than just say it's wrong, or write down what is correct'.

A less expected impact was how two other teachers appeared to become more critical about the way they set assessment tasks. Hsumei noted how the inquiry process led her to re-evaluate her assessment goals: 'when I'm testing them, what actually am I testing them on? Am I testing them on their ability to use a certain keyword or the ability to describe a process?'. She also highlighted how the awareness helped her in better crafting the assessment items 'I need to know how much am I scoping that question for. So ultimately, I would actually craft a better question that demands a specific aspect of a phenomenon rather than outline entire thing'. Similarly, Yiling admitted that 'I sometimes need to be a bit more aware also on how the question should be phrased, so as not to either mislead the students or it leads to their not understanding. Because to us, this is something that we know, but it may be something that students struggle with.' Baofei was even more specific about how his assessment practices were affected: 'I think assessment is affected because now I have to think carefully about the command words that I use. If I ask them to describe or at least the process, then my answer scheme [should] better have the components that I tell them they should include in class'.

The findings of this RQ, as with those in the first two RQs above, indicated the varied development among the teachers. Not only do the ways they supported their students in science writing and their TLA varied, but the impacts of the inquiry cycles on their beliefs on the role of language in science teaching and learning and assessment practices also may differ since not every teacher reported the same impacts. Some possible reasons for these differences are discussed in Appendix E.

CONTRIBUTIONS OF STUDY

Teaching

The findings suggest that raising TLA through the inquiry cycles can have an impact on how teachers use oral interactions to support students in science writing (see Appendix F for an overview diagrammatic representation of the impacts of the inquiry). Raising TLA through the inquiry seems to enable the teachers to tease out the various language challenges that their students were facing and henceforth addressed them in a deliberate, explicit and targeted manner during lessons. What is worth noting from the varied ways in which the teachers addressed the language demands is how each teacher was able to interpret the language challenges encountered by their students as discussed during the inquiry and addressed them in the lessons by integrating their new knowledge about language and about students with their existing pedagogical knowledge. It is through this knowledge integration that the teachers were able to make explicit the representational demands of science writing to their students through either the discursive means or activity-based approach.

Teacher learning

In addition to serving as analytical tools, the dimensions and components of the discursive strategies framework (Figure 1) and the TLA framework (Table 1 and Appendix D) can also be used to inform the professional learning content for developing the capacities of science teachers to support student writing. Both frameworks provide the structural resources for directing teacher attention to the different aspects of language, interactional goals, language resources that teachers can tap on to expand their discursive repertoires and other forms of teaching practices.

Assessment tools

This study has demonstrated the importance of getting teachers to inquire about the difficulties that their students face in using the language of science as such understanding makes them more likely to attend to language demands of science writing both when planning the lessons and during instruction. To be able to do so, teachers need a language lens to support their inquiry process. In our attempts to analyse the student artefacts to guide the teachers during the inquiry sessions, we have also developed a framework that teachers could use to evaluate their student writing (see Appendix G). This framework provides the question prompts and language features to look out for that could guide teachers in their analysis of students' writings.

General Implications for Policymakers

Science teacher preparation programmes could include a course on TLA that seeks to raise teachers' competencies in understanding and supporting students' learning in science. Examples of learning experiences from resources (e.g. CPDD Teaching and Learning Guide and student activity books) can be included in the course to provide opportunities for participants to understand and enhance their TLA in various topics and contexts.

[5]CONCLUSION

This study (OER 16/16 SLH) has demonstrated that enhancing TLA can be an effective way of building teachers' capacity to support students in science writing. Serving as a proof-of-concept, it validated our assumption that teachers can provide more explicit instruction on disciplinary literacy if they are more aware of the language features and demands of science. An important tool for learning about and teaching the language demands is metalanguage, especially those that help to deconstruct scientific texts and explicate the conventions of scientific language.

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Notes

To maintain confidentiality, pseudonyms have been used in place of the actual names of schools, teachers and pupils in this study.

REFERENCES

Andrews, S. (2008). Teacher language awareness. In J. Cenoz & N. H. Hornberger (Eds.), *Encyclopedia of language and education* (2nd Ed. ed., pp. 287-298).

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[5] For implications on future research, please refer to Appendix I.

Andrews, S.J., & Lin, A.M.Y. (2017). Language awareness and teacher development. In Peter Garrett & Josep Maria Cots (Eds.), *The Routledge Handbook of Language Awareness* (pp. 57–74). London: Routledge.

Fang, Z. H. (2005). Scientific literacy: A systemic functional linguistics perspective. *Science Education*, 89(2), 335-347.

Fang, Z. and S. Coatoam (2013). Disciplinary Literacy : What You Want to Know About It. *Journal of Adolescent & Adult Literacy* 56(8): 627-632.

Halliday, M. A. K., & Martin, J. R. (1993). *Writing science: Literacy and discursive power*. London: Falmer Press.

Halliday, M. A. K., & Matthiessen, C. M. I. M. (2004). *An introduction to functional grammar* (3rd ed.). London: Arnold.

Jung, K. G. (2019). Learning to Scaffold Science Academic Language: Lessons from an Instructional Coaching Partnership. *Research in Science Education* 49(4): 1013-1024.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, N.J.: Ablex Pub. Corp.

Moore, J. and M. Schleppegrell (2014). Using a functional linguistics metalanguage to support academic language development in the English Language Arts. *Linguistics and Education* 26: 92-105.

Seah, L. H. (2015). Elementary teachers' perception of language issues in science classrooms. International *Journal of Science and Mathematics Education*, 1-20. doi: 10.1007/s10763-015-9648-z

Seah, L. H. (2018, July). What does it take for science teachers to attend to the language and literacy demands of their subject domain. Paper presented in the invited colloquium 'Discipline literacies: An SFL perspective', chaired by Fang, Z.H. Invited colloquium presented at the meeting of the 45th International Systemic Functional Congress, Boston, United States.

Shanahan, M.-C. (2012). Reading for evidence through hybrid adapted primary literature. In S. P. Norris (Ed.), *Reading for evidence and interpreting visualizations in Mathematics and Science education* (pp. 41-63). Rotterdam: SensePublishers.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Tan, M. (2011). Mathematics and science teachers' beliefs and practices regarding the teaching of language in content learning. *Language Teaching Research* 15(3): 325-342.

Timperley, H., Wilson, A., Barr, H., & Fung, I. (2007). *Teacher professional learning and development: A best evidence synthesis iteration.* Wellington, New Zealand: Ministry of Education.

Thornbury, S. (1997). *About language*. Cambridge: Cambridge University Press.

Wellington, J. J., & Osborne, J. (2001). *Language and literacy in science education*. Philadelphia, USA: Open University.