Chapter 1
The Expanding Development of Literacy Research in Science Education Around the World

Kok-Sing Tang and Kristina Danielsson

Abstract This introductory chapter summarizes the research background that motivates this book volume and the broad conceptualizations of literacy adopted by the various contributors within the context of science education. It also provides an overview of the six sections in this book, namely (i) national curriculum and initiatives, (ii) content and language integrated learning (CLIL), (iii) classroom literacy practices, (iv) disciplinary literacy challenges, (v) disciplinary literacy and science inquiry, and (vi) teacher development, and summarizes the contributions within each section.

Keywords Literacy · content area literacy · disciplinary literacy · scientific literacy · multimodality · national curriculum · content and language integrated learning (CLIL) · classroom practices · literacy challenges · science inquiry · teacher development

1.1 Background

Literacy has been a major research area in science education for several decades. Researchers exploring the connection between literacy and science learning generally come from the language arts and science education communities, and they bring with them a diverse range of theoretical perspectives and methodological orientations. For some time, research in this area has tended to be situated in and originate from North America, culminating in two prominent conferences that brought scholars from literacy and science education together with a common interest in promoting literacy in science. The first conference – Crossing Borders: Connecting Science and Literacy,

K.-S. Tang (✉)
School of Education, Curtin University, Perth, Australia
e-mail: kok-sing.tang@curtin.edu.au

K. Danielsson
Department of Swedish, Linnaeus University, Växjö, Sweden
e-mail: kristina.danielsson@lnu.se

K.-S. Tang, K. Danielsson (eds.), *Global Developments in Literacy Research for Science Education*, https://doi.org/10.1007/978-3-319-69197-8_1

was held at the University of Maryland in 2001 (Saul, 2004) while the second conference – Ontological, Epistemological, Linguistic, and Pedagogical Considerations of Language and Science Literacy, was held at the University of Victoria in 2002 (Hand et al., 2003; Yore et al., 2004; Yore & Treagust, 2006). This "border crossing" conversation continued with the "Literacy for science in the Common Core ELA Standards and the Next Generation Science Standards" workshop in Washington, DC, in December 2013 (National Research Council, 2014).

The development of literacy research in science education has continued to expand and gained increasing attention across the globe. More countries are currently examining the role of literacy in their national curriculum and have undertaken research to integrate various literacy practices into the teaching and learning of science (e.g., see Chaps. 2–4). This edited volume aims to highlight this growing development around the world, in addition to seeking new ideas and perspectives that emerge when researchers in different parts of the world address literacy-related issues in science classrooms within their respective linguistic, cultural, and political contexts. Specifically, this volume showcases recent developments in literacy-science research from countries and territories such as Australia, Brazil, China, Finland, Germany, Hong Kong, New Zealand, Norway, Singapore, South Africa, Spain, Sweden, Taiwan, and the USA.

The majority of the chapters in this volume were based on selected studies presented at several international conferences, notably the 7th International Conference on Multimodality (ICOM) in Hong Kong in June 2014, the 3rd International Science Education Conference (ISEC) in Singapore in November 2014, and the 11th European Science Education Research Association Conference (ESERA) in Helsinki in September 2015. It was evident that a significant number of conference presentations had a strong literacy focus in descriptive or intervention research conducted within science classrooms. This reflects the growing trend of literacy research in science education around the world, and consequently, the relevance and timeliness of this collected volume.

1.2 Evolving Views of Literacy

Research focusing on literacy in science dates back many decades under the terms "content area literacy" or "literacy across the curriculum" (Shanahan & Shanahan, 2008). Researchers in this area argue that the importance of reading and writing is not confined to the language classrooms, but should extend to all content areas. To support content area literacy, a range of reading and writing strategies for making sense of text have been developed and advocated to be used in the science classrooms. Well-known strategies include reciprocal teaching, CORI (Concept-Oriented Reading Instruction) and SQ3R (Survey, Question, Read, Recite, Review). These strategies are widely used in the USA by reading experts during remedial programs for struggling learners with the intention of improving their reading skills. While research in this area sowed the ideas of infusing literacy teaching into content subjects, the research mostly emphasized the application of generalizable reading and writing skills in all subject matter classrooms, rather than focused on a specific skill or practice that is characteristic of a discipline. As Shanahan and Shanahan (2008) argue, these strategies tend to be more effective for primary school students and less beneficial at the secondary and tertiary level. This partly explains why content area teachers in secondary and tertiary schools have largely been resistant to content area literacy despite the efforts of their literacy counterparts (Moje, 2008).

In the 1990s, content area literacy saw a gradual turn toward the language aspects of the discipline and most notably, the linguistic and discursive features of science. Researchers during this turn have begun to study classroom discourse as a "kind of applied linguistics" consisting of interactional moves and exchanges (Cazden, 1988). They have also developed analytical frameworks to characterize classroom talk, such as the triadic Initiate-Response-Evaluate exchange pattern (Mehan, 1979) or the Initiate-Response-Follow-up sequence (Wells, 1993), and the distinction between authoritative and dialogic talk (Mortimer & Scott, 2003). In science education, Lemke's (1990) *Talking Science* was generally attributed as the landmark study that foregrounds the role of language in science classroom discourse (Kelly, 2007). Based on in-depth analysis of talk and interaction among the teachers and students in science classrooms, Lemke (1990) concludes that learning science is largely learning the language of science.

In written texts, the theory of systemic functional linguistics (SFL) was widely used to characterize the literacy of science according to the unique linguistic features of scientific texts. For instance, Halliday and Martin (1993) describe several characteristics of science register such as interlocking definitions, technical taxonomies, lexical density, and nominalization. Other researchers have also analyzed the recurring patterns of science genres, such as information report, experimental procedure, explanation, and argument (Unsworth, 1998; Veel, 1997) that students typically go through and need to learn in science lessons. These studies subsequently led to a specific literacy approach known as "genre pedagogy" that explicitly teaches students to unpack the register and genre of written texts in science (Hyland, 2007; Unsworth, 2001).

At the turn of this century, developments in multimodality began to shift and expand the scope of scientific language to representations such as images, graphs, symbols, and gestures that are ubiquitously used in science classrooms (Jewitt, 2008). For example, Kress, Jewitt, Ogborn, and Tsatsarelis (2001) document the complex ensemble of multiple modes of representation orchestrated by the science teacher as a way of shaping scientific knowledge through a process of sign-making. In an analysis of the literacy demands of the science curriculum, Lemke (1998) also demonstrates that scientific knowledge is made through joint meaning-making across multiple semiotic modes. In particular, he stresses that the "concepts" of science are "semiotic hybrids of verbal, mathematical, visual-graphical, and actional-operational modes" (Lemke, 1998, p. 88). Subsequently, many other studies have examined how science teachers and students used multimodal representations to construct an understanding of different science concepts at various grade levels (e.g., Danielsson, 2016; Márquez, Izquierdo, & Espinet, 2006; Prain, Tytler, & Peterson, 2009; Tang, Delgado, & Moje, 2014). A common conclusion from these studies is the lack of emphasis on addressing the literacy demands of the multimodal practices in science.

In more recent years, there has been a growing "practice turn" toward getting students to learn the disciplinary practices of science (Erduran, 2015; Ford & Forman, 2006). This emphasis on practice arose mainly from the beliefs that students should be engaged in the activities of scientists, rather than passively learn the products of their practices in the form of scientific knowledge or genres. At the same time, there has been a shift toward viewing literacy as not just the conceptual or linguistic tools to support content or language learning in science, but also a form of social practice (Gee, 1992) to support the epistemic processes specific to a discourse community (Moje, 2008). Thus, the focus is on using literacy to engage students in the practices of science so that they develop a deeper understanding of how knowledge in science is formed as well as an appreciation of how the discipline develops its unique ways of knowing. In terms of classroom teaching, the emphasis has been on disciplinary literacy where students are supported in their use of scientific texts and language as part of scientific inquiry process (Moje, Collazo, Carrillo, & Marx, 2001). The literacy instruction includes teaching students how to use language more effectively to: (a) construct scientific explanations, (b) engage in evidence-based arguments, and (c) obtaining, evaluating, and communicating multimodal information. These three practices are among the eight core practices identified in the Next Generation Science Standards (NGSS) – a recent science education standards document in the USA (National Research Council, 2012).

The authors in this volume adopt a broad conceptualization of literacy that reflects the various linguistic, multimodal, and practice turns of literacy described earlier. The authors also come from a mix of disciplinary backgrounds such as science education, language education, applied linguistics, and the learning sciences. Although the range of theoretical perspectives and research methods varies, most authors raise similar research questions concerning the role of literacy in science teaching and learning, such as:

1. How do students, of various cultural and linguistic backgrounds, learn science through the various languages and representations of science?
2. How do teachers use various literacy activities and instructions to engage their students in constructing scientific meanings and practices?
3. What literacy approaches or pedagogies are suited to support diverse groups of students in science learning, broadly conceived in terms of gaining scientific knowledge, languages, practices, and dispositions?

In using the term "literacy" in science education, the authors are mindful that this is different from the notion of "scientific literacy," which is generally accepted as the educational vision of producing future citizens able to participate in or make informed decisions on science-related societal and political issues (Roberts, 2007). Instead, we are more concerned with the "fundamental" sense of literacy – as ways of using language, in a broad sense, including multimodal forms of representing scientific ideas – that will help students develop the "derived sense" of scientific literacy associated with the conceptual knowledge of and dispositions toward science (Norris & Phillips, 2003). Nevertheless, it is evident that scientific literacy presupposes a certain level of literacy in its fundamental sense (Hodson, 2008). Access to scientific knowledge and communication, participation in science-related activities, and debate about socio-scientific issues cannot be carried out other than through the language and representations of science. In other words, the focus on literacy in this book is more related to the means and how of achieving scientific literacy, rather than postulating or debating about the visions and problems of scientific literacy.

1.3 Overview of Chapters

This volume, consisting of 22 chapters, is organized around six thematic sections: (1) National Curriculum and Initiatives, (2) Content and Language Integrated Learning (CLIL), (3) Classroom Literacy Practices, (4) Disciplinary Literacy Challenges, (5) Disciplinary Literacy and Science Inquiry, and (6) Teacher Development.

The first section opens the volume with a broad overview of the changing national curriculum landscape toward literacy with examples from three countries: Norway, Australia, and Singapore. With each country representing a unique geopolitical and historical context, the three chapters in this section provide a snapshot of curriculum development in different parts of the world and, at the same time, they highlight a common global trend in terms of foregrounding the role of literacy in the content areas. In Chap. 2, Knain and Ødegaard describe how the curriculum reform, which began in Norway in 2006, increased the focus on basic literacy skills across all subject areas. They also describe the challenges and issues faced by Norwegian teachers and school leaders in developing reading, writing, and oral communication competencies as part of their disciplinary curriculum. In Australia, as explained by Davison and Ollerhead (Chap. 3), the importance of literacy in every subject has a long history given Australia's multicultural society and its national priority in supporting learners of English as a second language. With the new Australian Curriculum, there has been even greater focus on teachers integrating subject-specific language and literacy requirements into their content teaching. In Singapore, as Ho, Rappa, and Tang (Chap. 4) report, the emphasis on disciplinary literacy has a different origin. Under the banner of "effective communication" spearheaded by the Ministry of Education, there is a growing awareness that good teaching should include the skillful use of subject-specific language to help students better process and understand the subject.

Besides providing the curriculum background of each respective country, each chapter also focuses on different aspects of research and developmental work undertaken in the country. Knain and Ødegaard report on various research projects in Norway from both language and science education research that have been carried out to support the national research agenda on literacy (one such project is further elaborated in Chap. 16). Davison and Ollerhead focus on preservice teacher education in Australia as this is a crucial element that determines success in integrating subject-specific literacy in the classrooms. In Singapore, Ho et al. elaborate on the systemic support provided by the Ministry of Education in collaboration with the National Institute of Education, and how this support has been a key factor for change in the educational system.

The second section features research studies that focus on content and language integrated learning (CLIL) which deal with classrooms where students are learning a majority language at the same time as they learn science. CLIL refers to an instructional approach that combines content and language teaching (Markic, Chap. 5) and the practice of teaching content using a second or foreign language (Lo, Lin, & Cheung, Chap. 6). Given the diverse linguistic background of students in Germany, Hong Kong, South Africa, Singapore, and the USA, the chapters in this section collectively provide a complex picture of what it means to help second language learners who are learning a new medium of instruction in the country as well as the unfamiliar language of science, in what is effectively a "multilingual science lesson." First, Markic explains in Chap. 5 the situation of migrant children in Germany and the problem of getting science teachers to address the teaching of German as a foreign language in their science lessons. She presents a participatory action research involving science teachers and German as a second language (GSL) teachers, and reports some success in helping linguistically disadvantaged students. Chapter 6 by Lo et al. follows up with a similar study in Hong Kong in terms of the rationale and approach of having science and English language teachers work together. An interesting aspect in their study was the teachers' use of the Sydney School's genre-based pedagogy (Rose & Martin, 2012), followed by their illustrations of how the teachers weaved English language teaching into the process of science knowledge construction.

In Msimanga and Erduran's Chap. 7, the focus shifts to South Africa where the problem is further compounded by most students learning English as their third or subsequent language and being taught by science teachers who themselves are not proficient in English. This unique situation led Msimanga and Erduran to investigate how teachers who were nonnative speakers of English consciously or unconsciously used meta-talk as a discursive tool to engage students in discussing scientific ideas. The attention to meta-talk, or metadiscourse, reflects the growing awareness of this discursive resource that can potentially be used to engage students in the learning of science (Tang, 2017). The last chapter in this section by Wu, Mensah, and Tang (Chap. 8) provides a contrasting view to the argument of CLIL. While a key benefit of CLIL is to use content learning to support second or additional language development, Wu et al. question the role of the students' native language in learning science. With case studies from English language learners (ELLs) in New York and Singapore, this chapter illustrates the content-language tension faced by ELLs and aptly reminds us that language use in science classrooms is not merely shaped by cognitive or linguistic considerations, but is also largely ideologically and politically contested.

The third section explores the role of literacy in science classroom discourse. Wilson and Jesson (Chap. 9) provide an overview of the nature of literacy teaching in several science classrooms in Auckland where the teachers were identified by their school leaders as effective at developing students' literacy in science. Given the vision for literacy in science expressed in the New Zealand Curriculum (similar to Australia as reported in Chap. 3), what is telling from their findings was the limited range of literacy teaching confined to vocabulary instruction, repeated practice tasks, and the use of short teacher-designed texts. Wilson and Jesson thus advocate the need for a broader focus on more disciplinary-appropriate ways of reading, writing, and talking. In Chap. 10, Cavalcanti Neto, Amaral, and Mortimer analyze the discursive interactions in three biology classrooms on the topic of environment. By unpacking teaching strategies (e.g., oral exposure, questioning, reading) in terms of discursive interactions, they highlight how different discursive patterns (e.g., dialogic, authoritative) can facilitate or hinder the development of scientific literacy, both in the fundamental sense (Norris & Phillips, 2003) and Vision II of scientific literacy (Roberts, 2007). Chapters 11 and 12 shift the attention of literacy toward its multimodal aspect. Jakobson, Danielsson, Axelsson, and Uddling in Chap. 11 investigate the role of multimodal classroom interaction in students' science meaning-making in a grade 5 multilingual classroom in Sweden. They illustrate in microanalytic detail how the concept of measuring time is a multimodal assemblage of spoken and written language, gestures, physical objects, models, and metaphors. In a similar approach, He and Forey (Chap. 12) study how a range of semiotic resources was used to construct a sequential explanation of digestion in a grade 9 Australian science classroom, and further elucidate the "multiplying meaning" principle first proposed by Lemke (1998).

The fourth section addresses the question of what makes the literacy practices of science so challenging for many students. Liu tackles this question in Chap. 13 by examining the language of symbolic formulae in secondary school chemistry textbooks. His analysis reveals that a chemical formula often incorporates two different types of meanings to represent both the quantitative and qualitative composition of a compound. Making this distinction can help educators understand the literacy challenges posed by symbolic formulation in chemistry texts. In Chap. 14, Danielsson, Löfgren, and Pettersson examine another aspect of literacy challenge in the disciplinary discourse of chemistry – the use of metaphors. From their analysis of chemistry lessons in Sweden and Finland focusing on the atomic structure and ion formation, they found that the teachers used an abundance of scientific, everyday, and anthropomorphic metaphors to foreground different properties of the atom. With each metaphor having different affordances, or "gains and losses," in understanding chemistry, they argue for the need to have more discussions around metaphors in the classrooms. In Chap. 15, Ge, Unsworth, Wang, & Chang turn to the role of image in students' reading comprehension of science texts in Taiwan. Combining perspectives from cognitive and semiotic theories, they designed and conducted an experiment to test the hypothesis that image designs with salient tree structure can lead to better reading comprehension of the concept of biological classification system. Their findings offer empirical evidence to support the principle of sound image design in science teaching and instructional design.

The fifth section focuses on the role of disciplinary literacy in science inquiry and practices, and features three design research projects aimed at integrating literacy and inquiry. These projects start with the guiding principle that literacy in the classroom should mirror the disciplinary practices of scientists (Pearson, Moje, & Greenleaf, 2010). The first project (Ødegaard, Chap. 16) is the Budding Science and Literacy research implemented as part of the Norwegian curriculum emphasis on disciplinary literacy (Chap. 2). Inspired by the *Seeds of Science/Roots of Reading* (Barber et al., 2007), a teaching model was developed and enacted by six primary science teachers in Norway. From various data sources, Ødegaard argues that literacy activities embedded in science inquiry provide crucial support for students' meaning-making in science. A similar project by Tang and Putra (Chap. 17) was carried out in four secondary physics and chemistry classrooms in Singapore, in alignment with the country's new emphasis on subject-specific literacy (Chap. 4). They adapted the 5E Inquiry Model (Bybee et al., 2006) and infused literacy strategies designed to support students in constructing scientific explanations. Focusing on the teachers' enactment of the pedagogical model, Tang and Putra illustrate how literacy instruction can enable inquiry-based science. In Chap. 18, Tytler, Prain, and Hubber focus on another core aspect of science disciplinary literacy, which is the construction of multimodal representations. They developed a "representation construction" approach to inquiry in Australia to engage students in experimenting, generating, and refining representations to explain the material world. Through this inquiry approach, Tytler et al. argue that students can achieve a meta-representational understanding of how texts and knowledge are produced in scientific work.

The last section in this volume explores the important issues and tensions faced in preparing science teachers to integrate disciplinary literacy in their teaching. In the context of training a group of preservice primary teachers in Spain to become CLIL teachers, Espinet, Valdés-Sanchez, and Hernández (Chap. 19) examine the student teachers' beliefs and expectations through their science and language experience narratives. They found that the student teachers' science experiences were more related to school contexts and associated with negative experiences, whereas their language experiences were connected to a variety of out-of-school contexts and were more positive. Their result points to the need to address the isolation of science from the social and personal life of not only young children, but importantly of our preservice teachers as well. It also raises the question of how to use the teachers' positive language experiences as contexts for anchoring their science experiences. In Chap. 20, Hand, Park, and Suh focus attention on in-service science teachers' epistemic orientations toward the role of language. Through a 3-year professional development program in Midwestern USA, they tracked changes in the teachers' epistemic orientations and pedagogical practices as they learned and implemented the Science Writing Heuristic (SWH) approach. Their preliminary findings underscore the importance of teachers understanding the critical role of language as an epistemic tool, and the potential impact of such epistemic orientations on improving student learning. Lastly, Airey and Larsson (Chap. 21) explore the disciplinary literacy goals of undergraduate physics lecturers in Sweden and South Africa, and argue that each discipline emphasizes varying communicative practices for three different settings: the academy, the workplace, and society. These interdisciplinary differences pose significant challenges for physics trainee teachers who have to navigate across the disciplines of physics and education during their preservice teacher education.

1.4 Concluding Remarks

In sum, the studies featured in these chapters provide a landscape of the research within the literacy-science nexus stretching across the globe. This niche area of research has seen "cross-border" dialogue between researchers from literacy and science education predominantly from North America for the last few decades, and now increasingly involves researchers from around the world. In this regard, this volume not only contributes notable literature to the expanding conversation, but also represents a shift of this "cross-border" dialogue from the initial disciplinary "borders" between literacy and science to the present international borders across national boundaries. We hope that this volume will serve as a catalyst for more studies that will contribute to the continuing global conversation in the intersection of literacy and science education research.

References

Barber, J., Pearson, P., Cervetti, G., Bravo, M., Hiebert, E., Baker, J., et al. (2007). *An integrated science and literacy unit. Seeds of science. Roots of reading*. Nashville: Delta Education.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., et al. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs: BSCS.

Cazden, C. B. (1988). *Classroom discourse: The language of teaching and learning* 1st ed. Portsmouth: Heinemann.

Danielsson, K. (2016). Modes and meaning in the classroom – the role of different semiotic resources to convey meaning in science classrooms. *Linguistics and Education, 35*, 88–99. https://doi.org/10.1016/j.linged.2016.07.005

Erduran, S. (2015). Introduction to the focus on … scientific practices. *Science Education, 99*(6), 1023–1025. https://doi.org/10.1002/sce.21192

Ford, M. J., & Forman, E. A. (2006). Redefining disciplinary learning in classroom contexts. *Review of Research in Education, 30*, 1.

Gee, J. P. (1992). *The social mind: Language, ideology, and social practice*. New York: Bergin & Garvey.

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

Hand, B., Alvermann, D. E., Gee, J., Guzzetti, B. J., Norris, S. P., Phillips, L. M., et al. (2003). Message from the "Island group": What is literacy in science literacy? *Journal of Research in Science Teaching, 40*(7), 607–615.

Hodson, D. (2008). *Towards scientific literacy*. Rotterdam: Sense Publishers.

Hyland, K. (2007). Genre pedagogy: Language, literacy and L2 writing instruction. *Journal of Second Language Writing, 16*, 148–164.

Jewitt, C. (2008). Multimodality and literacy in school classrooms. *Review of Research in Education, 32*, 241–267.

Kelly, G. J. (2007). Discourse in science classrooms. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 443–469). Mahwah: Lawrence Erlbaum Associates.

Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal teaching and learning: The rhetorics of the science classroom*: London: Continuum.

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

Lemke, J. L. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. Martin & R. Veel (Eds.), *Reading science* (pp. 87–113). London: Routledge.

Márquez, C., Izquierdo, M., & Espinet, M. (2006). Multimodal science teachers' discourse in modeling the water cycle. *Science Education, 90*(2), 202–226.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge: Harvard University Press.

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent & Adult Literacy, 52*(2), 96–107.

Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). "Maestro, what is' quality'?": Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching, 38*(4), 469–496.

Mortimer, E. F., & Scott, P. (2003). *Meaning making in secondary science classrooms*. Buckingham: Open University Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington: The National Academies Press.

National Research Council. (2014). *Literacy for science: Exploring the intersection of the next generation science standards and common core for ELA standards, a workshop summary*. Washington: The National Academies Press.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224–240.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science, 328*(5977), 459–463. https://doi.org/10.1126/science.1182595

Prain, V., Tytler, R., & Peterson, S. (2009). Multiple representation in learning about evaporation. *International Journal of Science Education, 31*(6), 787–808. https://doi.org/10.1080/09500690701824249

Roberts, D. (2007). Scientific literacy/science literacy. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Mahwah: Lawrence Erlbaum.

Rose, D. & Martin, J.R. (2012). Learning to Write, Reading to Learn: Genre, knowledge and pedagogy in the Sydney School. London: Equinox.

Saul, W. (2004). *Crossing borders in literacy and science instruction: Perspectives on theory and practice*. Newark: International Reading Association; Arlington: NSTA Press.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review, 78*(1), 40–59.

Tang, K. S. (2017). Analyzing teachers' use of metadiscourse: The missing element in classroom discourse analysis. *Science Education, 101*(4), 548–583. https://doi.org/10.1002/sce.21275

Tang, K. S., Delgado, C., & Moje, E. B. (2014). An integrative framework for the analysis of multiple and multimodal representations for meaning-making in science education. *Science Education, 98*(2), 305–326. https://doi.org/10.1002/sce.21099

Unsworth, L. (1998). "Sound" explanations in school science: A functional linguistic perspective on effective apprenticing texts. *Linguistics and Education, 9*(2), 199–226.

Unsworth, L. (2001). *Teaching multiliteracies across the curriculum: Changing contexts of text and image in classroom practice*. Buckingham: Open University Press.

Veel, R. (1997). Learning how to mean-scientifically speaking: Apprenticeship into scientific discourse in the secondary school. In C. Frances & J. Martin (Eds.), *Genre and institutions: Social processes in the workplace and school* (pp. 161–195). London: Cassell.
Wells, G. (1993). Reevaluating the IRF sequence: A proposal for the articulation of theories of activity and discourse for the analysis of teaching and learning in the classroom. *Linguistics and Education, 5*, 1–37.
Yore, L. D., Hand, B., Goldman, S. R., Hildebrand, G. M., Osborne, J. F., Treagust, D. F., et al. (2004). New directions in language and science education research. *Reading Research Quarterly, 39*(3), 347–352.
Yore, L. D., & Treagust, D. F. (2006). Current realities and future possibilities: Language and science literacy – empowering research and informing instruction. *International Journal of Science Education, 28*(2), 291–314.