JOURNAL OF WORLD LANGUAGES
2018, VOL. 5, NO. 2, 113–131
https://doi.org/10.1080/21698252.2019.1575014

Has the prose quality of science textbook improved over the past decade? A linguistic perspective

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ABSTRACT

Textbooks are a central pedagogical resource for science teachers. As such, they have been a subject of enduring interest in science education research, with many questioning whether their quality has improved over the past decades. In this paper, we examined the prose quality of an expository text on coral reefs in seven successive editions of one popular environmental science textbook. Specifically, using tools from systemic functional linguistics, we analyzed two discursive aspects that impact the comprehensibility of the texts – how causation is construed and how information is structured. Our analyses reveal that the prose quality of the texts on coral reefs has improved, regressed, or remained the same. In the area of causation, cause–effect relationships are construed in increasingly implicit ways, with causes and effects consistently constructed as grammatical abstractions that bury human or social agencies. In the area of information flow, semantic leaps and semantic ambiguities are reduced across the sample texts analyzed, which places fewer text processing demands on the reader. Our study suggests that writing a perfectly considerate text is a tall task and that micro-linguistic analysis can illuminate the comprehension challenges that school textbooks present to students and inform efforts to improve students' science literacy.

ARTICLE HISTORY
Received 30 October 2018
Accepted 24 January 2019

KEYWORDS
Science textbooks; linguistic analysis; prose quality; causation; information flow

Textbooks are ubiquitous in American education (Altbach et al. 1991). They have been a bastion of classroom instruction in American schools since the beginning of the past century (Venezky 1987). Despite decades of educational reform initiatives and technological advances, textbooks remain an indispensable, or even central, pedagogical resource for teachers at all levels (elementary, secondary, and tertiary) and across different subject areas (e.g., reading, language arts, science, mathematics, and social studies) (Chall 1987; Kelly 2008; Wade and Moje 2000). By some estimates, roughly two-thirds of class time is structured around printed materials such as textbooks and other commercially produced instructional materials. In many classrooms, textbooks have become the de facto

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curriculum through which teachers instruct toward district/state/national standards and students are socialized into literate and disciplinary practices.

Given the pervasiveness of textbook in school classrooms and its importance to teaching and learning, it is not surprising that textbook quality has been a topic of considerable interest to teachers, scholars, and publishers. Most studies of textbook quality have focused on pedagogical features such as format, organization, and tasks; content coverage such as the range and depth of topics, accuracy of information, types of genre included, and alignment with national standards; or political issues of textbook adoption and selection. This research generally found school textbooks to be inconsiderate and of unsatisfactory quality. For example, studies of elementary school basal readers (e.g., Chall 1987; Braker-Walters 2014; Brenner and Hiebert 2010; Moss 2008) have reported a plethora of issues with these textbooks, including imbalance between narrative and informational genres, inadequate volume of reading, lack of multicultural diversity and points of view, heavily prescriptive instructional procedures, and failure to meet national standards such as the Common Core State Standards. Studies of secondary content area textbooks (e.g., Armbruster 1988; Berkeley et al. 2014; Kesidou and Roseman 2002; King 2009; Leonard and Chandler 2003; Roseman, Stern, and Koppal 2010) reveal that these materials often fail to offer an in-depth, coherent, accurate, or concrete account of key concepts/ideas and to provide students with rich opportunities to make sense of and learn from them.

Textbook publishers have taken heed of these criticisms and worked hard to improve the quality of their products over the past few decades. But what are the outcomes of their efforts? Are today's school textbooks better and more considerate than their predecessors? According to Holliday (2004), today's textbooks present topics in a way that "seems relevant, interesting, and easier to comprehend" (387). However, Hayes, Wolfer, and Wolfe (1996) reported that the complexity and difficulty levels of textbooks have declined over the past few decades and that this decline contributed to a decline in students' academic readiness for college. Other researchers (e.g., Gamson, Lu, and Eckert 2013; Stevens et al. 2015) have produced evidence to the contrary, suggesting that school textbooks have actually become more complex and difficult to read since the 1970s. Berkeley et al. (2014) presented a more nuanced account of how the quality of history textbooks has improved over the past 20 years, noting that today's textbooks are generally clearer, more coherent, and more challenging than their predecessors.

It is worth noting that much of the research on school textbooks has traditionally focused on disciplinary content, chapter organization, and pedagogical features, with little or no attention to the quality of prose. When prose becomes the focus of an investigation, the goal almost invariably involves a determination of its difficulty level through quantifiable measures of lexical and syntactic complexity. What is missing in this body of work is research that examines prose qualitatively through careful, detailed analysis of its lexical and grammatical choices. This sort of analysis is important in that it can yield tangible data that illuminate the complexities and challenges of prose and inform teachers' instructional decision-making and publishers' efforts to make textbooks more accessible to students (Fang 2016).

The purpose of our study, then, is to examine qualitatively how the prose quality of a science textbook evolved over the past decade in ways that make them more or less comprehensible to their intended audience. Specifically, we conducted a detailed linguistic analysis of seven versions of writing on the degradation of coral reefs. The seven excerpts, A–G (see Appendix A), were taken from a chapter about biodiversity in aquatic ecology; they were written by the same author and appeared in seven successive editions of a popular high school environmental science textbook (Miller 2002, 2004, 2005, 2007; Miller and Spoolman 2009, 2011, 2014). Science textbooks are worthy of investigation because they continue to be an important source of information in science classrooms despite recent emphasis on hands-on inquiries (Holliday 2004; Roseman, Stern, and Koppal 2010). Moreover, many students find science textbooks challenging to read, and teachers need insights into what it is that makes science texts challenging so that they can design instruction that addresses students' needs.

Our analysis was informed by the work of systemic functional linguists (e.g., Halliday and Matthiessen 2004). This work explores how humans make sense of their experiences and surroundings through discursive practices that involve the use of congruent and incongruent (metaphorical) forms of language. It views language as an interlocking system of choices for making meaning and text as a semantic unit that is realized in clauses and other grammatical units. It illuminates how language choices shape meaning in ways that realize the author's purpose and attitude and provides insights into what makes a text more or less complex or challenging. Specifically, we drew on the work of Halliday (2004), which describes how the features of scientific English have evolved over time to meet the needs of scientists as they endeavor to produce an alternative, or uncommonsensical (ie, more technical), account of the universe. In general, Halliday found that scientific discourse "foregrounds things at the expense of qualities, processes and relations" (viii). The nominalizing grammar of science thus presents challenges to learners, who are used to the commonsensical, or process-oriented, ways of meaning.

More specifically, Halliday identified seven grammatical features of scientific English that are likely to cause problems of understanding and make reading science texts "a considerable intellectual task" (164). These features are (a) interlocking definitions: technical terms are used to define each other; (b) technical taxonomies: technical concepts derive their meanings from being organized into highly ordered constructions in which every term has a functional value; (c) special expressions: certain grammatical features tend to go together in science to form a kind of syndrome recognizable as the language of science; (d) lexical density: clauses in science text tend to pack a heavy load of information; (e) syntactic ambiguity: nominalized constructions are often open to multiple interpretations because they bury agency and logical relations; (f) grammatical metaphor: one grammatical class or structure is replaced by another for functional reasons; and (g) semantic discontinuity: science writers sometimes make semantic leaps, expecting readers to fill in the gaps. They configure in different ways in different texts for different purposes, as different contexts call for different constellations of features. In this paper, we focus on two linguistic features that are prominent in environmental science texts and that prior research (e.g., Chenhansha and Schleppegrell 1998; Halliday and Martin 1993) has found especially problematic for student understanding: causation and information flow. Two questions guiding our analysis are: (a) how are cause–effect relationships represented in the text? and (b) how is the information in the text structured? We read each text excerpt both holistically and clause-by-clause to ensure close and accurate examination.

1. Causation

Causation, i.e., why and how something happens, is one of the seven crosscutting concepts in science education that K-12 students are expected to understand (National Research Council 2012). It is central to environmental education, whose purpose is to provide students with opportunities to acquire knowledge, values, attitudes, commitment, and skills needed to protect and improve environment. Moving students from knowledge to action requires that they understand the true causes and consequences of environmental problems. This understanding can be promoted or hindered depending on the ways in which environmental concepts and issues are presented in the text (Chenhansha & Schleppgrell 1998). If the cause or the agent of an environmental problem is explicitly identified, students will be more likely to take actions to protect and improve environment. On the other hand, if the cause–effect relationship is presently implicitly, students may have trouble identifying causes and effects, which will in turn lead to diminished engagement with environmental issues. This means that textbook writers need to be cognizant of how they present the causes and effects of environmental issues so that they can maximally engage students and stimulate them to act on the issues.

Our examination of the seven sample science texts (A–G) reveals that cause–effect relationships are often presented in implicit ways and rarely through explicit means (Table 1). When causation is realized explicitly, through linguistic resources familiar to students, the task of identifying causes and effects is relatively simple. When causation is realized implicitly, through linguistic resources unfamiliar to students, the task of identifying causes and effects is rendered more challenging, especially for the unsophisticated readers who are still in the process of developing content knowledge in their field. A perusal of the table reveals that the number of explicit causation – realized through conjunction (*because*), preposition (*because of*), noun (*cause*), and verb (*cause*) – remains relatively stable (1–2 instances) across the seven texts, but the number of implicit causation fluctuates considerably, with Texts F and G registering the highest total (17 and 14, respectively) and Texts A, B, C, D and E having roughly the same number (9–11).

Table 1. Explicit and implicit realizations of causation in seven editions of an environmental science textbook.

Text	Examples
A	Explicit • Coral reefs sometimes are called the aquatic equivalent of tropical rain forests because they harbor such a high species biodiversity with myriad ecological interrelationships. • This occurs because of stresses such as increased water temperature… Implicit • … nearly 60% of the world's coral reefs are threatened by human activities … • One problem is coral bleaching, which occurs when a coral becomes stressed and expels most of its colorful algae. • This loss of algae exposes the colorless coral animals … • Unable to grow or repair themselves, the corals eventually die unless the stress is removed …
B	Explicit • Coral reefs sometimes are called the aquatic equivalent of tropical rain forests because they harbor such a high species biodiversity with myriad ecological interrelationships. • This occurs because of stresses such as increased water temperature… Implicit • More than one-fourth of the world's coral reefs have been lost to coastal development… • One problem is coral bleaching, which occurs when a coral becomes stressed and expels most of its colorful algae. • This loss of algae exposes the colorless coral animals … • Unable to grow or repair themselves, the corals eventually die unless the stress is removed … • … they harbor such a high species biodiversity with myriad ecological interrelationships
C	Explicit • Two causes are increased water temperatures and runoff of silt… Implicit • More than one-fourth of the world's coral reefs have been lost to coastal development… • It occurs when a coral becomes stressed and expels most of its colorful algae, leaving an underlying ghostly white skeleton of calcium carbonate. • Unable to grow or repair themselves, the corals eventually die unless the stress is removed …
D	Explicit • Two causes of bleaching are increased water temperature and … Implicit • … 20% of the world's coral reefs have been lost to coastal development … • Another 30% of these aquatic oases of biodiversity will be seriously depleted within the next 20–40 years. • It occurs when a coral becomes stressed and the algae on which it depends for food and color die out, leaving an underlying white or bleached skeleton of calcium carbonate. • Two causes of bleaching are increased water temperature and runoff of silt from the land (usually from forest clearing) that covers the coral and prevents photosynthesis.
E	Explicit • It occurs when stresses such as increased temperature cause the algae … Implicit • … 15% of the world's coral reefs have been destroyed and another 20% have been damaged by coastal development … • And another 25–33% of these centers of aquatic biodiversity could be lost within 20–40 years. • It occurs when stresses such as increased temperature cause the algae, upon which coral depend for food, to die off, leaving behind a white skeleton of calcium carbonate. • Another threat is the increasing acidity of ocean water as it absorbs some of the CO_2 produced by the burning of carbon-containing fossils fuels. • The CO_2 reacts with ocean water to form a weak acid, which can slowly dissolve the calcium carbonate that makes up the corals.

(*Continued*)

Table 1. (Continued).

Text	Examples
F	Explicit • Coral reefs are vulnerable because they grow slowly and are disrupted easily. Implicit • … another 20% of all coral reef ecosystems had been degraded by coastal development… • And another 25–33% of all reefs could be lost within 20–40 years. • … they grow slowly and are disrupted easily. • …and runoff of soil and other materials from the land can cloud the water and block sunlight needed by the reefs' producer organisms. • This explains why the biggest long-term threat to coral reefs may be projected climate change, which could raise the water temperature above this limit… • One resulting problem is coral bleaching. • It occurs when stresses such as increased temperature cause the algae, upon which corals depend for food, to die off. • Without food, the coral polyps then die, leaving behind a white skeleton of calcium carbonate. • Another threat is the increasing acidity of ocean water as it absorbs some of the carbon dioxide (CO_2) produced mostly by the burning of carbon-containing fossil fuels. • The CO_2 reacts with ocean water to form a weak acid, which can slowly dissolve the calcium carbonate that makes up the corals.
G	Explicit • Coral reefs are vulnerable because they grow slowly and are disrupted easily. • Pollution or water that is too warm can cause the algae … Implicit • … some 45–53% of the world's shallow coral reefs have been destroyed or degraded by pollution and other stresses… • … and another 25–33% could be lost within 20–40 years. • Also, deep coral reefs that are thousands of years old are being destroyed by large numbers of trawler fishing boats… • One result of such stresses is coral bleaching. • Pollution or water that is too warm can cause the algae, on which corals depend for food, to die off. • Without food, the coral polyps die, leaving behind a white skeleton of calcium carbonate. • … they grow slowly and are disrupted easily. • Runoff of silt and other materials from the land can cloud the water and block the sunlight that the algae in shallow reefs need for photosynthesis. • This explains why the two major long-term threats to coral reefs are projected climate change, which could raise the water temperature above this limit in most reef areas, and ocean acidification, which could make it harder for polyps to build reefs and could even dissolve some of their calcium carbonate formations.

Implicit causation in these texts is realized through the use of passive voice with or without explicit mention of agent (e.g., *are threatened by human activities, have been lost to coastal development, have been destroyed or degraded by pollution and other stresses, produced by the burning of carbon-containing fossil fuels, are being destroyed by large numbers of trawler fishing boats, could be lost, will be depleted, are disrupted easily*), conjunctions that denote cause (e.g., *why, unless*) or that conflate time or condition with cause (e.g., *when, and, as*), verbs other than "cause" (e.g., expel, *expose, depend upon, form*), the modal "can/could" (e.g., *can cloud, can … dissolve, could raise, could make*), prepositions indicating cause (e.g., *with, from*), adjective (e.g., *one resulting problem*), noun (e.g., *one result of such stresses*), and non-finite clause that indicates cause (e.g., *without food, unable to grow or repair themselves*) or effect (e.g., *leaving an underlying ghostly white skeleton of calcium carbonate*). These linguistic resources obscure the cause–effect relationship, presenting a significant comprehension challenge to students, who generally do not associate them with causation or use them regularly in their own writing to present cause–effect relationships.

Another comprehension issue that can arise in reading these seven texts is that causes and effects are often presented as abstractions with vague or no indication of human agency involved. These abstractions are in most cases nominalizations, which transform discursive vitality with actors engaging in action into a stasis that buries the concrete processes or happenings as well as the social agents responsible for or suffering from environmental problems. The nominalizations used across these texts include *coastal development, overfishing*, and *pollution* (Texts A, B, C, and D); *warmer ocean temperature* and *increased water temperature* (Texts A, B, C, D, E, and F); *runoff of silt* (Texts A, B, C, D, and G); *runoff of soil and other materials from land* (Text F); *forest clearing* (Text D), *this loss of algae* (Texts A and B), *increasing ocean acidity* and *the increasing acidity of ocean water* (Texts E and F), *ocean acidification* (Text G), *the burning of carbon-containing fossils fuels* (Texts E and F), *the projected climate change* (Texts F and G), *the decline and degradation of these colorful oceanic sentinels* (Texts B, C, D, E and F), and *large number of trawler fishing boats* (Text G).

The use of nominalization has both costs and benefits. On one hand, it helps the author distill information, theorize experience, and present an uncommonsensical account of the natural phenomena. It also facilitates the creation of discursive flow so that what is discussed in one sentence or paragraph gets to be picked up for continual discussion in the next sentence or paragraph. On the other hand, it results in greater difficulty for students to make personal connections with environmental issues (because the concrete happenings with specific actors have been elided) and therefore discourages them from taking initiatives to protect and improve environment. For example, phrases like “coral bleaching” and “ocean acidification” are technical or semi-technical terms that capture the concrete biological and chemical processes that may or may not be described in the texts in which they appear. As nominalizations, they are able to participate productively in causal reasoning by serving as either causes or effects in the subject or object position of a clause. Similarly, “the loss of algae” recapitulates the idea (i.e., expulsion of colorful algae) presented earlier in the text so that it serves as the departure point for subsequent discussion about the consequences of this loss.

Nominalizations pose a clear and present challenge to comprehension. They need to be unpacked to facilitate understanding. Uncovering the processes, or activities, embedded in these abstractions and the agents performing the processes, however, requires that students not only possess relevant background knowledge but also be able to recognize how nominalization works in meaning making and reasoning. For example, “forest clearing” is considered the cause of runoff of silt/soil and other materials. Although some clearings come naturally from fires or drought, many are created deliberately for cultivation of crops or construction of houses. In other words, the real agents behind runoff of silt/soil are usually people and their companies who clear forest to make room for planting and housing. As another example, one threat to coral reefs – not introduced until Texts E, F, and G – is *increasing ocean acidity, the increasing acidity of ocean water*, or *raised acidification*. These nominalizations bury a considerable amount of information that has to be unearthed for deeper understanding. From Texts E and F, it can be inferred that "the ocean acidity" is "increasing" because ocean water "absorbs some of the CO_2" and their reaction results in ocean water becoming acidic. But where does the CO_2 come from? From the text, the grammatical agent of the process of producing CO_2 is the nominal group "the burning of carbon-containing fossils fuels." Fossil fuels usually do not burn themselves. It is people who burn them for the purpose of obtaining energy. By transforming the verb group "to burn fossils fuels" into a nominal group "the burning of carbon-containing fossils fuels," the social agent responsible for this environmental problem is elided. What the reader sees in the text is just an abstract identity embedded in a nominal group. In Text G, no explanation for "ocean acidification" is offered. Only its effects are retained. It is only through a complex chain of reasoning and inferences – an inherently language and knowledge intensive process – that the reader is able to figure out that the ultimate social agents responsible for the phenomenon of "the increasing ocean acidity" are primarily humans.

It is the juxtaposition of nominalizations and verbs with implicit causation that renders a text not only abstract to process but also challenging to identify the true causes and consequences of environmental problems. In some texts, human agency is explicitly indicated, albeit still in generality, as in "nearly 60% of the world's coral reefs are threatened by human activities such as coastal development, overfishing, pollution, and warm ocean temperatures" (Text A). The prepositional phrase beginning with "by" in the passive voice construction identifies humans as a threat to the health of coral reefs because they engage in such activities as coastal development, overfishing, and pollution. In subsequent editions (Texts B, C, and D), however, the author replaces "are threatened by" with "have been lost to," making causation less discernible and human agency buried. Here, grammatical abstractions such as *coastal development, pollution, overfishing*, and *warmer ocean temperatures and other stresses* become the culprits for the disappearance of coral reefs. The human agents behind the activities codified in these abstractions are linguistically absent from the discussion.

Although Texts E and F continue to use passive voice constructions (e.g., *have been destroyed by, have been damaged by, had been destroyed, had been degraded*) with perhaps stronger verbs than "threaten," the parties responsible for the destruction, damage, or degradation of coral reefs remain grammatical abstractions without explicit mention of humans, who are the ones who engage in the processes encapsulated in these abstractions. The use of "could be lost" without preposition phrase “to + noun” in both texts eliminates agency altogether. In Text G, the latest edition, the same “could be lost” construction is used. The text also uses “have been destroyed or degraded by,” but the grammatical agents for these actions have been reduced to only “pollution” and a vague, catch-all phrase “other stresses.” In another instance, “large numbers of trawler fishing boats,” instead of more directly humans, is being mentioned as the one that destroys deep coral reefs through the activity of dragging huge weighted nets across the ocean bottom. Of the seven editions, it appears that Text G contains the fewest instances where social agents are explicitly mentioned as the party responsible for the degradation and destruction of coral reefs.

To summarize, an examination of how causation is construed in the seven editions of the text reveals that cause–effect relationships are increasingly presented in implicit ways, with the three latest editions containing the most instances of implicit causation. Instead of indicating causation through the more familiar resources of conjunctions, other grammatical resources such as nouns, verbs, prepositions, modals, and non-finite clauses are used. In addition, causes and effects are often constructed across the seven versions in grammatical abstractions, or nominalizations, which has the unfortunate effect of burying social agency. These linguistic technologies obscure the causes and effects of environmental problems, making it more difficult for students to comprehend the text and discouraging them from taking initiatives to protect and improve the environment.

2. Information flow

Science texts are typically tightly knit (Fang and Schleppegrell 2008). Their tight structure is accomplished in part through the strategic use of Theme-Rheme patterns. From the systemic functional linguistics perspective, theme is “the element which serves as the point of departure of the message” and appears first in a clause (Halliday and Matthiessen 2004, 64). The rest of the clause is called Rheme; it is where Theme is developed. Science texts often feature a zig-zagging pattern of Thematic progression, in which each topical Theme rewords (i.e., repeats with a difference) what has been stated in the Rheme of a previous clause. This pattern enables the next clause to further comment on or develop the new information introduced in the previous clause and at the same time creates a text that flows from one clause to the next. Thus, by analyzing the Theme-Rheme pattern in the prose, we can gain insights into how the author successively builds explanation and provides a coherent account of the decline of coral reefs. To ensure comparability, we focus on the portion where coral beaching is defined and explained, as it is the most important concept across all seven texts. Because of the close resemblance between Texts A and B, between Texts C and D, and among Texts E, F, and G, we focus only on Texts A, C, and F in our analysis.

2.1. *Thematic progression in Text A*

In Text A, ten non-embedded clauses are used to define and explain "coral bleaching" (Figure 1). This means there are ten topical Themes, stated either explicitly or implicitly (in parenthesis). The Theme of Clause 2, *which*, refers to *coral bleaching* in the Rheme of Clause 1. Theme 3 reiterates the information in the Rheme of Clause 1. The unstated Theme in Clause 4, *the stressed coral*, recaps the meaning of Clause 3. The meaning of *This*, the Theme of Clause 5, is ambiguous. It could refer to "one problem" in the Theme of Clause 1, to "coral bleaching" in the Rheme of Clause 1, or to the process discussed in the Rheme of Clause 4 (the expelling of its colorful algae). It could also have been used to summarize what is said in the previous four clauses so that the causes of coral bleaching can then be discussed.

a.

	Theme	Rheme
1	One problem	is coral bleaching
2	which	occurs
3	when a coral	becomes stressed
4	and (the stressed coral)	expels most of its colorful algae
5	This	occurs because of stresses such as increased water temperature and runoff of silt that covers the coral and prevents photosynthesis
6	This loss of algae	exposes the colorless coral animals and the underlying ghostly white skeleton of calcium carbonate
7	(The corals)	(are) Unable to grow or repair themselves
8	the corals	eventually die
9	unless the stress	is removed
10	and they	are recolonized by algae

b.

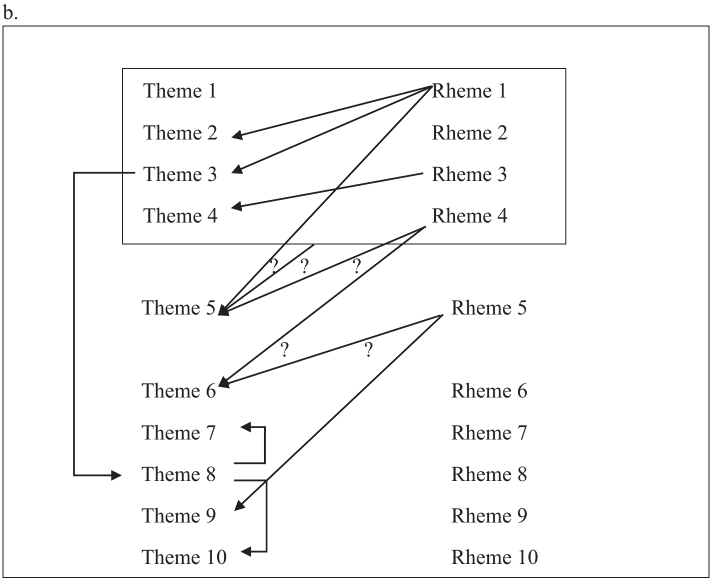

Figure 1. (a) Thematic structure of "coral bleaching" in Text A. (b) Thematic structure of "coral bleaching" in Text A.

Likewise, the referent of Theme 6 (*This loss of algae*) is not clear. It could be seen as referring to the information presented in the Rheme of Clause 4 (*expels most of its colorful algae*) or to the effect of the information stated in the Rheme of Clause 5 (*prevents photosynthesis*). The reader has to fill in the informational gaps here to ensure full understanding. The Theme of Clause 7, a non-finite clause, has to be recovered from the main clause - Clause 8. However, why the corals are not able to grow or repair themselves is not explained. The reason may be inferred from the Theme of Clause 6 (*This loss of algae*) or the Rheme of Clause 5 (a lack of photosynthesis); but to make this inference, the reader needs to bridge the semantic discontinuity from *This loss of algae* (Theme 6) to *the corals unable to grow or repair themselves*. In fact, a whole chain of causal inferences, or semantic leaps, need be made among the several concepts included in this passage: coral bleaching – expelling of colorful algae – stresses such as increased water temperature and runoff of silt that covers the coral – prevention of photosynthesis – the loss of algae – being unable to grow or repair themselves. These leaps are only possible if the reader has the appropriate background knowledge. Note, however, these leaps are bridged in Texts F and G, with the addition of sentences such as "Pollution or water that is too warm can cause the algae, on which corals depend for food, to die off.", "Without food the coral polyps die.", and "Runoff of silt and other materials from the land can cloud the water and block the sunlight that the algae in shallow reefs need for photosynthesis.". Finally, Theme 9 (*the stress*) reiterates the information that appears in the Rheme of Clause 5 (*stresses such as increased temperature and runoff of silt*), and Theme 10 (*they*) repeats the Theme of Clause 8 (*the corals*).

As can be seen from the above analysis, the information in Text A does not always flow smoothly from one clause to the next. Ambiguities and semantic leaps may present challenges for student readers, who often lack the background knowledge and/or language skills to cope with these challenges.

2.2. *Thematic progression in Text C*

Similar to Text A, ten clauses are used to define and explain coral bleaching in Text C (Figure 2). The Theme of Clause 1 (*One problem*) and the Theme of Clause 6 (*two causes*) introduce new topics. According to Halliday & Mattiessen (2004), the Theme is where the speaker chooses as the point of departure. The speaker usually chooses to start with something both the speaker and listener know and therefore, Theme is the place where old information is typically located. This is the unmarked pattern of Given within Theme and New within Rheme. But the speaker may also choose to start with something new. Then both Theme and Rheme contain new information. In this marked pattern of New within Theme, the new information is highlighted. Therefore, the Themes of Clause 1 and Clause 6 are highlighted by the marked pattern of New within Theme. The Theme of Clause 2 (*it*) picks up the Rheme of Clause 1 (*coral bleaching*). The Theme of Clause 3 repeats something (*coral*) mentioned in the Rheme of Clause 1. Each of the Themes in Clauses 4 and 5 recapitulates the Rheme in the immediate preceding clause. The Theme of Clause 7 has to be recovered from Clause 8 while the semantic leap from "prevents photosynthesis" to "unable to grow or repair" may cause reading difficulties. The Themes of Clauses 9 and 10 can likewise be problematic. They do not recap what is stated in the immediate preceding clauses. The Theme of Clause 9 (*the stress*) picks up the Rheme in Clause 3 (*becomes stressed*), instead of that in Clause 7. The Theme of Clause 10 "*algae*" appears in the Rheme in Clause 4, rather than that in Clause 9.

Compared with Text A, Text C presents a smoother progression of information. The explanation of the reasons for "coral bleaching" introduced by the problematic Theme "this" in Clause 5 in Text A is replaced by "two causes," which is the Theme of Clause 6 in Text C. This clears up the confusion in Text A caused by the ambiguous demonstrative pronoun "this." Despite the improved flow of information in Text C, semantic discontinuity regarding why the corals are unable to grow or repair themselves remains.

a.

	Theme	Rheme
1	One problem	is coral bleaching.
2	It	occurs
3	when a coral	becomes stressed
4	and (the stressed coral)	expels most of its colorful algae,
5	(the expelling)	leaving an underlying ghostly white skeleton of calcium carbonate
6	Two causes	are increased water temperatures and runoff of silt that covers the coral and prevents photosynthesis
7	(The corals)	unable to grow or repair themselves
8	the corals	eventually die
9	unless the stress	is removed
10	and algae	recolonize them.

b.

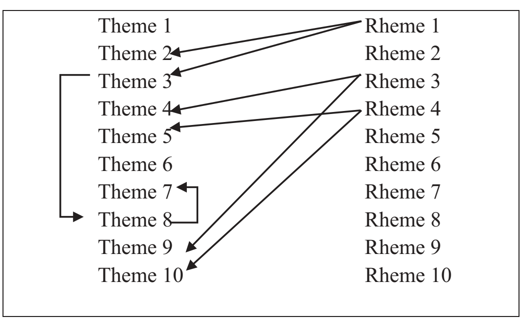

Figure 2. (a) Thematic structure of "coral bleaching" in Text C. (b) Thematic structure of "coral bleaching in Text C.

2.3. *Thematic progression in Text F*

The definition and explanation of "coral bleaching" is shortened since the release of the 15th edition (Text D). The Theme of the introductory clause for coral bleaching was changed from "one problem" in Texts A, B, C, D, and E to "one *resulting* problem" in Text F (Figure 3). This change prompts readers to make the connection between "one problem" and what is stated in the previous text. Specifically, the word "resulting" in the Theme of Clause 1 establishes a causal link between the Theme and the previous portion of the text. The Rheme of Clause 1 (*coral bleaching*) becomes the Theme of Clause 2 (*It*). Theme 3 contains new information that describes the causes of coral bleaching (*stresses such as increased temperature*). In Clause 4, the Theme "which" refers to "*the algae*" in the Rheme of Clause 3. Theme 5, "*without food*," picks up the topic "*food*" introduced in the Rheme of Clause 4 and restates the information presented in the Rheme of Clause 3 (the death of algae) and Clause 4 (coral's dependence on algae for food). Theme 6 in the non-finite clause needs to be recovered from the Rheme of the main clause (Clause 5).

To summarize, our Thematic analysis of three sample texts shows that as a whole information flow improves from the earlier editions to the latter editions, with Text F featuring what Eggins (2004) called a "zig-zagging" pattern of thematic progression, a type of text structuring that facilitates the flow of information in factual genres. Instances of semantic ambiguity and discontinuity decrease from Text A through Text C and to Text F. This reduction makes text processing less challenging and improves overall

a.

Clause	Theme	Rheme
1	One resulting problem	is *coral bleaching*.
2	It	occurs
3	when stresses such as increased temperature	cause the algae, [ ], to die off
4	[upon which	corals depend for food]
5	Without food	the coral polyps then die,
6	(the death of coral polyps)	leaving behind a white skeleton of calcium carbonate

b.

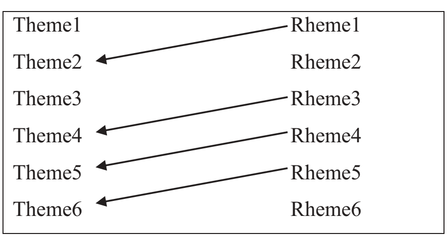

Figure 3. (a) Thematic structure of "coral bleaching" in Text F. (b) Thematic development of "coral bleaching" in Text F.

comprehension as it decreases the amount of background knowledge and inferences needed.

3. Conclusions and implications

Our micro-linguistic analyses indicate that across the seven editions of the textbook under examination, the quality of prose on coral reefs has improved, regressed, or remained the same. In the area of causation, cause–effect relationships are construed in increasingly implicit ways, with causes and effects consistently constructed as grammatical abstractions that bury human or social agencies. In the area of information flow, semantic leaps and semantic ambiguities are reduced across the sample texts analyzed, which places fewer text processing demands on the reader. Taken together, our exploration shows that detailed linguistic analysis can illuminate the comprehension challenges that school textbooks present to students. It can also offer insights that are useful to textbook writers and publishers as they strive to improve the prose quality of their products.

It is clear from our analysis that writing a perfectly considerate text is hard because the author needs to not only anticipate the needs of its target audience but also work within the limits of content load and space allocation, while at the same time attending to the discourse norms and conventions of their community. In other words, the linguistic choices a textbook author makes are a reflection of both the constraints they face and of the ideology and worldviews they intend to communicate. This augurs a need for teachers to be aware of the linguistic realizations of comprehension challenges. Recognizing and responding to the linguistic challenges of disciplinary learning is thus key to effective scaffolding of disciplinary literacy development. As Halliday (2007) observed, conceptualizing disciplinary learning as primarily a linguistic process is the best way we have of illuminating, understanding, and solving problems in teaching and learning. With a solid understanding of how language can be used as a creative, purposeful resource for making meaning, teachers will be better positioned to understand students' reading problems and support their development as proficient and critical readers in their discipline.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix

Text A (2002, 12th edition, p. 152)

According to a 1999 study by the World Resource Institute, nearly 60% of the world's coral reefs are threatened by human activities such as coastal development, overfishing, pollution, and warmer ocean temperatures.

One problem is *coral bleaching*, which occurs when a coral becomes stressed and expels most of its colorful algae. This occurs because of stresses such as increased water temperature and runoff of silt that covers the coral and prevents photosynthesis. This loss of algae exposes the colorless coral animals and the underlying ghostly white skeleton of calcium carbonate. Unable to grow or repair themselves, the corals eventually die unless the stress is removed and they are recolonized by algae.

Coral reefs sometimes are called the aquatic equivalent of tropical rain forests because they harbor such a high species biodiversity with myriad ecological interrelationships. These oceanic sentinels are warning us about the health of their habitats.

Text B (2004, 13th edition, p.144)

More than one-fourth of the world's coral reefs have been lost to coastal development, pollution, overfishing, warmer ocean temperatures, and other stresses that are increasing. One problem is *coral bleaching*, which occurs when a coral becomes stressed and expels most of its colorful algae. This occurs because of stresses such as increased water temperature and runoff of silt that covers the coral and prevents photosynthesis.

This loss of algae exposes the colorless coral animals and the underlying ghostly white skeleton of calcium carbonate. Unable to grow or repair themselves, the corals eventually die unless the stress is removed and algae recolonize them.

Coral reefs are sometimes called the aquatic equivalent of tropical rain forests because they harbor such a high species biodiversity with myriad ecological interrelationships. The decline and degradation of these colorful oceanic sentinels should serve as a warning about the health of their habitats.

Text C (2005, 14th edition, p.127)

More than one-fourth of the worlds coral reefs have been lost to coastal development, pollution, overfishing, warmer ocean temperatures, and other stresses. And these stresses are increasing.

One problem is coral bleaching. It occurs when a coral becomes stressed and expels most of its colorful algae, leaving an underlying ghostly white skeleton of calcium carbonate. Two causes are increased water temperatures and runoff of silt that covers the coral and prevents photosynthesis. Unable to grow or repair themselves, the corals eventually die unless the stress is removed and algae recolonize them.

Aquatic scientists view coral reefs as "aquatic biodiversity saving banks" and sensitive biological indicators of environmental conditions in their aquatic environment. The decline and degradation of these colorful oceanic sentinels should serve as a warning about the health of their habitats and the oceans that provide us with crucial ecological and economic services.

Text D (2007, 15th edition, p.126)

According to a 2005 report by the World Conservation Union, 20% of the world's coral reefs have been lost to coastal development, pollution, overfishing, warmer ocean temperatures, and other stresses. And if we don't take action now, another 30% of these aquatic oases of biodiversity will be seriously depleted within the next 20–40 years.

One problem is coral bleaching. It occurs when a coral becomes stressed and the algae on which it depends for food and color die out, leaving an underlying white or bleached skeleton of calcium carbonate. Two causes of bleaching are increased water temperature and runoff of silt from the land (usually from forest clearing) that covers the coral and prevents photosynthesis.

The decline and degradation of these colorful oceanic sentinels is a warning about aquatic health, the subject of this chapter.

Text E (2009, 16th edition, p. 162)

According to a 2005 report by the World Conservation Union, 15% of the world's coral reefs have been destroyed and another 20% have been damaged by coastal development, pollution, overfishing, warmer ocean temperatures, increasing ocean acidity, and other stresses. And another 25–33% of these centers of aquatic biodiversity could be lost within 20–40 years. One problem is *coral bleaching*. It occurs when stresses such as increased temperature cause the algae, upon which corals depend for food, to die off, leaving behind a white skeleton of calcium carbonate. Another threat is the increasing acidity of ocean water as it absorbs some of the CO_2 produced by the burning of carbon-containing fossils fuels. The CO_2 reacts with ocean water to form a weak acid, which can slowly dissolve the calcium carbonate that makes up the corals.

The degradation and decline of these colorful oceanic sentinels should serve as a warning about threats to the health of the oceans, which provide us with crucial ecological and economic services.

Text F (2011, 17th edition, p. 168)

In a 2008 report by the Global Coral Reef Monitoring Network, scientists estimated that 19% of the world's coral reefs had been destroyed. Other studies indicated that another 20% of all coral reef ecosystems had been degraded by coastal development, pollution, overfishing, warmer ocean temperatures, increasing ocean acidity, and other stresses. And another 25–33% of all reefs could be lost within 20–40 years.

Coral reefs are vulnerable to damage because they grow slowly and are disrupted easily. They thrive only in clear and fairly shallow water of constant high salinity, and runoff of soil and other materials from the land can cloud the water and block sunlight needed by the reefs' producer organisms. Also, the water in which they live must have a temperature of 18–30°C (64–86°F). This explains why the biggest long-term threat to coral reefs may be projected climate change, which could raise the water temperature above this limit in most reef areas. One resulting problem is *coral bleaching*. It occurs when stresses such as increased temperature cause the algae, upon which corals depend for food, to die off. Without food, the coral polyps then die, leaving behind a white skeleton of calcium carbonate.

Another threat is the increasing acidity of ocean water as it absorbs some of the carbon dioxide (CO_2) produced mostly by the burning of carbon-containing fossils fuels. The CO_2

reacts with ocean water to form a weak acid, which can slowly dissolve the calcium carbonate that makes up the corals.

The decline and degradation of these colorful oceanic sentinels should serve as a warning about threats to the health of the ocean ecosystems, which provide us with crucial ecological and economic services.

Text G (2014, 18th edition, p. 168)

Studies by the Global Coral Reef Monitoring Network and other scientist groups estimate that since the 1950s, some 45–53% of the world's shallow coral reefs have been destroyed or degraded by pollution and other stressors, and another 25–33% could be lost within 20–40 years. Also, deep coral reefs that are thousands of years old are being destroyed by large numbers of trawler fishing boats that drag huge weighted nets across the ocean bottom. One result of such stresses is coral bleaching. Pollution or water that is too warm can cause the algae, on which corals depend for food, to die off. Without food, the coral polyps die, leaving behind a white skeleton of calcium carbonate.

Coral reefs are vulnerable because they grow slowly and are disrupted easily. Runoff of silt and other materials from the land can cloud the water and block the sunlight that the algae in shallow reefs need for photosynthesis. Also, the water in which shallow reefs live must have a temperature of 18–30°C (64–86°F) and cannot be too acid. This explains why the two major long-term threats to coral reefs are projected climate change, which could raise the water temperature above this limit in most reef areas, and ocean acidification, which could make it harder for polyps to build reefs and could even dissolve some of their calcium carbonate formations.