Chapter 4
Meeting Disciplinary Literacy Demands in Content Learning: The Singapore Perspective

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Abstract This chapter examines how systemic language and literacy support for content-area teachers to enhance their students' learning is realised in Singapore with a focus on science at the secondary level. It highlights theoretical underpinnings that inform the perspective of disciplinary literacy guiding this work and describes how disciplinary literacy is contextualised in Singapore against what is broadly understood as effective communication. It unpacks the nature and extent of systemic support for developing literacy in science with specific reference to the professional learning courses and school-based collaborative research. The chapter addresses the challenges encountered and discusses the implications which impact curriculum and pedagogy in the integration of disciplinary literacy practices to meet students' needs in the learning of science.

Keywords Disciplinary literacy · science education · content teaching and learning · science communication

4.1 Introduction

This chapter offers the Singapore perspective to integrating literacy and content language learning in the curriculum, with a specific focus on the science curriculum at the secondary school level. The chapter unpacks the concept of 'disciplinary literacy' and how this has been contextualised to serve the needs of the local teaching

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fraternity. It outlines the growing attention to the importance of disciplinary literacy in national curricula in the learning of content and preparation for work life in the real world. Specifically, it describes the Ministry of Education (MOE) curricular focus in the Singapore education context which seeks to raise students' literacy levels in content areas on a nationwide level. The rationale and programme specifics of a nationwide initiative driven by the MOE are delineated along with the unpacking of the support model offered to schools. This chapter also highlights an instantiation of collaboration between the National Institute of Education and the MOE to support the development of disciplinary literacy in science. The chapter closes with a consideration of guiding principles that can inform teachers' pedagogic practice with a focus on disciplinary literacy in science.

4.2 Theoretical Foundations

In Singapore, theoretical understandings of disciplinary literacy have drawn largely on the work of scholars such as Fang (2005, 2012), Moje (2007) and Shanahan and Shanahan (2008). Disciplinary literacy refers to the specific ways of talking, reading, writing and thinking valued and used by people in a discipline in order to successfully access and construct knowledge in that discipline (Moje, 2007; Shanahan & Shanahan, 2008). Disciplinary literacy and disciplinary content are mutually constitutive with literate practices being fundamental to engaging in social and cognitive practices that develop and advance disciplinary knowledge (Fang & Coatoam, 2013). Therefore, the aim in developing students' literacy within a discipline is to build students' capacity to engage in literacy skills, strategies and practices, in line with those of content-area experts and as part of the process of socialisation into science discourse (Fang, 2012; Fang & Coatoam, 2013).

Fang and Coatoam (2013, p. 628) observe that there are differences in the way disciplinary content is 'produced, communicated, evaluated, and renovated'. This diversity calls for specificity in literacy practices taught. Moreover, the distinguishing features of scientific language described by Fang (2005) underscore the highly specialised nature of science discourse. It is thus not surprising that advocates of disciplinary literacy argue that literacy instruction should be situated within a given content area so that teachers can use their content-area expertise to give 'explicit attention to discipline-specific cognitive strategies, language skills, literate practices, and habits of mind' (Fang & Coatoam, 2013, p. 628). But how can the existing framework be adapted purposefully and meaningfully to incorporate disciplinary literacy and what kinds of systemic support would teachers need so that they can help students meet the specific challenges of reading, writing, speaking, listening and language in their respective fields? We address these questions in the following section.

4.3 Disciplinary Literacy Through the Lens of Effective Communication in the National Curricula

In Singapore, growing recognition of the importance of disciplinary literacy in the national curricula has led to this literacy being situated within the MOE 21st century competencies framework under the core competency of communication skills: 'Communicating effectively refers to the delivery of information and ideas coherently, in multimodal ways, for specific purposes, audiences, and contexts' (Ministry of Education, 2011, p. 9). Communication is conceptualised as 'the interactive process of sharing concepts, thoughts and feelings between people using the medium of language as a resource' (English Language Institute of Singapore, 2013, p. 1). In addition, this process involves the 'co-construction of meaning' by those involved (English Language Institute of Singapore, 2013, p. 1). Communication, as acknowledged in research literature, can encompass both linguistic skills and non-linguistic skills, such as body language, gestures, facial expressions, as well as cultural and social conventions for interacting with people (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). To the MOE in Singapore, 'Effective communication occurs when the audience or reader understands a message in the way the communicator intended it to be understood, or when the co-construction of meaning satisfies all parties involved' (English Language Institute of Singapore, 2013, p. 1).

Literacy in a discipline entails the ability to use language appropriately, meaningfully and precisely in a given subject area and this ability requires both proficiency in language and subject knowledge (English Language Institute of Singapore, 2013). Language itself mediates the learning of the concepts, models, theoretical frameworks and skills demanded by each subject (Bailey, Burkett, & Freeman, 2008). Language serves as a window to the content in the subject classroom where it is used to express, create and interpret meanings in the context of the subject. As students progress towards the higher levels in school, they move beyond the basic literacy level of decoding and generic comprehension to acquiring increasingly specialised literacy skills for each subject. Strong early reading skills do not necessarily translate into an ability to deal with the special language requirements required in content-area classrooms. Students have to read to learn, write to learn and talk to learn (Shanahan & Shanahan, 2012) in order to understand and communicate subject-specific content. This is especially so given that curriculum subjects differ in their communicative purposes, their typical text structures and characteristic language features. The linguistic implications are distinctive differences in how texts are organised, how the vocabulary is selected and how grammatical choices are made. Such knowledge and practices constitute the literacy skills and abilities that students need to acquire.

Effective communication by all content-area teachers from this perspective thus implies the skilful use of subject-specific language to help students better

understand, process and internalise subject knowledge effectively. This is achieved by explicit instruction of the content as well as explicit attention to the language specifics in teaching the content to help students access the language. As well as conveying subject content through presentational modes of language use, subject teachers can also facilitate thinking and understanding of content through interactional modes of language use in the classroom (Jocuns, 2012). By modelling effective communication, science teachers can raise students' awareness of the norms and conventions of reading, writing, talking and thinking like a scientist (Vacca & Vacca, 2008). As a corollary, students develop the language to understand and effectively explain the concepts of the subjects they are studying which essentially involves disciplinary literacy.

4.3.1 The Implications of Situating Disciplinary Literacy Within the Effective Communication Framework

The perspective on effective communication in Singapore schools is shaped by several contextual factors that have implications for the way teachers conceive disciplinary literacy. First, the desired outcomes for effective communication within the Singapore education context are oriented towards helping students become future-ready—students' communicative skills are intended to help them meet the expectations of employers or Institutes of Higher Learning upon leaving the secondary education system and every student is expected to communicate effectively in social situations with both local and overseas speakers of English (English Language Institute of Singapore, 2012).

The second factor relates to the focus on the specific English language variety used for communicating in the classroom. In multiracial Singapore, English, Mandarin, Malay and Tamil are the official languages. Bilingualism is 'a cornerstone of our education system' (Curriculum Planning and Development Division, 2010, p. 6) with students learning both English and their own Mother Tongue language in school. English is the common language facilitating bonding among the different ethnic and cultural groups. At the global level, English is recognised as 'the lingua franca of the Internet, of science and technology and of world trade' (Curriculum Planning and Development Division, 2010, p. 6). Given that standard English is the medium of instruction for all subjects in Singapore schools except the Mother Tongue languages (Curriculum Planning and Development Division, 2010), effective communication primarily addresses the use of standard English across the curriculum in content-area classrooms.

Finally, specificity in standard English employed in content-area classrooms is delineated by subject-specific notions of communication articulated in the subject syllabuses. We illustrate what they mean by subject-specific understandings of communication with reference to the MOE Secondary Science Syllabus. As the Upper Secondary Science Syllabus is at present undergoing a review, we refer to the Lower Secondary Science Syllabus (Ministry of Education, 2008) which describes 'scientific literacy' largely in terms of

cognitive and social practices (Bailey et al., 2008, p. 4). 'Scientific literacy' is outlined as follows:

(i) the capacity to engage in the discipline-specific inquiry process skills of 'identifying questions', 'drawing evidence-based conclusions', 'making decisions' as well as the 'skills and habits of mind' aligned with the aforementioned 21st century competencies such as 'reasoning and analytical skills, decision and problem solving skills, flexibility to respond to different contexts and possessing an open and inquiring mind';
(ii) having an understanding of the key features of scientific inquiry and its impact and;
(iii) having the appropriate ethical and attitudinal disposition.

While there are some overlaps with the notion of disciplinary literacy, Fang & Coatoam's (2013) broader definition of science literacy encompasses not only the linguistic but also the semiotic (Kress & van Leeuwen, 2001) which includes multimodal resources for communication (visual, verbal, gestural). This is reflected in their more encompassing definition of 'habits of mind' as 'ways of reading, writing, viewing, speaking, thinking, reasoning and critiquing' (Fang & Coatoam, 2013, p. 628).

In addition, in the syllabus document, communication is defined as 'the skill of transmitting and receiving information presented in various forms—verbal, tabular, graphical or pictorial' (Bailey et al., 2008, p. 8). While 'communication' in the Lower Secondary Science Syllabus is embedded within science inquiry, it is not viewed as a skill that cuts across and/or underpins the whole inquiry process. Instead, it is conceived as one of the several distinctive features of science inquiry, others being 'question', 'evidence', 'explanation' and 'connections' (Bailey et al., 2008). Moreover, the skill of communicating is confined to contexts where 'students communicate and justify their explanations when they form reasonable and logical argument to communicate explanations' (Bailey et al., 2008, p. 13) and the teacher guidance for communicating is in the form of steps, procedures, guidelines and coaching (Bailey et al., 2008). As have been articulated by others (Adger, Snow, & Christian, 2002; Bailey et al., 2008), working 'side by side with content and grade-level teachers to collaboratively adapt curriculum and classroom instruction to meet the specific needs' (Bailey et al., 2008, p. 19) of students is what those providing support to content teachers can offer. Understanding not only the structure but also 'how language mediates students' access to content, classroom learning processes and assessments' (Adger et al., 2002) is critical. Tang's (2015) deconstructing scientific explanation through the explicit framing of Premise-Reasoning-Outcome (PRO) to help students reason the underlying logic and casual sequencing of an explanation has proved beneficial to students.

By incorporating disciplinary literacy into an existing framework of effective communication in the national curricula, understandings of disciplinary literacy are shaped by, first, the strong emphasis on standard English as the mode of communication and, secondly, the aforementioned entrenched curricular definitions of scientific literacy amongst teachers. The emphasis on standard English is not

necessarily at odds with the notion of disciplinary literacy but can potentially detract from the focus on the literacy demands of a discipline. As such, distinctions between the two need to be clearly articulated. The prevailing understanding of scientific literacy, however, presents a more restrictive perspective of literacy. For this reason, it is imperative that the notion of disciplinary literacy is made explicit for science teachers.

4.4 Systemic Support for Developing Literacy in the Content Areas

In Singapore, support for the development of effective communication in all schools is spearheaded by the MOE. In 2012, the Whole School Approach to Effective Communication in English (WSA-EC) was initiated by the MOE English Language Institute of Singapore (ELIS) to enhance the professional standing of teachers as role models of English and to help students become effective communicators in English (English Language Institute of Singapore, 2016a) in line with the emphasis on 21st-century competencies (Ministry of Education, 2016). The emphasis is on content-area teachers modelling good communication skills to communicate subject knowledge more clearly and effectively in every classroom for every subject, providing opportunities for all students to develop these skills, and creating a whole-school environment where effective communication is valued. MOE held the belief that immersion in such an environment would over time help students develop a wide repertoire of communication skills such as questioning, evaluating, explaining, comparing and contrasting, classifying, hypothesising, and distinguish between subject-specific communication skills. The WSA-EC programme has been rolled out to primary, secondary and pre-university institutions in phases.

The support model of the WSA-EC comprises: (i) professional learning courses, (ii) collaborative school-based research, (iii) provision of resources and (iv) interaction with experts (English Language Institute of Singapore, 2016a). For the purposes of this chapter, we focus on the first two components of the support model to illustrate and examine how systemic support impacts the classroom environment.

4.4.1 Professional Learning Courses: Key Features and Challenges

The MOE recognises that the onus of developing a whole-school environment supportive of effective communication and of modelling effective communication skills within the disciplines rests on the teachers. To deepen content-area teachers' understanding of disciplinary literacy, schools on the WSA-EC went through three

core curriculum professional learning courses on disciplinary literacy. These courses are targeted at mixed content-area teams from primary and secondary schools comprising teacher leaders (also referred to as 'Champions of Effective communication') in science, mathematics and the humanities. The courses aim to develop a greater awareness and understanding of the strong connection between learning a subject and the language used to convey content and skills in that subject. The courses aim to:

(i) develop teachers' awareness of the importance of language and literacy for teaching disciplinary content and highlight the role language plays when students are learning the concepts, skills and processes of disciplinary content (Language and Literacy in Subject Classrooms);
(ii) examine how talk and interaction can help facilitate deeper learning and engagement for students through a framework for supporting high-quality talk and interaction in content-area classrooms and explore strategies that facilitate productive talk for effective teaching and learning of disciplinary content (Opening Up Talk for Learning in Subject Classrooms);
(iii) examine how talk and writing can be integrated to deepen learning in content-area classrooms through a framework for integrating talk with writing and explore strategies for monitoring and evaluating student learning through talk and writing (Integrating Talk with Writing in Subject Classrooms) (English Language Institute of Singapore, 2016b).

One important feature of the courses is that the content-area teacher leaders representing different disciplines are encouraged to implement the strategies they jointly developed or identified in their content-area group as salient for a given task in their classroom, and reflect on the effectiveness of this implementation before the next session of the course. These teacher leaders, upon completion of the courses, return to school and work towards transferring learning to their colleagues in their specific disciplines. Embedding the implementation within the programme itself gives content-area teachers a platform to share their experiences with one another and develop collective wisdom on literacy instruction that benefited their students the most, identify areas to improve upon and pitfalls to avoid. Moreover, it encourages commitment to developing subject-specific communication skills as an integral part of their subject teaching and proficiency in the use of pedagogy that will enable student to develop these skills. In-course and post-course follow-up by the teacher-leaders allow them to trial and experience the strategies introduced in the course with their own classes. There is further on-site co-facilitation of cascading of learning by content teacher leaders to their subject teams supported by MOE language specialists and subject literacy officers.

Given that these courses are usually facilitated by language specialists, the general approach taken by facilitators has been to highlight key MOE policies and key findings in the research literature, engage content-area teachers in analysing the literacy demands of a given task and elicit from them the strategies they collectively worked out for addressing students' specific literacy needs anticipated for that given task. These courses, therefore, provide a means for teachers to engage

in both 'theoretical knowing' and 'experiential knowing' (Nutley, Walter, & Davies, 2007, p. 24) to inform their use of sound pedagogy to facilitate the development of students' literacy in a discipline.

Having participated in the first course, the team of content-area teachers from each school would then develop plans to enhance the development of effective communication skills suited to its particular environment and culture. The strategies outlined in these plans would over time be infused into the school practices and systems. Our focus after teachers return to their schools is on school-based disciplinary literacy instruction in order to meet students' specific literacy needs as this shows how schools transfer the learning to their subject colleagues and the impact the courses might have had.

Having described this systemic support, we are also mindful of challenges content-area teachers face when attending courses on disciplinary literacy. Content-area teachers, as the more proficient and knowledgeable learners and users of the discourse, possess the ability to recognise pertinent texts and how to interact with them. They have a critical role to play in bringing the students along the path of a deeper and broader understanding of curriculum (Draper, Broomhead, Jensen, & Siebert, 2010). To do this, content-area teachers need to conceptualise 'language and literacy practice as an integral aspect of subject area learning, rather than as a set of strategies for engaging with texts' (Moje, 2008, p. 99). This entails literacy being viewed not as generic skills taught in isolation, separately from the content, but contextualised and adapted within their own disciplines to facilitate learning of the content. The challenge, therefore, lies in the fact that a mixed group of content-area teachers representing each school attends these courses together. These teachers need to consider individually and together with their content-area colleagues back in school how they could adopt or adapt literacy strategies they encountered or came up with during the course to help students understand and construct disciplinary content in ways consistent with social norms and ongoing semiotic and cognitive practices. The Champions of Effective Communication work closely with their content-area colleagues through their in-house professional learning and mentoring sessions to consider ways to synergise their efforts during implementation to best meet their students' learning needs.

In science, the specific challenge concerns situating literacy strategies within the inquiry process (Draper & Siebert, 2010) outlined in the MOE Science Syllabus in order to facilitate students interpreting and constructing texts with the distinguishing features of scientific language. The difficulty also arises from identifying and employing literacy strategies that enable students to use and interpret different kinds of representations in the discipline (Draper & Siebert, 2010; Tang, 2011b; Tytler, Prain, Hubber, & Waldrip, 2013). Fang and Coatoam (2013) caution against the problem of generic strategies being re-packaged as discipline-specific ones. As such, content-area teachers need to address the question of which literacy strategies enable students to interpret these representations in ways consistent with norms and recognise nuanced changes in meaning with changes in the mode of representation and the purpose of these different modes of representations.

Further, as content-area teachers develop and refine these literacy strategies for their discipline, they need to heed Draper et al.'s (2010) caution against a general form of literacy applicable only to a school or examination context and is neither useful within the discipline nor in adolescents' lives outside of school. In our view, the first point is problematic only if the inquiry process outlined in the MOE Science Syllabus is not consistent with the real-world practices of scientists and only if assessment methods are not consistent with the inquiry process described. The second point presents the more persistent challenge of developing literacy strategies that draw on adolescents' out-of-school interests and experiences with popular texts and/or hybrid texts on the science topics. This is an important area that warrants further investigation to better inform content-area teachers as they endeavour to develop pedagogical practices that support the development of disciplinary literacy. Some exploratory studies were carried out in this area to investigate the role of out-of-school media representations of science (Parkinson & Adendorff, 2004; Tang, 2013) and the agency of science students across the informal and formal domains (Bell, Lewenstein, Shouse, & Feder, 2009; Rappa & Tang, 2017; Tang, 2011a).

We want to emphasise that what content-area teachers face should not be handled by them alone. According to Fang and Coatoam (2013, p. 629), literacy teachers trained in 'reading instruction, focussed on phonics, vocabulary, fluency and cognitive strategies' lack disciplinary expertise in two areas—they are unfamiliar with the 'content, discourse patterns, literate practices and habits of mind within specific disciplines' and 'they lack knowledge of the big ideas, unifying concepts and key relationships related to the content of the disciplines'. Having said that, Fang and Coatoam (2013, p. 629) also argue that content-area teachers 'lack the necessary language awareness and literacy strategies to help students cope with the specific language and literacy demands of their discipline'.

In the light of the aforementioned view, there is much that ELIS language specialists and the National Institute of Education (NIE) education researchers can do and have done to support content-area teachers. First of all, language specialists have a role to play in bringing to the fore the literacies specific to a discipline (Draper et al., 2010). What this means is that language specialists can begin by helping content-area teachers reflect on the background knowledge and self-questioning practices that support text interpretation, how they go about interpreting texts and the norms for constructing texts (Draper et al., 2010). Second, language specialists can provide support by drawing content-area teachers' attention to instructional frameworks for literacy (Draper et al., 2010). We acknowledge what Draper and Siebert (2010), citing Conley (2008), have highlighted regarding generic strategies, that they 'fit poorly with content-area goals and discipline-specific practices'. One approach lies in adapting instructional frameworks which different disciplines have adhered to by incorporating elements of literacy instruction. Draper and Adair (2010) provide an illustration of how this might be achieved in relation to the 5E Learning Cycle (Bybee et al., 2006), which is popularly known among science teachers. Following this approach, a research collaboration with NIE and two secondary schools developed and tested an integrated literacy-inquiry instructional model that infused literacy elements into the 5E Learning Cycle (Tang & Putra, Chap. 17).

This brings us to the second component of the ELIS support model, which concerns research collaboration with science education researchers at NIE. In the following section, we describe the synergistic relationship between the MOE, NIE and schools as all parties worked towards helping teachers communicate effectively in their subjects.

4.4.2 School-Based Collaborative Research: Impact on Pedagogy

One common form of collaboration between NIE researchers and school teachers is the joint partnership of carrying out design-based research (Collins, Joseph, & Bielaczyc, 2004) with the dual purposes of informing education theory and improving classroom practices situated in the school context. Aligned with the MOE's emphasis on disciplinary literacy, various research studies across a range of school contexts were carried out to integrate some aspects of language and literacy into existing science classroom practices. The range of intervention research includes examining and enhancing primary school teachers' capacity in addressing the language demands of science (Seah, 2016), developing instructional models and strategies for secondary school teachers to explicitly address the language and multimodal demands of science (Tang, 2016a; Tang, Ho, & Putra, 2016), using a genre-based heuristic to support students in constructing scientific explanations at the primary (Seah, 2015) and secondary level (Tang, 2015), harnessing out-of-school media representations of science to foster critical literacy in high school (Rappa & Tang, 2017), and exploring the use of argumentation to foster group discussion in university chemistry (Tan, Lee, & Cheah, In press).

Through design-based research projects situated in science classrooms, the teachers benefited from just-in-time professional development and joint development of resources with researchers with notable changes in the teachers' pedagogical practice. For instance, four teachers in one of the research studies learned a new literacy strategy, called PRO, that was designed to teach students how to construct scientific explanations (Tang, 2015). From classroom observations of their teaching over 2 years, the teachers were able to integrate the PRO strategy into classroom talk in a way that supported logical reasoning and content mastery (Putra & Tang, 2016; Tang, 2015). The teachers were also able to adapt other literacy practices introduced during the professional development session to support classroom talk (Tang et al., 2016). Analysis of the students' writing suggests a positive impact in the use of the PRO strategy to improve the quality of the students' written explanations (Tang, 2016a).

4.5 Implications

Subject-based mixed teams of content teacher leaders applying their learning acquired from courses to their school-based subject teams and co-facilitation professional learning sessions with MOE officers present opportunities for empowering

content teachers at various levels. This can also pave the way for more ground-up collaborative school-based research partnerships with the MOE officers and NIE faculty inquiring into identified areas of concern or challenge in the process of seeking solutions collaboratively to enhance students' content learning. At the same time, there is a need to ensure initiatives made to support subject teachers' professional learning and facilitate collaborative research are meeting targeted needs, particularly where students' learning is concerned. Indeed, it is acknowledged that the 'integration of language, subject content, and thinking skills requires systematic planning and monitoring' (Gibbons, 2002, p. 6). These can be framed around the following aspects which have surfaced as not only necessary but also critical in subject-specific learning contexts: Coherence, Contextualisation and Cascading.

4.6 Coherence

Implementation and monitoring of effective communication skills across the whole school must be easily integrated into existing school practices to reinforce current initiatives. There is a need for coherence in literacy programmes/initiatives in order to examine the impact on different stakeholders at different levels and to differing degrees. In education, features of programme design and research initiatives resembling coherence have been advocated under other names—such as integration, articulation. 'Coherence' denotes 'connectedness which, in turn, suggests consistency and accord among elements' (Buchmann & Floden, 1991). The move towards connection among various components is epitomised by Tyler's (1949) seminal work with the consequent continuity, sequence and integration that would ensue. Each of these qualities is a form of connectedness. Continuity means having links between one component and another in the system. Sequence extends the idea of continuity, requiring that links over time—'vertical' relations (Tyler, 1949)—involve a broadening and deepening of what is examined or focused, rather than mere repetition. Integration refers to connections across different aspects in different subjects—'horizontal' relations. Connectedness is required given that haphazard, isolated experiences are unlikely to ensure intended learning.

Coherence extends to the links across teacher facilitation, school leadership, subject teaching and student learning, and how these support and reinforce each other. Decisions about professional learning and development must be based on a good understanding of the relationship between the different layers. For example, if the students' needs-analysis identifies students' content vocabulary as a common 'gap', it would be important to understand how current teaching impacts student content vocabulary learning, and how current leadership and organisational practices contribute to that pattern of teaching through channels such as professional learning communities focused on evidence of teaching and learning (Ministry of Education NZ, 2013, p. 14). The strong school leadership support from the key personnel provided a foundation for the alignment of disciplinary literacy

initiatives adopted by the content teachers in the school context with the overall thrust of schools' strategic goals for effective classroom pedagogical practice. In particular, quality academic experience, staff engagement and development, and partnerships were identified among the strategic thrusts in one school as critical considerations in driving initiative and programmes implemented in the school. In another, disciplinary literacy initiatives reinforced the schools' strategic thrusts that included academic excellence in terms of customised instructional approaches catering to diverse students' needs and developing skilful teachers to be curriculum leaders and reflective practitioners in their disciplines.

4.7 Contextualisation

There is a need for the contextualisation of literacy skills to meet the specific demands and requirements of learning environments and particular curricular contexts. The extent to which initiatives mediated by language and literacy facilitate content learning can be adapted or modified to aid transferability to similar or related contexts or settings must be considered in any whole-school implementation of a disciplinary literacy-based programme. At the same time, there is a need to address on-the-ground realities, contextual constraints in order to support science teachers and students in their learning endeavour. This will ensure a more targeted approach in supporting students to acquire the relevant disciplinary literacy skills required. Systematic scaffolding as realised in specific disciplinary literacy practices outlined in Tang (2015) is attentive to students' needs and aligned with their ability level, and seeks to address specific challenges in constructing scientific explanation.

Uncovering the critical aspects in authentic contexts or actual settings can inform the science learning experience which the targeted research is addressing. Understanding the learning context can reveal much more with an enhanced understanding of general and specific participant behaviours and decisions taken to provide the most relevant, engaging experience possible for students and teachers. Important insights as to what works and should be sustained and what may need further refinement can be gleaned from the research process, and the learning experiences and expectations of those involved. Such information is essential if meaningful analyses are to be provided. There is also a need to extend beyond 'surface manifestations (discrete activities, materials, or classroom organisation)' to inculcating in teachers an enhanced awareness of deeper pedagogical principles' (Century & Levy, 2002, p. 4). This could mean that the underlying principles of the literacy initiatives or programmes and the associated teacher beliefs and expectations of students are maintained over time.

The need for contextualising what is investigated within appropriate disciplinary discourses and paradigms cannot be overemphasised. This will develop teachers' capacity to recognise and contextualise research questions or hypotheses within specific disciplinary frameworks, and provide them with the opportunity to explore theoretical frameworks and methodologies in relation to their particular

contexts. Initiatives adopted must be interpreted in the context of the specific classroom setting and examined with attention given to the on-the-ground realities, contextual constraints and implementation challenges.

4.8 Cascading

For any literacy initiative or programme implemented to support science teachers, the need for sustainability over a period of time is not to be overlooked. Initial efforts taken to implement literacy strategies to support content learning deserves attention to maintaining scaling up through the transfer of learning and cascading disciplinary literacy practices that have proven to be worthwhile. The central question to be addressed is: how does one ensure that literacy initiatives or programmes implemented will last? This question begs another: which specific aspects of literacy initiatives or programmes would be lasting in 1, 5 or 10 years' time? Research has shown that 'the programme or pedagogical approaches that were promoted through the professional learning/development experience' (Timperley, Wilson, Barrar, & Fung, 2007, p. 218) are the ones that may have a great lasting impact. A key criterion identified for judging sustainability appears to focus on 'continued, improved, worthwhile student outcomes' (Timperley et al., 2007, p. 218). The belief is that 'the conditions for sustainability are set in place during the professional learning experience as much as after it' (Timperley et al., 2007, p. 218).

Sustainability under these circumstances requires 'sufficient depth of principled knowledge for teachers to be able to recognise what is consistent and inconsistent with the changed practice being promoted' (Timperley et al., 2007, p. 219). Indeed, earlier work in the local context has surfaced the need for sustained, focused professional learning over a period of time rather than 'just-in-time' feedback for instructional planning and resources (Tang, 2016b) in order for scaling up pedagogic efforts and initiatives that support disciplinary literacy practices.

The following guiding principles for infusing disciplinary literacy practices into subject-specific pedagogy could inform schools that are focused on strategising disciplinary literacy practices to support content learning:

(i) Which aspects of the professional learning (e.g., specific expectations, principles, theories) are expected to be sustained (if stated or implied)?
(ii) At what level is the implementation (e.g., classroom/level/school-wide) expected to be sustained?
(iii) What kind of conditions created for sustainability was evident during the professional development? (tools for evidence-informed study, focus on theory/principle, other conditions)
(iv) What kind of conditions created for sustainability was evident after the professional development? (integration of implementation efforts that are coherent with school curriculum policy/framework, institutionalisation of implementation through school restructuring/re-culturing?) (Adapted from Timperley et al., 2007, pp. 219–220).

4.9 Conclusion

This chapter has examined how focused planning and strategic design of professional learning programmes and collaborative school-based research have reinforced the concretising of disciplinary pedagogic practices that draw on literacy support to meet students' learning needs in the science curriculum. Purposeful strategising at the systemic level informed by curricula focus that clearly delineates the parameters for the integration of content and language-specific tasks and processes. With the support of key partners (MOE, NIE) in collaboration with school partners, this has facilitated the school-level implementation of disciplinary literacy initiatives that is extending to more of the unreached among schools in the local context. At the same time, the cascading of learning to school-based subject teams at various levels has been set in place with structures supporting the co-facilitation of subject teacher leaders working closely with language specialists and subject literacy officers to infuse disciplinary literacy practices into content teaching at the classroom level.

Further work necessitates ongoing monitoring of the impact of disciplinary literacy initiatives adopted and adapted by schools to enable the necessary adjustments and modifications based on what is or is not enhancing student improvements in learning (Kaufman, Grimm, & Miller, 2012). Attempts to assess disciplinary literacy, as Fang and Coatoam (2013, p. 630) remind us, necessitate collaboration between language specialists and content subject teachers on identifying core skills for developing content and habits of mind, selecting relevant and significant texts, and designing authentic tasks and experiences. More studies along this line will contribute to a comprehensive picture of how perspectives on disciplinary literacy practice in the science curriculum are enacted to support students in reading, thinking, writing and speaking science the way scientists do.

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