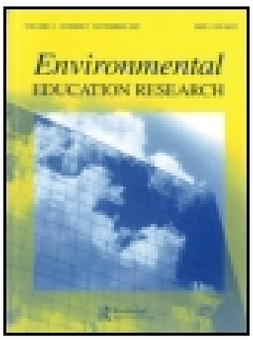

Routledge
Taylor & Francis Group

Environmental Education Research

ISSN: 1350-4622 (Print) 1469-5871 (Online) Journal homepage: http://www.tandfonline.com/loi/ceer20

Textbooks of doubt: using systemic functional analysis to explore the framing of climate change in middle-school science textbooks

Diego Román & K.C. Busch

To cite this article: Diego Román & K.C. Busch (2015): Textbooks of doubt: using systemic functional analysis to explore the framing of climate change in middle-school science textbooks, Environmental Education Research, DOI: 10.1080/13504622.2015.1091878

To link to this article: http://dx.doi.org/10.1080/13504622.2015.1091878

Published online: 28 Sep 2015.

Environmental Education Research, 2015
http://dx.doi.org/10.1080/13504622.2015.1091878

Routledge
Taylor & Francis Group

Textbooks of doubt: using systemic functional analysis to explore the framing of climate change in middle-school science textbooks

Diego Román[a]* and K.C. Busch[b]

[a]*Department of Teaching and Learning, Southern Methodist University, Dallas, TX, USA;*
[b]*Graduate School of Education, Stanford University, Stanford, CA, USA*

(*Received 19 March 2015; accepted 18 August 2015*)

Middle school students are learning about climate change in large part through textbooks used in their classes. Therefore, it is crucial to understand how the language employed in these materials frames this topic. To this end, we used systemic functional analysis to study the language of the chapters related to climate change in four sixth grade science textbooks adopted in the state of California. The linguistic variables investigated were: types of nominal groups; processes; circumstances; and the modality system. Our findings showed that these textbooks framed climate change as uncertain in the scientific community – both about whether it is occurring as well as about its human-causation. The implications for science education are discussed in relation to how the current political and public discourses of climate change, rather than the scientific discourse, is influencing how textbooks discuss this topic.

Keywords: systemic functional analysis; climate change; textbooks; uncertainty; framing

Introduction

A recent poll conducted in the United States showed that 51% of American teenagers believe that scientists do not agree about whether climate change is happening (Leiserowitz, Smith, and Marlon 2011). What might be the sources of this erroneous belief among American youth? Some answers may be found in the students' classrooms. Because most science teachers in the United States rely on textbooks for their instruction (Kloser 2013; Slough et al. 2010; Weiss et al. 2003), science textbooks are one example of the materials students will likely use when learning about climate change. Consider the following text extracted from a sixth grade science textbook:

> 1. Not all scientists agree about the causes of global warming. Some scientists think that the 0.7 Celsius degree rise in global temperatures over the past 120 years may be due in part to natural variations in climate. (Prentice Hall 2008, 377)

A likely inference that can be drawn from this extracted text is that there is a high level of uncertainty among the scientific community about the causes of climate change – this uncertainty is exemplified in expressions such as 'not all scientists' or 'some scientists.' While it is accurate that agreement is not unanimous, it is esti-

*Corresponding author. Email: dxroman@smu.edu

mated that only 3% of climate scientists disagree about the causes of climate change (Cook et al. 2013). Furthermore, 'natural variations' are the only agents of climate change explicitly identified in text sample one. Contrast this extract with the language used in the following text from the Intergovernmental Panel on Climate Change's (IPCC 2013, 13) most recent report:

> 2. Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

In the second extract, linguistic expressions that construe uncertainty about human influence on climate change are absent. Human influence is described as 'clear' in this text. Whereas the textbook refers to what scientists 'think' about climate change, the IPCC report specifically lists sources of observable evidence from which scientists made the inference about human causation of this phenomenon.

Yet, how common are the framings of high scientific uncertainty about climate change and the human influence on the climate system in science textbooks? To answer this question, we conducted an exhaustive examination of the choices and frequency of language – both the level of uncertainty as well as the agents involved – in all the chapters that covered the topic of climate change in four sixth grade science textbooks, each by a different publisher, adopted in the state of California.

In what follows, we locate our study in the current literature about the framing of climate change and in prior research that has addressed the language of science and science textbooks. We then describe our research questions, the methodology, and the results of our study. Finally, in the discussion section, we posit that the language in science textbooks addressing climate change incorrectly portrays a low level of agreement among scientists about this phenomenon and does not sufficiently discuss the impact of human influences on the climate system. In other words, we argue that the language found in the science textbooks analyzed is more akin to the public discourse of doubt rather than to the scientific discourse. Finally, in the implications section, we discuss how our research could aid in improving the manner in which school textbooks present climate change.

Student perspectives on and knowledge of climate change

Much like the adult public, polling results paint a bleak picture of youths' engagement around the issue of climate change. Only 54% of American teens believe that climate change is actually happening, and 43% do not believe that it is caused by humans. Therefore, it is perhaps not surprising that 57% of teens are not concerned about climate change (Leiserowitz, Smith, and Marlon 2011).

Often the lack of youths' concern about climate change is attributed to their lack of knowledge. An extensive body of research indicates that students hold many misconceptions about climate science (Shepardson, Niyogi, and Charusombat 2011). For example, students confuse the causes of climate change with other atmosphere-related pollution issues such as acid rain and ozone depletion. In addition, students are unclear about the effects of climate change, incorrectly linking climate change to skin cancer and believing that the effects will be the same for all parts of Earth. While there are likely many contributions to student perceptions and understandings of climate change, information they encounter in their school science textbook is likely one influence.

While numerous studies have carefully cataloged the many misunderstandings students have about climate change, we found only one other peer-reviewed study that characterized the representation of climate change in school science textbooks. Building on their previous work about student misconceptions, Choi et al. (2010) reviewed seven earth and environmental science textbooks in order to determine if science textbooks may be contributing to student misconceptions about climate change. They found that many of these misconceptions could be mapped onto similar misrepresentations of or lack of coverage about those topics within the texts. For example, it was noted that the textbooks failed to distinguish between and relate the types of radiation: incoming solar radiation and outgoing infrared radiation. This lack of understanding, the authors argue, can contribute to students misunderstanding of the causes of climate change.

Uncertainty, understanding, and concern

While the previous study does provide a well-supported argument that content in textbooks can be correlated to student misconceptions, it did not specifically address the representation of uncertainty in these texts. In fact, many scholars have questioned the prevailing assumption that a lack of knowledge is the main cause for lack of concern (Kahan, Jenkins-Smith, and Braman 2011; Möser and Dilling 2011). Rather, among adults, perception of scientific consensus may be more predictive of concern and action (Ding et al. 2011; McCright, Dunlap, and Xiao 2013). And, in some cases, the link between knowledge and concern can be mediated by perception of scientific consensus (Malka, Krosnick, and Langer 2009). Because uncertainty is such an inherent part of climate science as well as the climate 'debate,' – a 'debate' fueled in large part through intentional deception (Oreskes and Conway 2011) – we find this additional component worth studying.

Although uncertainty is an inherent aspect of scientific study, 'within the climate change discourse it functions as an obstacle to action' (Hayden 2011, 118). Experimental research has shown that perception of high uncertainty has been correlated to reduced willingness to take pro-environmental behavior (Bamberg and Möser 2007; Fortner et al. 2000; de Kwaadsteniet et al. 2007). Malka and colleagues (2009) found that when skeptical language was introduced into a scientific message about climate change, it not only resulted in less favor for public policy to mitigate and adapt, it also resulted in a decreased belief that climate change was happening, and a decreased belief of the scientific consensus. Additionally, research suggests that uncertainty can affect learning. The more uncertain an environmental issue is, the more likely learners are to have misconceptions about the issue (Boyes, Chuckran, and Stanisstreet 1993; Boyes and Stanisstreet 1992; Fortner et al. 2000; Stanisstreet and Boyes 1996).

While being clear about levels and sources of uncertainty is considered to be 'good science' by scientists, the public perceives uncertainty as 'not knowing' (Möser 2010). Confusion has been fueled in part due to the accepted language used in scientific writings. For instance, when non-scientists interpret the qualitative expressions the IPCC has used in their reports, such as 'very likely,' they consistently underestimate the quantitative probabilities intended by scientists (Budescu et al. 2014).

Taken together, these studies show that understanding uncertainty about climate science is an important part of understanding and acting on climate change. In

addition, one of the learning goals for K-12 science students is to understand the 'nature of science' defined as the 'the values and assumptions inherent to the development of scientific knowledge' (Lederman and O'Malley 1990, 225). Uncertainty of scientific knowledge is considered an extremely important aspect of the nature of science that students should understand (DiGiuseppe 2014; Osborne et al. 2003). Next, we consider how framing theory may provide a unique insight into how uncertainty about climate change is being portrayed in school science.

The framing and discourses of climate change

Frames are 'interpretive story lines that communicate what is at stake in a societal debate and why the issue matters' (Nisbet and Scheufele 2009, 1770). According to framing theory, society, the media, and the audience are connected through three framing processes: frame building, frame setting, and the individual-level effects of framing (Scheufele 1999). For example, in discussing the topic of climate change, some segments of the media use the journalistic norm of 'balance' – giving equal weight to all positions about this phenomenon – when building frames to present to the public (Boykoff 2007). When frame setting, segments of the media that adhere to this norm give equal time to a climate scientist and a climate denier when addressing climate change. For example, Fox News presents climate change as uncertain by interviewing a greater proportion of climate deniers (Feldman et al. 2012). As a result, at the individual-level effects of framing stage, the audience may come to understand human-caused climate change as controversial. And indeed, viewers of Fox News are more likely to be climate skeptics even when taking into account political affiliation (Feldman et al. 2012). The effects of framing go beyond individual positions about specific topics. Frames accumulate into larger discourses, which are 'a shared way of apprehending the world … enabling those who subscribe to it to interpret bits of information and put them together into coherent stories or accounts' (Dryzek 2013, 9). We see two discourses prevalent in climate change communication: a 'scientific discourse' and a 'public discourse.'

The 'scientific discourse' can be seen in scientific writings such as the IPCC reports. The IPCC asserts that the human impact on climate change is clear and action is warranted. According to the IPCC (2013, 17), 'continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.' Thus, the scientific discourse frames climate change as an environmental problem with immense risk, and as a result, we should take immediate mitigating action.

In contrast, the 'public discourse' can be seen in mass media reports in which climate change is characterized by portraying the human-causes of this phenomenon as unsettled science with high levels of uncertainty among the scientific community (Boykoff 2007; Feldman et al. 2012). The effect of presenting human-caused climate change as controversial could be seen in a recent survey conducted in the United States. According to the Pew Research Center (2015), only 50% of American adults polled in that survey agree that the Earth is getting warmer due to human activity. The public discourse often adopts a 'wait-and-see' approach, reflected in polling results which indicate that only 33% of the US public believes that climate change is a serious threat (Pew Research Center 2015).

Within the US and globally, risk perception is highly correlated to communication access and education (Lee et al. 2015). While mass media is the main source of information about climate change for the public (Leiserowitz, Smith, and Marlon 2010), school still serves as an important source of information for youth (Dupigny-Giroux 2010; Jeffries, Stanisstreet, and Boyes 2011). So, how is climate change framed within school contexts and materials?

Framing of climate change in school science

School frames are evident in the language used by teachers and textbooks. Busch (2015) examined the *frame-setting process* and found that teachers used two different discourses – the science discourse and the social discourse – when lecturing about climate change. In the science discourse, teachers framed climate change as an issue of data and scientists, at the global scale, as a current problem, and one that primarily affects physical systems such as precipitation and temperature. When using the social discourse, however, teachers discussed the effects of climate change on social structures such as economics and politics, emphasizing the impact on people at a local scale, and placing these effects in the future. School frames are also evident in the language choices found in textbooks in sections about climate change. In this study, we aim to characterize the way in which climate change is represented in textbooks (Figure 1).

At the macro level, textbook writers and teachers make language choices when *frame-building* based on ideology, beliefs and attitudes, the school context, and community influences. One influence on school textbooks is likely the state science standards. Although climate change has been neglected in previous science standards (Hoffman and Barstow 2007), this topic is included in the recently developed United States' Next Generation Science Standards (NGSS Lead States 2013) as well as in the science curriculum of various countries (e.g. the Australian Curriculum and the National Curriculum in England). Unequivocally, climate change is considered to be real and human actions are identified as both a cause of and as a solution. Thus, the standards align more so with the scientific discourse rather than the public discourse. Yet, do the language choices employed in science textbooks to discuss climate change reflect the public discourse, the scientific discourse, or both? Before delving into this question, we provide a brief review of the importance of science textbooks and the characteristics of the language they use to present scientific concepts.

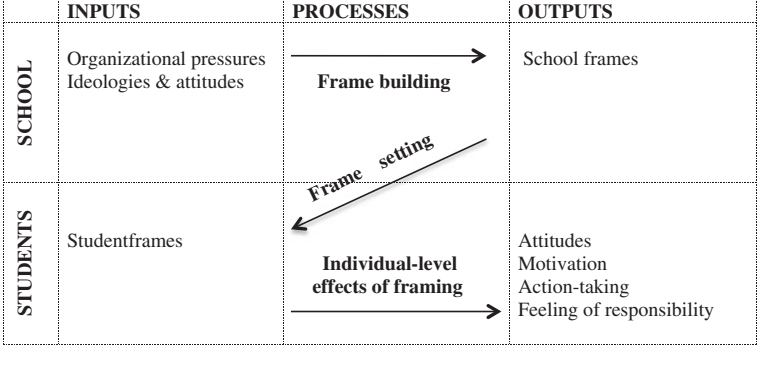

Figure 1. The theoretical relationship between society, schools, and students (Busch 2015).

Science textbooks and science discourse

At the K-12 school level, science textbooks are one of the main sources of science discourse (Bryce 2011). However, there seems to be a consensus that these materials are flawed (Slough and McTigue 2010), particularly with respect to how they misrepresent the nature of science and by their inability to justify claims (Drew 2011). For instance, after conducting an extensive review of science textbooks in the United States, Kesidou and Roseman (2002) report that these programs lacked clarity in presenting key scientific ideas and offer minimal support to teachers and students in learning these key concepts.

Textbooks have also been criticized for merely emphasizing the descriptions of facts, instead of explanations (Smolkin, McTigue, and Yeh 2011), and promoting memorization rather than critical thinking (National Research Council 1990). These findings have been reflected in the few studies that have addressed the syntactic and discourse level features of science textbooks (Fang and Schleppegrell 2008). For instance, Butler and her coauthors (2004) found that most sentences in science textbooks presented information as a series of statements of fact – what these authors characterized as 'extended definition' (32).

The language of science textbooks has evolved within the wider context of the discourse used by scientists. In discussing the historical development of science discourse, different authors have posited that it has evolved to present scientific knowledge using language that is simultaneously technical, abstract, dense, and tightly knit (e.g. Halliday and Martin 1993). According to Montgomery (1995), science discourse is characterized by the persona of univocity, in which objects or abstractions – commonly in the form of nominalizations – perform the actions. Consider example 3 in which a nominalization (i.e. radiation) is performing an action (i.e. heating up the air):

> 3. Then infrared radiation from these surfaces heats the air in the greenhouse. (Prentice Hall 2008, 375)

Schleppegrell (2004) points out that nominalization are nouns or nominal groups (e.g. *infrared radiation*) that present information that would have required a whole clause (e.g. *the Sun radiates invisible energy*). In other words, nominalization is a linguistic process through which verbs (e.g. radiate) and adjectives (e.g. radioactive) serve as nouns (e.g. radiation, radioactivity) to convey specialized meanings in academic texts. Furthermore, authors of science texts often use nominalization to present information in technical and concise ways, but one consequence of nominalization is that human agents and temporal aspects of the scientific processes described are not made explicit.

Yet, when used in school textbooks, this impersonal authoritative stance does not allow exploration of ideas, obscures the human agents involved, and only presents the school science point of view (Montgomery 1995). Furthermore, the type of science discourse used in textbooks does not usually reflect the various degrees of uncertainty in scientific knowledge (Kloser 2013) – an important aspect of the nature of science that students should understand if they are to differentiate between knowledge that is 'well-established and beyond reasonable doubt, and why other scientific knowledge is more open to legitimate doubt' (Osborne et al. 2003, 701).

In addition, various researchers have described the critical role that science language plays in science instruction (e.g. Lee, Quinn, and Valdés 2013; Shanahan and

Shanahan 2008; Yore 2012). Yet, few studies have focused on how specific linguistic features, such as ways of expressing uncertainty, impact students' understanding of scientific concepts (Chenhansa and Schleppegrell 1998). Language, however, has been called the major obstacle most students face in learning science (Norris and Phillips 2003) because almost all of what we call knowledge is presented using language (Wellington and Osborne 2001) and 'doing science' depends on understanding how science gets communicated to different audiences (Lemke 1990).

Research questions

School materials, such as textbooks, are framing how climate change is presented to students. These frames are visible and salient via the language choices used in textbooks to discuss this topic. Given the importance of science textbooks and the role that language plays in science instruction, we used systemic functional analysis (SFA) (Fang and Schleppegrell 2008, 2010) to investigate how uncertainty and human attribution are construed in the language of the chapters that discussed climate change. Specifically we asked:

(1) How does the language used in science textbooks indicate how certain scientists are that climate change is occurring?
(2) How are human beings positioned as the causes of or the solution for climate change?

Methodology

Broadly speaking, linguistic studies of textbooks have followed two approaches: the formal perspective that focuses on the technical aspects of language (e.g. Butler et al. 2004) and a functional perspective that studies language according to its context of use (e.g. Moss 2006). Among the functional approaches, Halliday's (1994) Systemic Functional Linguistics (SFL) has had a strong influence in the field of education because it has offered educators insights into how language varies between genres and content-areas (Moje 2008). SFL has provided educators with a meaning-based metalanguage they can use to discuss the linguistic characteristics of content-area texts (Fang and Schleppegrell 2008).

SFL is distinctive from other methodologies because it seeks to develop both a theory about language as a social process, and an analytical methodology that would allow the systematic description of language patterns (Eggins 2007). As Halliday (1994, xiii) states, '… every text – that is everything that is said or written – unfolds in some context of use; furthermore, language has evolved to satisfy human needs and it is organized as a function of those needs.' In education, language analysis using SFL is conceptualized as examining the linguistic features of the discourse of each content area (e.g. science).

The present study used SFA, an SFL-based approach developed by Fang and Schleppegrell (2008, 2010). SFA was chosen because it studies language using a three dimensional perspective: (1) the conceptual information being presented in the text, that is, experiential meaning; (2) the relationship between the language users, or between readers and authors, that is interpersonal meaning; and (3) how texts are organized, that is, textual meaning (Schleppegrell 2004). In other words, SFA takes

into account how content is instantiated, how the writer and readers negotiate roles, and how texts are structured to express abstract, technical, and evaluative meanings.

To analyze uncertainty and human-attribution of climate change using an SFA approach, we examined four linguistic variables to explore the experiential, interpersonal, and textual meaning in texts about climate change. These linguistic variables were: types of nominal groups as expressed in the participants or subjects of each clause (human agents vs. abstractions); types of processes (doing, being, saying, sensing) as expressed by verbs and their configurations of participants; circumstances as expressed by prepositional and adverbial phrases, and conjunctions (e.g. millions of years ago, therefore); and the modality system as expressed in modal verbs (e.g. would, could, might). The reasons behind choosing each of these four groups are described below.

Experiential meaning: participants and processes

Experiential meaning refers to the concepts discussed in the text, or what the text is about. Nouns and noun phrases (nominal groups) and processes (construed in clauses via verbs and its participants) are key resources in presenting conceptual information. From an SFL perspective, '… all nominal groups are grammatical participants in a text; presenting the actors, sayers, thinkers, and other semantic roles in the processes [of doing sensing, sensing, saying, and being] constructed by each clause' (Fang, Schleppegrell, and Cox 2006, 252). For this study, we focused on the nominal and verbal groups authors used to describe: (1) the work done by scientists in the area of climate change; (2) if human beings were explicitly identified as being responsible for this phenomenon; and (3) the activities that human beings can do to mitigate the effects of climate change.

The roles nouns play in texts from different academic contexts vary because authors use nominal groups to express concrete, abstract, or technical participants depending on the topic. As indicated earlier, in science discourse authors often use nominalization as a resource to pack information in a nominal group instead of using a whole clause (Fang and Schleppegrell 2008; Schleppegrell 2004; Snow 2008). Consider example 4 that uses the nominalization *deforestation*:

> 4. Deforestation is the process of clearing forests. (Holt, Rinehart, and Winston Inc. 2007, 471)

In example 4, readers are expected to know not only what deforestation means, but also that human actors are the ones causing this environmental problem. In other words, the use of *deforestation* in this example resulted in the deletion of the agent and the object to which the actions are directed. According to Chenhansa and Schleppegrell (1998) nominalizations can be especially problematic in students' ability to envision solutions to environmental problems because these problems are presented in language that seems to indicate that no human actors are involved.

Besides the participants (i.e. the nominal groups), the experiential meaning of texts also takes into account the verbs presented in each clause. Clauses in which verbs define, describe, or classify entities are considered part of the being process (e.g. are, is). If the clause is about saying, the verb is classified as a saying process (e.g. say, tell). If the clause describes feelings, the verb is classified as a sensing process (e.g. feel, sense). Finally, if the clause describes actions, the verb is classified as a doing process (e.g. do, work, transform). In the present study, clauses that had

verbs such as think, believe, or consider were grouped together as part of the saying process because the goal of this article was to analyze both how participants were represented as saying, and how participants were represented as thinking.

Interpersonal meaning: modality system

In SFA, interpersonal meaning involves understanding the relation established between the author and the readers. One way SFA does this is by examining the modality system expressed in texts to examine the authoritativeness, attitudes, interpretations, and judgments construed by the author in each clause. In other words, SFA considers the meanings of certainty, possibility, or obligation expressed through modal verbs such as could, can, might, will, would or adverbs like probably or certainly. Adjectives such as positive, negative, or beneficial provide a window into the authors' opinions about a topic. Consider example 5:

> 5. Global warming could have some positive effects. (Prentice Hall 2008, 377)

The nominal group or participant is the abstract noun phrase global warming and the process is instantiated by the verb and modal verb could have. Although the author uses the modal verb could to express uncertainty, he uses the adjective positive to indicate an optimistic view of the effects of climate change.

Because most textbooks present science as a collection of facts, they usually employ language that reflects high levels of certainty (Gibbs and Lawson 1992). This language is characterized by a series of statements of fact, in which modal verbs appear infrequently or not at all (Butler et al. 2004). For example:

> 6. Scientists use two main factors – precipitation and temperature – to describe the climate of a region. A climate region is a large area that has similar climate conditions throughout. For example, the climate in the southwestern United States is dry, with hot summers. (Prentice Hall 2008, 346)

This way of presenting knowledge, however, does not reflect scientific epistemology because even well proven theories (e.g. cell theory) that '… have become generally accepted by members of the scientific community, the possibility of coming up with a better theory that contradicts one or more of the postulates always remains' (Gibbs and Lawson 1992, 143). In the area of interpersonal meaning, we examined if the language used to discuss climate change in middle school textbooks followed the final form science language that seems to be characteristic of these materials, or a language that expressed high levels of uncertainty about the theory of climate change.

Textual meaning: circumstances

Textual meaning from a SFA perspective is analyzed by looking at the linguistic devices employed to structure cohesive and coherent texts (e.g. logical connectives, repetition of the same terms). In this study, we examined how logical connectives – including adverbs, conjunction, adverbial, prepositional, and noun phrases – were used to construe the following circumstances or logical relations between clauses: time (e.g. *thousands of years ago*, *glaciers covered part of North America*); cause-effect (e.g. *therefore, human beings need to use less fossil fuels*); contrast-comparison (e.g. *however*, *climate change could have positive effects*); and

condition (e.g. *if the ice caps melt*, *the ocean water level will rise*). When clauses did not have explicit connectives, for our analysis, we inserted the connective that best represented the relationship between the clauses being connected. Finally, we also included a lexical cohesion category, which we called description, to classify the instances that used word repetition rather than logical connectives, to achieve cohesion (e.g. when the nominal group ice ages was repeated in more than one clause in the same paragraph). If the main logical relation was ambiguous, all the possible relations between clauses were annotated.

Table 1 summarizes all the linguistic elements that were analyzed using the SFA framework described in this section.

Corpus

Our corpus consisted of an exhaustive sample of all the sections that discussed the topic of climate change in four sixth grade science textbooks: *Focus on Earth Science* (Prentice Hall 2008), *Focus on Earth Science* (Glencoe-McGraw-Hill 2007), *Focus on Earth Science* (CPO Science 2007), and Earth Science (Holt, Rinehart, and Winston Inc. 2007). All of these textbooks were adopted in the state of California. Sixth grade textbooks were chosen because sixth grade is: (1) the first year of middle school in the United States and textbooks start becoming more discipline-specific and expository rather than covering various subjects (Gamson, Lu, and Eckert 2013); (2) this grade level is the first time that science is taught by a specialized teacher with little or no training in linguistics and literacy development (Slough et al. 2010); and (3), sixth grade is the first time that students in California encounter climate change in their formal science curriculum as indicated by the state science standards (California State Board of Education 1998).

The unit of analysis was the clause. The corpus in its entirety consisted of 279 clauses and 2770 words (Table 2). The authors of this paper compiled and coded all the texts in the present study. For the coding, we first divided each section into its constituting paragraphs. Next, each sentence was identified using punctuation marks

Table 1. SFA framework used in this study.

Experiential meaning	Interpersonal meaning	Textual meaning

• Nominal groups (participants):
  ○ Human-related: (scientists, human activity)
  ○ Abstractions (pollution, deforestation)
• Verbs (processes):
  ○ Sensing (feel)
  ○ Saying (present, think)
  ○ Doing (cause, make)
  ○ Being (are, is)
	• Determiners (some, many)
	• Adjectives (positive, recently)
	• Modal verbs (might, could, can)
		• Subordinating conjunctions (because, when, since)
		• Coordinating conjunctions (and, or)
		• Adverbial phrases and prepositional phrase adverbials (however, therefore, on the other hand, as a result)

Table 2. Number of clauses and words analyzed in each textbook.

	Prentice Hall	Glencoe-McGraw-Hill	CPO Science	Holt, Rinehart, and Winston	Total
Clauses	80	35	33	131	279
Words	863	335	361	1211	2770

(e.g. periods, question marks) and then divided into independent and subordinated clauses. The main criteria for classifying a discourse segment as a clause was the presence of a subject and a conjugated verb.

After clauses were identified, we coded separately the same section for each publisher. For each clause, we coded: the nominal groups; verbs and their configurations of participants; circumstances (i.e. prepositional, adverbial phrases, and conjunctions); and the modal verbs.

Then, we compared our results and re-coded the section if we had not arrived to at least 80% agreement. This percentage of inter-coder agreement was determined following Artstein and Poesio's (2008) recommendation of measures of 0.8 as an indicator of high coding quality in linguistic analyses. After we have solved any coding disagreements, we continued coding the rest of the sections for each publisher.

Results

RQ1: *How does the language used in science textbooks indicate how certain scientists are that climate change is occurring?*

The results of our exploration of this question are shown using the three dimensions of SFA analysis: experiential meaning, interpersonal meaning, and textual meaning. The topic of uncertainty is presented below according to those dimensions.

Experiential meaning

Nominal groups were classified into two categories: nominal groups that instantiated abstractions (e.g. climate change, weather, ice ages) and nominal groups that instantiated human-related agents (e.g. scientists, human activities, farmers). Out of 279 clauses in the corpus, 52 (19%) had human-related nominal groups. The plural noun, scientists was the most frequent with 22 occurrences and the noun researcher was used one time. Only one scientist, Milutin Milankovitch, was identified by his name – one time – in the corpus and the personal pronoun they was used two times to refer to scientists. Therefore, a total of 26 instances contained nominal groups semantically related to the noun scientists – 50% of the 52 clauses that had human-related nominal groups.

There were also eleven instances in which the human agents were instantiated using the personal pronoun you. From these, the pronoun you was used overtly six times to create a dialog between the textbook authors and the students (e.g. have you heard, have you noticed, are you surprised?) while there were five imperative clauses in which the pronoun you implicitly gave directions to students (e.g. recall that, notice that, look at, think about).

Finally, all the nominal groups instantiated by the pronouns we and our, and by the nouns farmers, countries, people, individuals, and human activities were grouped

Table 3. Verbs used to describe the activities performed by scientists.

Process	Verbs	Total
Saying	Think (8), hypothesize (2), believe (1), predict (1), present (1), propose (1)	14
Doing	Do, find, form, observe, determine, measure, obtain, study, use (1 each)	9
Being	Are not sure, do not agree (1 each)	2
Sensing	Are concerned (1)	1

under the umbrella category of human actions. This category is analyzed as part of our second research question.

To understand the experiential meaning construed by processes, we analyzed the verbs in clauses where the nominal groups were human related participants. We were particularly interested in the verbal groups used to describe the activities performed by scientists, researchers, and the pronoun they when it referred to scientists. Table 3 shows that the most common verb used in relation to scientists was think (eight times), followed by hypothesize (two times). Verbal groups that were used one time were: believe, find, form, observe, determine, propose, measure, obtain, do, predict, study, use, present, and are concerned. Two verbal groups were used to describe disagreement among scientists: are not sure and do not agree. Each appeared only one time in the corpus.

Using SFA, the clauses in which these verbs appeared were classified in four different processes: being, doing, sensing, and saying (Table 3). Clauses in which verbs such as believe or think appeared were classified as part of the saying process – rather than in the sensing category – because these verbs were used to communicate scientists' ideas.

Interpersonal meaning

To understand the authors' perspective on climate change, we examined the interpersonal meaning in these texts. This analysis allowed us to gain insight into the levels of authoritativeness textbook authors construed when discussing climate change (i.e. authors presented climate change as a set of facts or as tentative claims).

We found 37 clauses in the corpus (13% of all clauses) that had modal verbs. The most frequent of these modal verbs was could (17 occurrences), followed by can (ten occurrences), may and would (four occurrences each), and might (three occurrences). All of these modal verbs were used to express various levels of uncertainty about factors related to climate change. Consider examples 7 and 8:

> 7. Some scientists predict that the level of carbon dioxide could double by the year 2100. (Prentice Hall 2008, 376)
>
> 8. Scientists are concerned that the resulting rise in Earth's average surface temperature might alter climates and other aspects of our environment. (CPO Science 2007, 116)

As seen in the examples above, the authors of these textbooks expressed uncertainty, not only by using modal verbs, but also by using unquantifiable determiners (e.g. some). Overall, a wide range of quantifiers was used to describe the number of scientists who agree with positions: some (seven occurrences), many (six occurrences), most (one occurrence), and not all (one occurrence). When no quantifier was used, textbooks presented the generic noun scientists, researchers, and the pro-

noun they. Not one clause in all of the textbooks analyzed mentioned a percentage of scientists that agree or disagree about climate change.

Although all four publishers discussed the natural factors that contribute to climate change, only in one instance did authors used the noun research to describe the various studies scientists have done to understand climate change. Furthermore, the nouns data and evidence were used only two times across the corpus. As seen in the following example, one of the uses of evidence, however, was to indicate that ice ages have happened in the past:

> 9. Scientists have found evidence of many major ice ages during Earth's geologic history. (Prentice Hall 2008, 377)

Putting climate change in a historical lens was also reflected in the usage of the adjectives gradual (two instances) and the adverb gradually (three instances). As example 10 shows:

> 10. However, climates have gradually changed throughout Earth's history. (Prentice Hall 2008, 374)

Finally, all four textbooks mentioned the negative effects of climate change, but two of them also discussed the potential positive results of this phenomenon:

> 11. But farther north, such as in Canada, weather conditions for farming would improve. (Holt, Rinehart, and Winston Inc. 2007, 471)

Textual meaning

We analyzed lexical repetition, adverbs, conjunctions, and adverbial and prepositional phrases to understand how authors structured texts about climate change. These linguistic features were classified using the following semantic categories: description, cause-effect, time, contrast, and condition.

We found that almost half of all the clauses (142 clauses or 48%) were statements that provided definitions and were cohesive in relation to previous clauses through lexical repetition. Consider example 12, in which the noun, periods links these two clauses:

> 12. During an ice age, there are periods of cold and periods of warmth. These periods are called glacial and interglacial periods. (Holt, Rinehart, and Winston Inc. 2007, 467)

The second most frequent category was cause-effect with 74 clauses. In the texts analyzed, authors described different natural factors that could cause changes in climate (example 13) or the potential effects of climate change (example 14):

> 13. Water molecules in the atmosphere are responsible for a large percentage of the additional warming of Earth's surface. (Glencoe-McGraw-Hill 2007, 399)

> 14. The melting of glaciers and polar ice caps could also increase sea level. (Prentice Hall 2008, 377)

It is worth mentioning that only 16 of the 74 clauses that identified cause-effect relations had human agents. Therefore, human agents were identified as having an effect on climate change in only 21% of the clauses that discussed this topic. However, consider example 15 in which scientists are described as only 'believing' that human activities can affect Earth's climate:

15. Some scientists believe that human activities can affect the climate of our planet. (Glencoe-McGraw-Hill 2007, 399)

The third most frequent category were clauses that used a time perspective to describe climate change. Two of the four textbooks mentioned that climate change, as exemplified by ice ages, is a phenomenon that has occurred several times in Earth's history (example 16). However, all textbooks indicated that recently scientists have started to 'think' that human activities could be causing this phenomenon.

16. In the past two million years there have been many major ice ages. (Prentice Hall 2008, 374)

Finally, there were 24 clauses in a contrast rhetorical relation and 21 clauses in a conditional rhetorical relation. The contrast relation was exemplified by clauses that indicated that changes in climate are not new (example 17), while the conditional relation was illustrated by clauses that described the potential reasons or effects of climate change (example 18):

17. However, climates have gradually changed throughout Earth's history. (Prentice Hall 2008, 374)

18. If the average surface temperature of Earth increases, scientists hypothesize that changes in global climate could occur. (Glencoe-McGraw-Hill 2007, 487)

In summary, the clauses that contained nominal groups related to scientists had verbs that mostly described vague mental processes such as *think* and *believe* rather than verbs that describe specific scientific practices like *observe*, *evaluate*, or *measure* that scientists undertake to investigate climate change. In addition, these textbooks used generic quantifiers that ranged from *not all* to *most* to describe the proportion of scientists that agree that climate change is occurring as a result of human actions. Finally, only 21% of the clauses that contained a cause-effect relation with each other identified human actions as having an effect on climate change.

RQ2: *How are human beings positioned as the causes of or the solution for climate change?*

All four textbooks dedicated a substantial portion of the chapters about climate change to describe the natural factors that could be causing this phenomenon. Although all four textbooks indicated that human beings could be having an impact on climate change, they framed this topic as an issue in which not all scientists are in agreement as can be seen in the following example:

19. Not all scientists agree about the causes of global warming. Some scientists think that the 0.7 Celsius degree rise in global temperatures over the past 120 years may be due in part to natural variations in climate. (Prentice Hall 2008, 377)

As mentioned earlier, for our analysis the nominal groups instantiated by the pronouns we and our, and by the nouns farmers, countries, people, individuals, and human activities were grouped under the umbrella category of human actions. The first person plural pronoun we was used three times (e.g. *we add more carbon dioxide*) and the possessive pronoun our was used one time (e.g. *our ability*). Finally, the noun people was used two times while the nouns humans, individuals, countries, and farmers were used only one time. The nominal group human activities was used four times.

Where human actions were described, all four textbooks described the effects of human actions on climate change both as a recent discovery and as a recent phenomenon, as can be seen in example 20:

> 20. Until recently, climatic changes were connected only to natural causes. However, studies indicate that human activities may have an influence on climate change. (Holt, Rinehart, and Winston Inc. 2007, 467)

Three of the textbooks identified the last 100 years – specifically the late 1800s – as the period in which the amount of carbon dioxide has significantly increased in the atmosphere, causing a rise in Earth's temperature. Consider example 21:

> 21. The amount of carbon dioxide in the atmosphere has increased by 30 percent since the 1800s. Also, Earth's average surface temperature has increased 0.6 to 1.2 degrees Fahrenheit over that same time period. (CPO Science 2007, 308)

Although all textbooks described the connection between an increase in the amount of CO_2 in the atmosphere and a rise in temperature, these materials varied greatly in how specific they were in linking this increase to human actions. For instance, in example 22 the nominalization 'the increase' hides the actors that are obviously responsible for the burning of fossil fuels:

> 22. Most evidence indicates that the increase in carbon dioxide is caused by the burning of fossil fuels that releases carbon dioxide into the atmosphere. (Holt, Rinehart, and Winston Inc. 2007, 470)

Similarly, two other publishers used the nominal group human activities but did not mention specific human actors as can be seen in example 23. Example 23 also expresses the supposed uncertainty of scientific knowledge about the human effects on climate change using the modal verb *may*:

> 23. But recently, scientists have observed climate changes that may be the result of human activities. (Prentice Hall 2008, 375)

Regarding what humans can do to remediate the effects of climate change, only two publishers listed a set of specific actions, as example 24 shows:

> 24. Using public transportation, using less electricity (turn out the lights!), and driving hybrid vehicles can all help reduce carbon dioxide levels. (CPO Science 2007, 308)

However, the language used to list the actions humans can do to mitigate the amount of CO_2 released to the atmosphere, employed the generic nouns humans, people, individuals, industrial practices, or community projects. Not one textbook use the pronoun you to tell students what they could do to mitigate the effects of climate change.

Discussion

We systematically analyzed the clauses in all the sections about climate change in four middle school science textbooks to characterize the ways in which they represented uncertainty among the scientific community and human-causation as well as what humans can do about this phenomenon. In this section we address these topics in light of the possible implications for student understanding from using these texts in their science classes.

How uncertainty was represented in textbooks

While uncertainty is an inherent part of science, the degree of certainty among climate scientists is much greater than the certainty perceived by the public. In the media, uncertainty has been used to downplay the seriousness of, even the existence of climate change, sowing doubt within the public (Boykoff and Boykoff 2007; Oreskes and Conway 2011). This uncertainty plays a part in hindering decision-making and action-taking (Fortner et al. 2000). So, how was uncertainty discussed in the school-based text, and, what could we hypothesize might be the implications for student readers?

By using modal verbs such as could, may, or might, the causes of climate change were shrouded in uncertainty in the texts we analyzed. Specifically, the human contribution to climate change was presented as a possibility rather than a certainty. While there is uncertainty about the predictions and future forecasts of effects, there is little doubt about the causes of current climate change. As the IPCC (2013) indicates, human actions are responsible for climate change and have outstripped the natural sources of warming since the mid-twentieth century. This conclusion is drawn from multiple scientific studies and has a high degree of certainty (greater than 95%). Therefore, the representation of uncertainty about human-caused climate change within the science textbooks is scientifically inaccurate.

Likewise, the effects of climate change were cast in doubt by the use of modal verbs as can be seen in the following example that uses the modal verbs *could*, *would*, and *might* to describe the possible effects of this phenomenon:

> 25. Global warming could have some positive effects. Farmers in some areas that are now cool could plant two crops a year instead of one. Places that are too cold for farming today could become farmland. However, many effects of global warming are likely to be less positive. Higher temperatures would cause water to evaporate from exposed soil, such as plowed farmland. Dry soil blows away easily. Thus, some fertile fields might become 'dust bowls'. (Prentice Hall 2008, 377)

It is worth pointing out that in example 25 not only the potential negative effects were presented as uncertain, but also this description of possible effects of global warming began with a discussion of the potential 'positive' effects of this phenomenon. Moreover, when the negative effects are discussed, these effects are not called 'negative' but 'less positive.' Unfortunately, the presentation of positive effects of global warming could reduce the sense of urgency for students to do something about this phenomenon and even create in them a view that global warming is a phenomenon that is beneficial to human beings.

There is some variation in climate models being used to make predictions about future effects. Thus, the careful couching used in the language choices to describe future effects may be more justifiable than was seen in the text about human attribution. However, much of the variation in the model outputs has to do with aspects of unknown human behavior. For example, the models use different scenarios to account for how much carbon dioxide continues to be emitted through human activities. At this time, we are on the worst-case emissions scenario. Considering these levels of carbon emissions, the likely range of global surface temperature increase is 1.4–2.6 °C (2.5–4.68 °F) by 2065. The IPCC report uses 'likely' to mean a greater than 66% probability of occurrence (IPCC 2013). Again, the textbook is creating a false sense of uncertainty about climate change and is scientifically inaccurate.

Scientists were included as actors in the text, however, in this case, it was often used to instill doubt and controversy by including unquantifiable determiners such as the expression 'not all scientists' cited in text example 19. While this statement is technically true, the degree of scientific agreement about climate change is high. Only 3% of climate scientists are in disagreement about the anthropogenic causes of climate change (Cook et al. 2013). Furthermore, disagreement among the scientific community revolves around not whether humans affect the climate at all but rather the degree to which humans will influence future climate change. So, do the texts discuss the sources of uncertainty so that students may understand what is agreed upon, what is not, and why? Unfortunately, they do not.

When the texts described what climate scientists do, the actions the scientists were performing were not in alignment with authentic activities of science. Scientists were often said to think or believe but rarely were scientists said to be inferring from evidence or data. While it is true that scientists think, in this case it could be interpreted as counter to what scientists know or deduce from observable evidence. In common language, to think or to believe is often synonymous with holding an opinion. There was one occurrence when the noun evidence was used:

> 26. Scientists have found evidence of many major ice ages throughout Earth's geologic history. (Holt, Rinehart, and Winston Inc. 2007, 467)

The statement presented in example 26 could hardly be less contestable and was used to support the idea that climate had been changing well before humans were here and, therefore, is a naturally occurring phenomenon. Again, this language choice could instill doubt among science students about the validity of the statements made about human-caused climate change.

How agency was represented in textbooks

Who were the agents within the school-based text and what might be the implications for student readers? Primarily, the text emphasized abstractions as agents, such as climate change, atmosphere, or the burning of wood. The use of abstractions is not uncommon in science text, and they have been used in the discipline to help distill complex processes so that scientists can build theories and arguments (Halliday 1994). However, for students of science, this distillation and abstraction could be problematic because the human agents responsible for the increase in the amount of CO_2, for example, are not explicitly listed. When human actions were explicitly referenced – such as the burning of fossil fuels – students may still be left wondering who is doing this burning? Most likely, students do not know if they directly take part in such activities, especially if they do not make the connection between electricity production and transportation to the burning of fossil fuels.

When human agents were represented, the most common actors were scientists. The use of the noun scientists is positive because it helps students to connect science to the people who do it, establishing that science is a human endeavor. However, if the main actors are scientists, then this could create the perception that this is only a scientific problem to be solved by scientists. This type of language use is called technocratic discourse, and it could be disempowering for students (Halliday and Martin 1993). The technocratic discourse sends the message: This is too hard for you to understand, so it is better to leave the decisions to us, the scientific experts. On the other hand, if other sections of the textbook do not identify scientists as

carrying out scientific activities (e.g.: developing competing theories, collecting data), the human element introduced by the use of the noun scientists in the discussion of climate change could be perceived as adding uncertainty or subjectivity vis-à-vis the final-form science discourse that seems to characterize the language of science textbooks.

Lastly, no textbook contained a call to action explicitly linking student ability or need to take mitigating actions. One of the barriers to taking action is not knowing the appropriate actions to take (Hines, Hungerford, and Tomera 1986). Boyes, Chuckran, and Stanisstreet (1993) have shown that students often do not know which actions would lead to mitigation of climate change. If students are not getting this information from their schools, then they may have scant opportunity to learn what they can do.

Conclusion and recommendations

Taken together, the frames found within the textbooks more closely match the public discourse of doubt about climate change rather than the scientific discourse. The message was that climate change is possibly happening, that humans may or may not be causing it, and that we do not need to take immediate mitigating action. The same message that was identified in the book *Merchants of Doubt* as being used within the misinformation campaign waged against climate science (Oreskes and Conway 2011) has made its way into school science textbooks. We find this to be problematic not only for students but also for science education. The primary purpose of science education is to represent the science accurately, but this analysis shows this not to be the case for climate science.

Although the findings of this study may not apply to all science textbooks, this intensive analysis does suggest problems within texts that reach a large number of students – states with large student populations such as California and Texas represent a major percentage of the American textbook market (Bianchini and Kelly 2003), and thus, disproportionally influence the content of textbooks used across the United States. As the Next Generation Science Standards (NGSS Lead States 2013) become adopted and implemented, publishers will be writing new textbooks that include climate change. This reworking of science textbooks provides a rare opportunity to reflect on how we can create texts that enhance science teaching and learning. Based on the results of this analysis, there must be a definitive effort to improve the text about climate change so it reflects scientifically accurate portrayals of uncertainty and includes specific agents. By doing so, we could foster the type of science student who can effectively meet the environmental challenges they will undoubtedly face. We specifically recommend not stripping uncertainty out of the science text, but clarifying what exactly is unknown and why (Osborne et al. 2003). The current science topic of climate change offers a rich context for this explicit teaching to occur.

Additionally, we recommend the inclusion of humans as agents and as the cause of climate change. This is scientifically supported and not controversial within the science community. However, what may be more of a stretch would be to include people, in this case with specific reference to teenage individuals, as a part of the solution to climate change. What can teenagers do in their everyday lives to reduce their personal contribution to carbon emissions? We should look to research about teenage action-taking to craft messaging that will resonate with them and have the

largest effect on carbon emission reductions. Research in England and in Australia conducted by Skamp, Boyes, and Stanisstreet (2013) suggests that the actions to focus on for youth are: eating less meat, using renewables, and eating fertilizer-free food.

The creation of textbooks is a slow process, and once adopted, textbooks tend to stay in classrooms long after their contents are proven inaccurate. Therefore, another implication from this research is to create professional development to show teachers how to read and engage with texts like these. Likewise, teachers must teach their students to read and decipher scientific texts. In texts about climate change, teachers must go beyond the literal reading of the material and engage in interpretation and application (Wellington and Osborne 2001). Certainly, textbooks are not the only sources of information youth will encounter that will shape their attitudes about climate change, but it is our hope that this study will also highlight the larger issues of language choices for climate communication.

Climate change is an issue that will affect young people's lives profoundly. School science classes offer a unique and important opportunity to inform youth about this environmental problem. Accurate accounts of the sources and degree of uncertainty should be a part of all school topics, but perhaps because of the misrepresentation of scientific uncertainty in the media, may be much more important for textbook language about climate change. Texts must be explicit about the agents – the actors – in both the causes and the solutions of climate change. By doing so, texts can help empower science students to take on the challenge of mitigating and adapting to their changing world.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Artstein, R., and M. Poesio. 2008. "Inter-Coder Agreement for Computational Linguistics." *Computational Linguistics* 34 (4): 555–596.

Bamberg, S., and G. Möser. 2007. "Twenty Years after Hines, Hungerford, and Tomera: A New Meta-Analysis of Psycho-Social Determinants of Pro-Environmental Behaviour." *Journal of Environmental Psychology* 27 (1): 14–25.

Bianchini, J. A., and G. J. Kelly. 2003. "Challenges of Standards-Based Reform: The Example of California's Science Content Standards and Textbook Adoption Process." *Science Education* 87 (3): 378–389.

Boyes, E., D. Chuckran, and M. Stanisstreet. 1993. "How Do High School Students Perceive Global Climatic Change: What Are Its Manifestations? What Are Its Origins? What Corrective Action Can Be Taken?" *Journal of Science Education and Technology* 2 (4): 541–557.

Boyes, E. D., M. Stanisstreet. 1992. "Students' Perceptions of Global Warming." *International Journal of Environmental Studies* 42 (4): 287–300.

Boykoff, M. T. 2007. "From Convergence to Contention: United States Mass Media Representations of Anthropogenic Climate Change Science." *Transactions of the Institute of British Geographers* 32 (4): 477–489. doi:10.1111/j.1475-5661.2007.00270.x.

Boykoff, M. T., and M. J. Boykoff. 2007. "Climate Change and Journalistic Norms: A Case-Study of US Mass-Media Coverage." *Geoforum* 38 (6): 1190–1204. doi:10.1016/j.geoforum.2007.01.008.

Bryce, N. 2011. "Meeting the Reading Challenges of Science Textbooks in the Primary Grades." *The Reading Teacher* 64 (7): 474–485.

Budescu, D. V., H. Por, S. Broomell, and M. Smithson. 2014. "The Interpretation of IPCC Probabilistic Statements around the World." *Nature Climate Change* 4 (6): 508–512.
Busch, K. C. 2015. "Polar Bears or People? Exploring Ways in Which Teachers Frame Climate Change in the Classroom." *International Journal of Science Education, Part B*: 1–29. doi:10.1080/21548455.2015.1027320
Butler, F., C. Lord, R. Stevens, M. Borrego, and A. Bailey. 2004. *An Approach to Operationalizing Academic Language for Language Test Development Purposes: Evidence from Fifth-Grade Science and Math* (CSE Technical Report No. 626). Los Angeles: University of California, National Center for Research in Evaluation, Standards, and Student Testing (CRESST).
California State Board of Education. 1998. *Science Content Standards for California Public Schools*. http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf.
Chenhansa, S., and M. Schleppegrell. 1998. "Linguistic Features of Middle School Environmental Education Texts." *Environmental Education Research* 4 (1): 53–66.
Choi, Soyoung, D. Niyogi, D. P. Shepardson, and U. Charusombat. 2010. "Do Earth and Environmental Science Textbooks Promote Middle and High School Students' Conceptual Development about Climate Change? Textbooks' Consideration of Students' Misconceptions." *Bulletin of the American Meteorological Society* 91 (7): 889–898.
Cook, J., D. Nuccitelli, S. A. Green, M. Richardson, B. Winkler, R. Painting, R. Way, P. Jacobs, and A. Skuce. 2013. "Quantifying the Consensus on Anthropogenic Global Warming in the Scientific Literature." *Environmental Research Letters* 8 (2): 024024. doi:10.1088/1748-9326/8/2/024024.
CPO Science. 2007. *Focus on Earth Science*. California ed. Cambridge, MA: Cambridge Physics Outlet.
DiGiuseppe, M. 2014. "Representing Nature of Science in a Science Textbook: Exploring Author–Editor–Publisher Interactions." *International Journal of Science Education* 36 (7): 1061–1082.
Ding, D., E. W. Maibach, X. Zhao, C. Roser-Renouf, and A. Leiserowitz. 2011. "Support for Climate Policy and Societal Action Are Linked to Perceptions about Scientific Agreement." *Nature Climate Change* 1 (9): 462–466.
Drew, D. E. 2011. *STEM the Tide: Reforming Science, Technology, Engineering, and Math Education in America*. Baltimore, MD: Johns Hopkins University Press.
Dryzek, J. S. 2013. *The Politics of the Earth: Environmental Discourses*. Oxford: Oxford University Press.
Dupigny-Giroux, L.-A. L. 2010. "Exploring the Challenges of Climate Science Literacy: Lessons from Students, Teachers and Lifelong Learners." *Geography Compass* 4 (9): 1203–1217. doi:10.1111/j.1749-8198.2010.00368.x.
Eggins, S. 2007. *An Introduction to Systemic Functional Linguistics*. 2nd ed. New York: Continuum.
Fang, Z., and M. J. Schleppegrell. 2008. *Reading in Secondary Content Areas: A Language-Based Pedagogy.* Ann Arbor: University of Michigan Press.
Fang, Z., and M. J. Schleppegrell. 2010. "Disciplinary Literacies across Content Areas: Supporting Secondary Reading through Functional Language Analysis." *Journal of Adolescent & Adult Literacy* 53 (7): 587–597.
Fang, Z., M. J. Schleppegrell, and B. Cox. 2006. "Understanding the Language Demands of Schooling: Nouns in Academic Registers." *Journal of Literacy Research* 38 (3): 247–273.
Feldman, Lauren, Edward W. Maibach, Connie Roser-Renouf, and Anthony Leiserowitz. 2012. "Climate on Cable: The Nature and Impact of Global Warming Coverage on Fox News, CNN, and MSNBC." *The International Journal of Press/Politics* 17 (1): 3–31. doi:10.1177/1940161211425410.
Fortner, R. W., J. Y. Lee, J. R. Corney, S. Romanello, J. Bonnell, B. Luthy, C. Figuerido, and N. Ntsiko. 2000. "Public Understanding of Climate Change: Certainty and Willingness to Act." *Environmental Education Research* 6 (2): 127–141. doi:10.1080/713664673.
Gamson, D., X. Lu, and S. Eckert. 2013. "Challenging the Research Base of the Common Core State Standards: A Historical Reanalysis of Text Complexity." *Educational Researcher* 42 (7): 381–391. doi:10.30102/0013189X13505684.

Gibbs, A., and A. Lawson. 1992. "The Nature of Scientific Thinking as Reflected by the Work of Biologists & by Biology Textbooks." *The American Biology Teacher* 54 (3): 137–152.
Glencoe-McGraw-Hill. 2007. *Focus on Earth Science*. California ed. Columbus, OH: Glencoe-McGraw-Hill.
Halliday, M. A. K. 1994. *Functional Grammar*. London: Arnold.
Halliday, M. A. K., and J. Martin. 1993. *Writing Science: Literacy and Discursive Power*. Pittsburgh, PA: University of Pittsburgh Press.
Hayden, M. 2011. "Pedagogies of Empowerment in the Face of Climate Change Uncertainty." *Journal for Activist Science and Technology Education* 3 (1): 118–130.
Hines, J. M., H. R. Hungerford, and A. N. Tomera. 1986. "Analysis and Synthesis of Research on Responsible Pro-Environmental Behavior: A Meta-Analysis." *The Journal of Environmental Education* 18 (2): 1–8.
Hoffman, M., and D. Barstow. 2007. *Revolutionizing Earth System Science Education for the 21st Century: Report and Recommendations from a 50-State Analysis of Earth Science Education Standards*. Cambridge, MA: TERC.
Holt, Rinehart, and Winston Inc. 2007. *Earth Science*. California ed. New York: Houghton Mifflin Harcourt Publishing Company.
IPCC. 2013. *Climate Change 2013: The Physical Science Basis*. New York: Cambridge University Press.
Jeffries, H., M. Stanisstreet, and E. Boyes. 2011. "Knowledge about the "greenhouse effect": Have college students improved?." *Research in Science & Technological Education* 19 (2): 205–221. http://doi.org/10.1080/02635140120087731
Kahan, D. M., H. Jenkins-Smith, and D. Braman. 2011. "Cultural Cognition of Scientific Consensus." *Journal of Risk Research* 14 (2): 147–174.
Kesidou, S., and J. E. Roseman. 2002. "How Well Do Middle School Science Programs Measure Up? Findings from Project 2061's Curriculum Review." *Journal of Research in Science Teaching* 39 (6): 522–549.
Kloser, M. 2013. "Exploring High School Biology Students' Engagement with More and Less Epistemologically Considerate Texts." *Journal of Research in Science Teaching* 50 (10): 1232–1257.
de Kwaadsteniet, E. W., E. van Dijk, A. Wit, D. De Cremer, and M. de Rooij. 2007. "Justifying Decisions in Social Dilemmas: Justification Pressures and Tacit Coordination under Environmental Uncertainty." *Personality and Social Psychology Bulletin* 33 (12): 1648–1660.
Lederman, N. G., and M. O'Malley. 1990. "Students' Perceptions of Tentativeness in Science: Development, Use, and Sources of Change." *Science Education* 74 (2): 225–239. doi:10.1002/sce.3730740207.
Lee, Tien Ming, Ezra M. Markowitz, Peter D. Howe, Chia-Ying Ko, and Anthony A. Leiserowitz. 2015. "Predictors of Public Climate Change Awareness and Risk Perception around the World." *Nature Climate Change*. doi:10.1038/nclimate2728.
Lee, O., H. Quinn, and G. Valdés. 2013. "Science and Language for English Language Learners in Relation to Next Generation Science Standards and with Implications for Common Core State Standards for English Language Arts and Mathematics." *Educational Researcher* 42 (4): 223–233.
Leiserowitz, A., N. Smith, and J. Marlon. 2010. *Americans' Knowledge of Climate Change*. New Haven, CT: Yale Project on Climate Change Knowledge. http://environment.yale.edu/climate/files/ClimateChangeKnowledge2010.pdf.
Leiserowitz, A., N. Smith, and J. Marlon. 2011. *American Teens' Knowledge of Climate Change*. New Haven, CT: Yale Project on Climate Change Knowledge.
Lemke, J. L. 1990. *Talking Science: Language Learning, and Values*. New York: Ablex.
Malka, A., J. Krosnick, M. Debell, J. Pasek, and D. Schneider. 2009. "Featuring Skeptics in News Media Stories about Global Warming Reduces Public Beliefs in the Seriousness of Global Warming." (Technical Paper). Woods Institute for the Environment, Stanford University. http://woods.stanford.edu/research/global-warming-skeptics.
Malka, A., J. Krosnick, and G. Langer. 2009. "The Association of Knowledge with Concern about Global Warming: Trusted Information Sources Shape Public Thinking." *Risk Analysis* 29 (5): 633–647. doi:10.1111/j.1539-6924.2009.01220.x.

McCright, A. M., R. E. Dunlap, and C. Xiao. 2013. "Perceived Scientific Agreement and Support for Government Action on Climate Change in the USA." *Climatic Change* 119 (2): 511–518.
Moje, E. 2008. "Foregrounding the Disciplines in Secondary Literacy Teaching and Learning: A Call for Change." *Journal of Adolescent & Adult Literacy* 52 (2): 96–107.
Montgomery, S. 1995. *The Scientific Voice*. New York: Guilford Press.
Möser, S. C. 2010. "Communicating Climate Change: History, Challenges, Process and Future Directions." *Wiley Interdisciplinary Reviews: Climate Change* 1: 31–53. doi:10.1002/wcc.011.
Möser, S., and L. Dilling. 2011. "Communicating Climate Change: Closing the Science-Action Gap." In *The Oxford Handbook of Climate Change and Society*, edited by J. Dryzek, R. Norgaard, and D. D. Schlosberg, 161–174. Oxford: Oxford University Press.
Moss, G. 2006. "Textbook Language, Teacher Mediation, Classroom Interaction and Learning Processes: The Case of Natural and Social Science Textbooks in Barranquilla, Colombia." *Proceedings of the 33rd International Systemic Functional Congress*, Sao Paulo.
National Research Council. 1990. *Fulfilling the Promise: Biology Education in the Nation's Schools*. Washington, DC: National Academies Press.
NGSS Lead States. 2013. *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.
Nisbet, M. C., and D. Scheufele. 2009. "What's Next for Science Communication? Promising Directions and Lingering Distractions." *American Journal of Botany* 96 (10): 1767–1778. http://www.amjbot.org/cgi/doi/10.3732/ajb.0900041.
Norris, S., and L. Phillips. 2003. "How Literacy in Its Fundamental Sense is Central to Scientific Literacy." *Science Education* 87 (2): 224–240.
Oreskes, Naomi, and Erik M. Conway. 2011. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York: Bloomsbury Publishing.
Osborne, J. F., S. Collins, M. Ratcliffe, R. Millar, and R. A. Duschl. 2003. "What 'ideas-about-science' Should Be Taught in School Science? A Delphi Study of the Expert Community." *Journal of Research in Science Teaching* 40 (7): 692–720. doi:10.1002/tea.10105.
Pew Research Center. 2015. *Public and Scientists' Views on Science and Society*. http://www.pewinternet.org/2015/02/15/how-scientists-engage-public/.
Prentice Hall. 2008. *Focus on Earth Science*. California ed. Upper Saddle River, NJ: Pearson Prentice Hall.
Scheufele, D. A. 1999. "Framing as a Theory of Media Effects." *Journal of Communication* 49 (1): 103–122.
Schleppegrell, M. J. 2004. *The Language of Schooling: A Functional Linguistics Perspective*. Mahwah, NJ: Erlbaum.
Shanahan, T., and C. Shanahan. 2008. "Teaching Disciplinary Literacy to Adolescents: Rethinking Content-Area Literacy." *Harvard Educational Review* 78 (1): 40–59.
Shepardson, D. P., D. Niyogi, and U. Charusombat. 2011. "Students' Conceptions about the Greenhouse Effect, Global Warming, and Climate Change." *Climatic Change* 104 (3–4): 481–507. doi:10.1007/s10584-009-9786-9.
Skamp, K., E. Boyes, and M. Stanisstreet. 2013. "Beliefs and Willingness to Act about Global Warming: Where to Focus Science Pedagogy?" *Science Education* 97: 191–217. doi:10.1002/sce.21050.
Slough, S. W., and E. M. McTigue. 2010. "Introduction to the Integration of Verbal and Visual Information in Science Texts." *Reading Psychology* 31 (3): 206–212.
Slough, S. W., E. M. McTigue, S. Kim, and S. K. Jennings. 2010. "Science Textbooks' Use of Graphical Representation: A Descriptive Analysis of Four Sixth Grade Science Texts." *Reading Psychology* 31 (3): 301–325.
Smolkin, L., E. M. McTigue, and Y. Yeh. 2011. "Searching for Explanations in Science Trade Books: What Can We Learn from Coh-Metrix?" *International Journal of Science Education* 35 (8): 1367–1384.

Snow, C. 2008. "What is the Vocabulary of Science?" In *Teaching Science to English Language Learners*, edited by A. Rosebery and B. Warren, 71–83. Arlington, VA: NSTA Press.

Stanisstreet, M., and E. Boyes. 1996. "Young People's Ideas about Global Environmental Issues." In *Environmental Issues in Education*, edited by G. Harris and C. Blackwell, 37–52. Cambridge: Cambridge University Press.

Weiss, I. R., J. D. Pasley, P. S. Smith, E. R. Banilower, and D. J. Heck. 2003. *Looking inside the Classroom: A Study of K-12 Mathematics and Science Education in the United States*. Chapel Hill, NC: Horizon Research.

Wellington, J., and J. Osborne. 2001. *Language and Literacy in Science Education*. Glasgow: Open University Press.

Yore, L. D. 2012. "Science Literacy for All: More than a Slogan, Logo, or Rally Flag!" In *Issues and Challenges in Science Education Research*, edited by K. Tan and M. Kim, 5–23. New York: Springer.