Chapter 9
A Case Study of Literacy Teaching in Six Middle- and High-School Science Classes in New Zealand

Aaron Wilson and Rebecca Jesson

Abstract This chapter reports a case study of the literacy practices and knowledge of six science teachers in Auckland, New Zealand (NZ). In NZ, the national curriculum requires that students develop sophisticated, subject-specialised literacy in science. However, little is known about actual patterns of literacy teaching and learning in NZ science classrooms. Participants were six teachers of science from schools serving low to middle socio-economic status communities. Two teachers taught Year 7 (students aged 11–12 years), two taught Year 9 (13–14 years) and two taught Year 11 (15–16 years). The data included observations of literacy teaching in science lessons, interviews with teachers and measures of teachers' subject literacy pedagogical content knowledge. Data from all three sources indicated that teachers considered vocabulary to be the key to literacy learning in science, and the literacy teaching observed was consistent with this. This vocabulary teaching tended to focus on definitions, supplied by the teacher and learned through repeated practice activities. Texts used in science lessons were most commonly short, teacher designed texts. Students had few opportunities to read science texts independently. We identify a need to expand the learning outcomes that are valued, from a primary focus on assessed science content to a broader focus that encompasses reading, writing, disciplinary and critical literacy outcomes. We see an opportunity to frame students, rather than teachers, as being responsible for the reading and writing of science text and to move from constrained to open-ended literacy learning tasks. Finally, we identify a need to move beyond short-term strategies towards a focus on generative teaching so that students are in a position to read and write the texts they need as citizens or as emerging science professionals.

Keywords New Zealand · disciplinary literacy · adolescent literacy · science · teacher observations

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This chapter reports a case study of the literacy practices and knowledge of six science teachers in Auckland, New Zealand (NZ). The teachers in the case study taught in two high schools (Years 9–13) and two intermediate schools (Years 7–8) serving low- to mid- socio-economic status communities. The two intermediate school teachers taught Year 7 classes (comprising students of 11–12 years of age) and, of the four high school teachers, two taught Year 9 (13–14 years) and two taught Year 11 (15–16 years). Despite an increasing awareness of the importance of literacy in subject-areas such as science, little research had previously been conducted to investigate patterns of literacy instruction in NZ schools.

Our focus here is with students' developing knowledge of the language of science and how students learn to read, write, speak and listen to texts in science. Our focus is not on 'scientific literacy' which we take to refer to understanding of the natural world and key science concepts, principles and ways of thinking (Pearson, Moje, & Greenleaf, 2010). We do work from an assumption however that developing literacy in science contributes to the development of scientific literacy.

Students' ability to read, write, speak and listen to texts in science is considered to have a powerful effect on their overall science achievement. While a causal relationship between improved reading and improved scores on subject-based assessments has yet to be empirically established (Kamil et al., 2008), the correlations between PISA Reading scores with PISA scores in mathematics and science scores, for example, are 0.81 and 0.86, respectively (Kirsch et al., 2002). Moreover, like nations worldwide, meeting the challenges NZ faces as a society increasingly depends on its citizens' knowledge of science. A recent government report (Office of the Prime Minister's Science Advisory Committee, 2011), for example, argues that the objectives of science, for both 'pre-professional education' and 'citizen-focused education', require children to take 'an informed participatory role in the science-related decisions that society must make' and to 'distinguish reliable information from less reliable information' (p. 4). These objectives demand sophisticated forms of literacy specific to the teaching and learning of science.

There is consensus that the literacy and language demands of different subjects become more sophisticated and specialised as students move up the year levels (Lee & Spratley, 2010; Moje, 2008). The increased specialisation is closely related to the 'clearly demarcated subject orientation' (May & Wright, 2007, p. 374) of secondary schools, and their organisation into different, reasonably autonomous, subject-based departments (Hargreaves & Macmillan, 1995; Siskin, 1997). The texts that students encounter provide one instance of this subject specialisation. Mathematics word problems are almost exclusive to mathematics classrooms, historical documents to history classroom and scientific research reports to science classrooms (Lee & Spratley, 2010; Moje, Stockdill, Kim, & Kim, 2011).

Helping students develop knowledge to cope with increasing linguistic complexity and specialisation is the key feature of a body of recent research advocating for more attention to *disciplinary literacy* (Fang & Schleppegrell, 2010; Shanahan & Shanahan, 2008). From a disciplinary perspective generic reading skills such as decoding and general comprehension strategies are necessary but not sufficient for students to meet the sophisticated and specialised demands of reading in middle- and high-school science.

The statement of official policy that sets the direction for student learning in English-medium schools, New Zealand Curriculum (NZC), includes explicit messages about literacy learning in science (Ministry of Education, 2007). The vision for literacy in science expressed in NZC is an ambitious one. Students are expected not only to read texts for information but also to read texts that help them apply that knowledge to real world contexts. Students are expected to become critically literate users of popular and science texts: by Year 6, students are expected to begin to question the authors' purposes for constructing texts and, by Year 10, to use their understanding of science to evaluate both popular and scientific texts. The vision in NZC is consistent with a disciplinary literacy perspective insofar as students are expected to learn 'what science is and how scientists work' and 'how science ideas are communicated' (Ministry of Education, 2007, p. 28).

There is a range of instructional practices warranted in the literature as potentially effective in developing these valued literacy outcomes in science; our review of these practices shaped our inquiry. Firstly, there was a need to know about the amount and types of text use and the characteristics of those texts. Literacy learning in science is likely enhanced when students have plentiful opportunities to read appropriately challenging texts that have properties well aligned to curriculum expectations (Darling-Hammond & Bransford, 2005; Kuhn & Stahl, 2003). There is general agreement that the nature of the texts students encounter should change as they progress through secondary school. Texts are expected, across subjects, to become longer, and the words, sentences, structures and ideas within them more complex. Graphic representations increase in importance and there is more variety in texts across subject-areas (Carnegie Council on Advancing Adolescent Literacy, 2010). We see opportunities to read and write texts of the types valued in the discipline as a precondition of effective literacy instruction; no instructional effort to improve reading and writing can compensate for an absence of reading and writing.

Secondly, we were interested in the opportunities students had to discuss texts. One of the most powerful ways to raise students' subject-literacy is for them to engage in rich extended discussions about the texts that they read in different learning areas (Soter et al., 2008; Wilkinson & Son, 2009). Extended discussion contrasts with typical patterns of classroom discourse in that there is more time for open-ended discussion, greater use of authentic open teacher questions to explore rather than 'test' students' understanding, and attempts to increase 'uptake' whereby teachers prompt for elaboration and incorporate and build on students' ideas (Applebee, Langer, Nystrand, & Gamoran, 2003).

Thirdly, there was a need to investigate how science teachers developed students' knowledge of texts in order to navigate and make meaning from such texts. Given that every science topic presents students with a plethora of technical new terms to learn (Fang & Schleppegrell, 2010), and because students need to know a high proportion of words to comprehend a text (Lesaux, Kieffer, Faller, & Kelley, 2010), teaching of vocabulary is an important component of literacy instruction in science. Moreover, because science texts, such as science reports, differ from those of other subjects at the global text level (e.g. noncontinuous texts requiring students to move back and forward between running text, illustrations and diagrams) and the local text level (e.g. specialised types of graph and diagram), instruction to develop students' knowledge of structural or organisational features of texts is also warranted. Students would also benefit from knowing about specialised features of science texts at the level of sentences, particularly since many of the features identified as being common in science (Fang & Schleppegrell, 2010) are also identified as features known to inhibit comprehension (White, 2012). Such features include ellipsis, the use of lengthy noun phrases, complex sentence structures, passive voice and nominalisation.

Fourthly, it was important to investigate teaching to develop students' strategies for reading and writing. After all, the aim of disciplinary literacy instruction is to develop students' independent reading and writing in science. Such instruction might involve deliberate teaching of reading strategies (Conley, 2008; Pressley, 2004) or metacognitive reflection (Schoenbach, Greenleaf, & Murphy, 2012).

Finally, given the explicit statements about the importance of critical literacy in NZC, we needed to know about teaching practices to develop students' critical literacy. Such practices include teachers encouraging students to read from the perspective of someone with an opposing perspective, setting tasks where students produce counter texts, providing multiple perspectives on the same topic and conducting student-choice research projects (Behrman, 2006; Janks, 2013).

The research questions we addressed in this study were: 'What practices do teachers use in the teaching of science to support students' learning and achievement?' and 'What knowledge, beliefs and understandings do teachers have about the literacy and language of science?'

9.1 Methods

The settings of the study were six classrooms in three secondary and two intermediate schools in Auckland. Secondary schools in NZ serve students in Years 9–13 (approximately 13–18 years old) whereas intermediate schools are attended by students in Years 7 and 8 (approximately 11 and 12 years old). The schools served mid- to low- socio-economic status communities with ethnically diverse student populations. The six classrooms comprised two science classes from each of Years 7, 9 and 11.

The selection of schools and teachers was purposive; we wanted to investigate the literacy teaching practices and knowledge of science teachers identified as effective in literacy instruction and who worked in schools serving low- to mid-SES, ethnically diverse communities. One purpose of the study was to identify future directions for literacy and language pedagogy, and we reasoned that these would be most fruitfully built on a foundation of already effective teaching. We used publicly available data about schools' performance in national qualifications as the first step in identifying potential schools. The main school qualification in NZ is the National Certificate of Educational Achievement (NCEA) which is a standards-based assessment system. To gain an NCEA qualification students are assessed against a range of 'standards' in different subjects, each of which represents a particular skill, understanding or competency (New Zealand Qualifications Authority, n.d.). We focused specifically on standards identified by national subject experts as having a significant reading and writing component. First we identified all low- to mid-decile secondary schools in Auckland where more than 60% of the Year 11 roll were enrolled in these standards. We then ranked those 29 schools according to pass rates and invited the highest ranked schools to participate. The schools with the highest and fourth highest pass rates agreed to participate.

We then invited the principal and head of science to identify science teachers whom they judged to be particularly effective at developing students' literacy in science. We also asked the principal and head of science to nominate a local intermediate school which they judged to have been effective in preparing students for the literacy demands of high school science.

We used three sources of data: Teacher observations, a measure of teacher subject literacy pedagogical content knowledge (SLPCK), and teacher interviews. Members of the research team observed each teacher over three consecutive science lessons (typically 50–60 minutes) using an observation template. Researchers actively observed the teaching for 3 minutes then recorded their observations during the next 3 minutes, in a rotating cycle, enabling a 50% sample of each observed lesson. Instances of literacy or language instruction were coded according to their content focus and for what we called 'instructional depth'. The categories of content focus were vocabulary (words and sub-word parts), text structure (e.g. teaching students about organisational features of graphs such as titles and labels or about section-headings commonly used in science reports), language features (e.g. teaching students about passive voice) and spelling and punctuation. The categories of instructional depth were *item* (e.g. teaching an item of knowledge such as a definition), *activation of students' prior knowledge* (e.g. asking students to brainstorm synonyms for a word), *practice* (e.g. matching activities designed to reinforce understanding of meanings of previously taught words), *strategy*: developing students' metacognition/strategy use (e.g. discussing reading comprehension strategies; strategies for 'solving' unfamiliar words using sub-word parts such as prefixes and suffixes) and *critical literacy* (e.g. closely analysing a writer's word choices to identify bias). Detailed field notes were made about all texts and teaching and learning activities, particularly those that had a literacy or language focus.

Teacher observation data were analysed to determine the types of texts used, and the amount of time teachers spent engaged in different teaching activities. These quantitative data were supplemented with qualitative analyses of field notes using the same codes to give us a richer picture of how these forms of literacy teaching were enacted in classrooms.

To explore teachers' knowledge of features of a science text that might complicate comprehension, we employed a Subject Literacy Pedagogical Content Knowledge (SLPCK) tool (Wilson, Jesson, Rosedale, & Cockle, 2012) that was completed by the four secondary teachers. The SLPCK tool provided teachers with a science text to read (one used in a recent national external examination) and asked them to identify aspects of the language and literacy that might act as potential barriers for students' reading, and to suggest teaching moves they might make in response. Content analysis of the completed tools identified themes from the responses.

Teacher interviews occurred at the end of each observed lesson, when teachers were asked whether their learning goals for the lesson included a specific literacy goal and, if so, the methods used to assist the students in achieving that goal, and any measures they had used to understand whether students had achieved that goal. The researcher recorded a summary of the teacher responses, and these summaries were later qualitatively analysed to identify themes.

Qualitative data from the SLPCK measure and teacher interviews were then analysed in combination to identify the themes emerging from both data sources. Members of the research team met regularly to test thematic ideas. Percentages were then calculated to describe the relative frequency of each theme.

The study was approved by the University of Auckland Human Participants Ethics Committee. The participation of schools, teachers and students was completely voluntary and all participants were provided with a detailed Participant Information Sheet and signed a Consent Form.

9.2 Findings

We report firstly on the main activities that teachers and students were engaged in, regardless of whether or not these activities were focused on aspects of literacy or language. We then look more specifically at the frequency and properties of text use and literacy and language instruction observed in the lessons. Data from our analyses of the SLPCK tool and from the teacher interviews are used where appropriate to illustrate, nuance and explain observed patterns of teaching.

9.3 An Overview of Teaching and Learning Activities

Key finding: students' time in science lessons was divided fairly evenly between whole-class activities, such as question-and-answer discussions, and individual tasks such as completing worksheets. There were few opportunities for students to work in small groups or to engage in extended discussions.

For each 3-minute observation interval, observers made a judgement as to the main forms of teacher activity, student activity and student grouping.

Students in science lessons participated mainly in whole-class activities (50% of observed intervals) or in individual (albeit not individualised) tasks such as completing worksheets (43%). Although students commonly sat in groups, the tasks were rarely designed as group tasks (7%). The main teacher activities during whole-class sessions were question and answer sessions, which accounted for a third (32%) of all observed intervals, and lectures (17%). The overwhelming focus of these whole-class activities was on teachers explaining science concepts and terminology to students. The individual student activities consisted mainly of practice and reinforcement-type activities such as completing worksheets. While students worked on individual tasks, teachers divided their time between roving (20%), management (17%), conferencing (8%) and modelling (6%). Only one teacher (Teacher 1) incorporated practical science work such as experiments into their observed lessons. There was an absence of extended discussion (either about texts or about science more generally) in the lessons, with no intervals at all coded as having this as the main activity. Class and group discussions, when they took place, took the form of question-and-answer sequences characterised by teachers asking closed, checking-type questions about science ideas and students providing brief answers, often of just one or two words.

9.4 Opportunities for Reading

Key finding: the majority of texts observed in science lessons were short, teacher designed texts.

Working from an assumption that texts should be at the heart of literacy instruction, we analysed the frequency with which texts were used, and what the features of those texts were. We took a reasonably broad view of texts and included all texts with any written words, including diagrams with labels or headings and symbolic expressions, but did not count texts that had no written words whatsoever and were therefore solely oral or visual. In total, 82 texts were observed in science classrooms.

Texts were predominantly short, with the highest proportion (38%) of texts containing between 11 and 50 words and a quarter (26%) having 10 or fewer words. The majority of texts (72%) were created by the classroom teacher and presented as whiteboard or computer-projected notes or as worksheets. About a fifth (18.2%) of all texts were sourced from published print sources (books, magazines and newspapers) but only one-third of those (6.1%) were presented to students in their original published form; most of the texts sourced by teachers from published print sources were presented to students as photocopies or computer-projected copies. About half of the texts (49%) comprised written text only with the remainder of texts including at least one visual representation such as a diagram (20%), illustration (11%), photograph (6%) or table (5%). Forty-five per cent of the texts consisted mainly of running text in paragraphs, 27% consisted primarily of information presented in bullet points and 27% were predominantly visual representations of information.

There was little evidence of ‘real world’ texts or digital text. Newspaper or magazine articles were only observed in two intervals each. Also, all of the text use observed or discussed in the interviews was limited to single-texts; teachers made no mention of, and were not observed to use, multiple texts on a related topic or theme.

9.5 What Do Science Teachers Teach When Science Teachers Teach Literacy?

Key finding: teachers were very aware of the importance of specialised subject vocabulary and frequently taught new terminology. There were few instances of teaching to develop students’ understanding of other aspects of literacy or language in science such as the structures or language features of texts.

Some form of literacy or language instruction was observed in 70% of the observed intervals. Vocabulary was by far the main focus of literacy and language instruction and this was observed in 62% of all observed intervals. Of the remaining 11 literacy-coded intervals, six included instruction about text structure, four about spelling and one about the audience and purpose of a text. The literacy focus of three of the teachers was solely on vocabulary whereas one teacher each also taught about structure or spelling, and one taught about vocabulary, structure and spelling. All of the intervals coded as relating to structure related to one form of representation within a text (such as a Punnett square) rather than to the structure of the text as a whole (for example about the challenges related to reading discontinuous text that incorporated running text, illustrations and specialised forms of visual representation). No intervals were coded as having any instruction about language features at the level of sentences. We observed little deliberate instruction directly related to reading or writing processes or strategies. Furthermore, no intervals were coded as mainly focussed on developing students’ critical literacy, although there were instances of incidental teacher questioning to promote critical thinking (e.g. about possible explanations for unusual phenomena or unexpected results in experiments).

Unsurprisingly, given the high rates of vocabulary instruction we observed, teachers in the interviews viewed teaching vocabulary as an integral part of effective instruction in science. As one teacher put it, ‘If they (students) don’t have the vocabulary, they can’t express ideas. Definition is the language of science’ (Teacher 3). In the interviews, all six teachers articulated a learning goal related to vocabulary. In contrast, none of the six teachers identified a reading goal and although three stated a writing goal, these goals were expressed more as students *doing* writing than *learning about* writing: a typical writing goal was for students ‘to be able to write a paragraph for the assessment’ (Teacher 5). Consistent with the other data sources, teachers’ responses to the SLPCK tool identified student knowledge of vocabulary as the most common barrier to text understanding and task completion.

Assessment success was a key rationale for vocabulary teaching at the upper levels. The two Year 11 teachers framed the importance of vocabulary instruction in terms of what students needed to know and do to succeed in high stakes qualifications. Teacher 5 said in the interview that it was important to focus on vocabulary 'as the markers in the assessments are tough on terminology' and Teacher 6 told her class that it was 'vital to use these words when it comes to assessments'.

The main vocabulary focus was on teaching specialised subject and general academic vocabulary. In the SLPCK measure for example, all four secondary school teachers cited academic topic words, such as *sterilise*, *process* and *micro-organism*, as potentially problematic vocabulary for students in the provided text. Three of the four secondary science teachers also identified that students needed to recognise that general academic vocabulary items, specifically instructional verbs, such as *Name* and *Explain* as they provide clues as to the expected length and depth of student responses to the tasks. In contrast with the strong focus on academic vocabulary, no science teacher identified examples of more general, literate vocabulary related to the context of the text, such as *bottling* (meaning *preserving*), *air bubbles* or *refrigerated*, as potentially problematic for students. Consistent with this, there was no mention of non-scientific vocabulary in the interviews or observed lessons.

Teachers clearly valued and tried to promote the use of correct technical scientific vocabulary. A typical example of this occurred in one of Teacher 1's lessons with his Year 7 science class when a student spoke of a solid having 'hardness' and Teacher 1 responded that 'I'd rather we talked about density'. Another teacher said 'it's important students use the vocabulary correctly in context and to know why it's not appropriate to use the word *spin* instead of *rotate* say'.

Technical scientific vocabulary was seen as being particularly important in the first few lessons of a topic. One teacher described the key words introduced in the first lesson of a topic as providing 'a springboard to the concepts covered in the next lessons' (Teacher 1, Year 7) and another stated that vocabulary at the beginning of a topic because 'you want to sort it out first because you're going to use a lot more of these words throughout the next six weeks' (Teacher 5).

9.6 Teaching Approaches for Teaching Vocabulary

Key finding: the vocabulary instruction comprised explicit teaching of definitions of subject-specific items followed by multiple exercises of constrained vocabulary use. There were few observed instances of teaching to develop students' independent strategies for 'solving' and learning new vocabulary.

The typical sequence of vocabulary teaching consisted of explicit teaching of new words followed by constrained activities designed to reinforce students' knowledge of those words. Each of the 109 intervals that featured literacy instruction was coded according to its 'instructional depth'. The two most prevalent categories of instructional depth were *item teaching* (e.g. teaching word meanings) and *practice* (providing students with opportunities to reinforce content covered previously) which accounted for 31% and 48% of the literacy intervals respectively.

The bulk of literacy intervals coded for item teaching involved the explicit teaching of word meanings. Most commonly this was done through the teacher telling students the meaning of new words and/or writing new words and their definitions on the whiteboard for students to copy. In the interviews and SLPCK measure all teachers noted the importance of explicitly teaching key science topic words. There were no instances where the task specifically required students to infer the meaning of new words from texts, as they would likely have to do when reading texts independently. The absence of such opportunities is likely related to the very limited use of extended, contextualised and non-instructional text reported previously. There were teacher-designed activities however where students were given a term and definition and had to match it to a slightly reworded definition, for example, in Teacher 3's class when students were instructed to read a text that stated 'inside the nucleus are thread-like chromosomes' and then to write the name of 'the thread-like strands inside the nucleus of each cell'.

Teachers were very aware of the importance of repeated practice in developing and reinforcing students' vocabulary knowledge. One teacher in the interviews referred to such reinforcement as students needing to 'play' with new words. Teachers in the interviews and SLPCK measure identified a wide range of activities in which students 'played' with new vocabulary in written, visual and oral forms, including through cloze exercises, matching activities, poems, songs and crosswords. All of the teachers except Teacher 2 were observed using a variety of different activities to give students repeated exposure to new words. The most common approaches for reinforcing new vocabulary that we observed in the classroom lessons were matching activities (5/6 teachers) cloze activities (4/6 teachers), labelling diagrams and word finds (3/6 teachers each). In most cases, students matched words to definitions, although sometimes additional examples, including pictures, were required. In some cases the reinforcement teachers provided was embedded in activity but nevertheless very deliberate, for example when Teacher 1 was conferencing with a group during an experiment he said, 'How are you going to separate sand from the salt solution', emphasising *solution* through tone and volume.

While most of the item teaching we observed was limited to the teaching of word meanings, four of the teachers also were observed, or discussed the importance of, teaching students about morphology. For example, Teacher 6 (Year 11) drew students' attention to the prefix *bi-* when she introduced the term *binary fission* by saying: 'Bi meaning two, as in bicycle or bilingual'. Similarly, Teacher 1 explained to his class that the suffix *–ology* means 'The study of something'. Teacher 3 said in her interview that an important learning goal was on developing her students' 'word knowledge and breaking down word parts to find clues to scientific terminology'.

There was limited evidence of teaching of strategies students could use for 'solving' new words. The strategies observed consisted of morphemic strategies to break words down words to sub-parts to infer meaning and the use of mnemonics to memorise key terms. We did not observe instances where students were asked to articulate or reflect on vocabulary strategies they had used or could use independently, although one teacher (Teacher 6) tried to capitalise on students' knowledge of vocabulary from other subject-areas by asking her class what they knew about the prefix *–micro* from mathematics.

The instruction we observed was mainly focused on developing students' receptive understanding of new science words rather than on supporting students to use the words themselves in their speaking or writing. The absence of a strong focus on productive vocabulary in the observed lessons was at odds with the interviews in which five of the six teachers expressed both a receptive ('to understand') and productive ('to use') vocabulary learning goal in the interviews. A typical example of this type of goal was that 'they (students) have to develop definitions, they have to know what they are, and they should be able to write a paragraph using some of these words' (Teacher 6). Despite such goals, there were very few opportunities for independent and extended writing and the majority of tasks designed to develop students' proficiency in using new vocabulary were highly constrained. Most commonly, students at all levels were required to complete cloze (fill-the-gaps) activities or to use new words to label diagrams provided by the teacher with original labels blanked out. In a few cases this required students to write the missing words in gaps in a short paragraph but more often they only had to complete short sentences such as 'Particles in a – (solid) are close together'. In some cases, even at secondary school, the tasks were even more constrained: 'There are 365 ¼ d … in a y …, 8 p … in the s …. s …' (Teacher 4, Year 9).

In summary, data from all three sources indicated that teachers considered vocabulary to be the key to literacy learning in science, and the literacy teaching observed was consistent with this. This vocabulary teaching tended to focus on definitions, supplied by the teacher and learned through repeated practice activities. Texts used in science lessons were most commonly short, teacher designed texts. Students had few opportunities to read science texts independently.

9.7 Discussion

Literacy in science can be viewed as a valued learning outcome itself and as a vehicle for achieving other valued learning outcomes such as understanding science concepts. The combined results of this study indicate that understanding subject-content knowledge was the student outcome most valued by the science teachers; apart from vocabulary, there was little evidence of disciplinary literacy being viewed as a valued outcome itself. Neither was literacy seen as a primary means of developing students' subject-content knowledge; students had few opportunities to read, write, discuss or learn about the kinds of texts thought to be valued in the discipline, or indeed, the curriculum. The assumed shift from reading in primary to secondary school is commonly thought to be a shift from 'learning to read' to 'reading to learn' (Jetton & Alexander, 2004) but we saw limited evidence of either. Rather, science teachers typically provided content instruction, including vocabulary instruction, through telling, by adjusting or writing texts, and by providing constrained practice activities such as worksheets. In general this seemed to be a feature of teachers who compensated for perceived gaps in their students' literacy by identifying the science ideas and vocabulary students need to know, and summarising this in the form of teacher-made notes or modelling for students.

It is important to note that the general pattern of teaching we identified, while limiting from a disciplinary literacy perspective, was employed by teachers nominated as effective within schools that were demonstrably effective in promoting student success. This may be related to three potential issues with our sampling procedures. Firstly, it could be that the qualification standards which assess students' content knowledge *through* reading and writing are not a direct enough measure of students' reading and writing. Secondly, we did not have access to data at the level of classes and therefore the teachers we observed were not necessarily the teachers whose students achieved the highest results. Thirdly, it may be that the principals' and department heads' knowledge of literacy and effective literacy instruction in science may have been insufficient for them to accurately identify the science teachers who were the most effective teachers of reading and writing. It is possible too that although the rates of literacy instruction for the case study teachers were relatively low, they may have been higher than those of teachers more generally.

This apparent mismatch potentially challenges our assumption that high pass rates in science assessments would be associated with high rates of literacy instruction. It may be that students' relatively high pass rates in these Year 11 assessments happened because of, rather than despite, the teachers' efforts to ameliorate reading and writing demands; developing students' knowledge of science ideas in more direct ways may be more effective as well as more expedient than having them struggle to read challenging text. The evidence we have reported here does not refute that possibility.

Even if a focus on content at the expense of literacy might help students pass examinations in the earliest year of the formal qualification system, we are concerned for two reasons. Firstly, the teaching seems more geared to helping students answer specific test questions than towards the development of deep conceptual understanding of science in general or disciplinary literacy in science more specifically. Secondly, such practices may constrain students' future science learning, particularly when the time comes, as we hope it will, that students read science-related texts in situations where no teacher is available to mediate the texts, such as in the later years of schooling, at university, in the workplace, or in everyday life.

Fundamentally, literacy learning in science requires text access and use. There was little alignment between the types of texts students encountered in class and those that the curriculum implies would be important, and those that students will encounter in external examinations in later years, in the disciplines themselves and in ‘real world’ contexts. To become skilled users and producers of valued science texts, students need opportunities to read, write, think about and discuss those types of texts. We are not suggesting that written texts supplant other ways of teaching content or providing meaningful contexts to which students can apply their developing science knowledge, but we are suggesting that written texts should be used more often for these two purposes. There was ample scope for more time spent engaged in reading and writing texts. This is fundamental as until teachers expect students to regularly read and write valued texts in science, there will be little reason for them to teach students about the features of such texts or about strategies for reading and writing them.

Alongside text use, students need strategies to demand meaning from these texts. There were limited opportunities for students to develop knowledge about the specialised features of science texts, particularly those features identified in the literature as potential inhibitors of comprehension and meaning-making. The absence of teaching of such features is no doubt related to the absence of texts with these features in the observed classes. The teachers were however very aware of the importance of receptive vocabulary knowledge and invested considerable instructional time to this. The teachers taught students new words and their meanings and also designed repeated opportunities for students to play with new words and develop students’ understanding of word parts. The pattern of high rates of vocabulary instruction but low rates of instruction about other aspects of texts does not support the conclusion that there was a generalised antipathy to the notion that science teachers address language and literacy, as has been found in much of the historical literature (O’Brien, Stewart, & Moje, 1995). It does suggest however limits to the role that language and literacy is understood to play in science learning; there was next-to-no instruction employing science texts or about purposes of science texts, how they are organised or about language features at the level of sentences. As well as employing texts with features that are valued in science, it is important that teachers have deep knowledge of how science texts work so they can anticipate or diagnose reading and writing problems, employ appropriate teaching strategies to address these problems and evaluate the effectiveness of these actions.

Finally, in line with both the citizenship and professional preparation roles of science advocated by NZ policy, students need to engage critically with the content and purposes of scientific (or purportedly scientific) texts. Critical literacy involves a shift away from ‘getting the correct answer’ to questioning the assumptions in texts, critiquing and challenging. In our observations of teachers we saw no evidence of any instruction that could be characterised as critical literacy. We would therefore argue, from a position of instructional depth, that students need opportunities to engage with issues, ideas and concepts, to challenge and critique them as part of deep learning in science.

In conclusion, we identify four opportunities for subject-specific literacy teaching to shift in ways that prepare students better to read and write science text. Firstly, we see a need to expand the learning outcomes that are valued, from a primary focus on assessed science content to a broader focus that encompasses using texts in science appropriate ways, with reading, writing, disciplinary literacy and critical literacy outcomes as central to these. Secondly, we see an opportunity to frame students, rather than teachers, as being responsible for the reading and writing of science text. Thirdly, there is a need to move from constrained to open-ended literacy learning tasks. Fourthly, there is a need to move beyond short-term strategies towards a focus on generative teaching so that students are in a position to read and write the texts they need as citizens or as emerging science professionals.

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