The Potential of Graphic Nonfiction for Teaching and Learning Earth Science

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Our comparative analysis demonstrates the utility of graphic nonfiction for teaching and learning scientific concepts. This study supports including graphic nonfiction along with other types of trade books as a supplement to textbooks in a multiple-text approach that allows for constructing knowledge through a cross-text comparison. Graphic nonfiction, through its visuals and conversational style, can assist in deepening understandings of content concepts and serve as an appropriate resource for science instruction, research, and enrichment.

Although researchers have identified the importance of investigating alternative texts for content instruction (Alvermann, Moon, & Hagood, 1999), relatively few studies (e.g., Guzzetti, 2009; Tatalovic, 2009) have addressed the utility of graphic nonfiction for teaching and learning in secondary science classrooms. Yet, adolescents typically find these popular culture texts in comic format more appealing than academic texts, particularly for science instruction (Tatalovic, 2009). Youth enjoy their attractive art and intriguing narratives which can be both humorous and educational (Tatalovic, 2010).

Science literacy researchers and professional organizations have suggested that alternative texts supplement textbooks. These texts can provide multiple perspectives (Stahl & Shanahan, 2004); facilitate students' knowledge constructions through cross-text comparisons (Spoer & Spoer, 1994); and foster conceptual understanding (Spiro, Coulson, Feltovich & Anderson, 2004). In addition, science trade books can provide constructed knowledge, vicarious experiences of science processes, positive attitudes toward science, and increased levels of literacy (Daisey, 1994). The National Science Teachers Association website noted that "trade books have the potential to enrich and inspire" (http://www.nsta.org/publications/ostb/ostb2013.aspx).

In considering alternative texts for content instruction, graphic nonfiction trade books have been under-used and under-researched, however. Yet, these hybrid texts may motivate adolescents as they provide the best of art, journalism, and scholarship (Butler, 2011). Graphic nonfiction promotes multimodal learning and facilitates understanding through a combination of words and images (Buckingham, 2003).

Exactly how graphic nonfiction's treatment of a science topic compares to a textbook's presentation has yet to be explored, however. Because much of the research on alternative texts for science instruction has been done at the elementary level (Madrazo, 1997; Rice, 2002) or with other forms of trade books, such as graphic fiction (Guzzetti & Mardis, 2011) or nongraphic nonfiction (Farland, 2006; Ford, 2006), it is unclear if and how graphic nonfiction could support the curriculum and be useful for teaching science concepts commonly taught in high schools. It is also unclear if there is any common ground among the various titles of these alternative texts in

presenting a scientific concept. Therefore, researchers have called for investigations of the utility of graphic nonfiction for teaching and learning science (Crowson & Hopper, 2009).

Purpose

This study aimed to determine the utility of graphic nonfiction as alternative texts for addressing concepts in earth science. Our goal was to describe and analyze the benefits and limitations of each type of text as instructional support in teaching a common topic in secondary science. We asked: What concepts are presented in graphic nonfiction that support teaching and learning about climate and climate change, topics addressed in secondary earth science classes? How do the range and frequency of concepts, visuals, reading aids, and supplemental features in graphic nonfiction texts compare to the presentation of climate concepts, visuals, and supporting features in a textbook?

Theoretical Frame

The New Literacies (Gee, 2003; Lankshear & Knobel, 2006) that expands the definition of text to include visual images informed this study. These new literacies include multiple forms of textual representations, such as graphics, pictures, and visuals and include both print and digital forms of text (Cope & Kalantzis, 2000). Meaning making is made in multimodal ways, including written linguistic modes, as well as visual, audio, and spatial ways.

Visual literacy is a core learning skill increasingly needed in the 21st century and is foundational to content areas (Mitchell, 1995). Visual representations can be used to create and represent knowledge. Including visuals with words can mean the difference between telling and showing. Images are a medium distinct from print that communicate differently than words (Mitchell, 1995). Linguistic and visual literacies interact and complement each other. For members of a visual generation in which much is communicated in visual form, promoting visual literacy is consistent with current forms of communication (Sibanda & Sibanda, 2013).

This theoretical framework provided us with the broadest definition of text, allowing us to consider graphic nonfiction and narrative or expository nonfiction, including the visuals, as texts to be read in conveying meaning. This perspective also facilitated our examination of the texts' supporting websites and their visuals and features as conveyers of concepts in new textual forms.

Methods

Data Collection

We selected three texts for analysis due to their relevancy to the science topic. Since graphic nonfiction is a relatively new genre, we chose the only two widely available and current graphic nonfiction titles (as noted by their Library of Congress classifications) relating to climate change, *Understanding Global Warming* (Biskup, 2008) and *Weird Weather* (Evans, 2007). We also selected a textbook for earth science that is currently being used in secondary schools in the Southwestern United States for earth science instruction, *Earth Science* (Spaulding & Namowitz, 2005).

Data Analysis

We identified and examined the content terms/concepts regarding climate and climate change in these texts because vocabulary terms represent concepts (Alvermann, Phelps, & Gillis, 2010). We analyzed the vocabulary in these three texts through matrix analysis (Miles & Huberman, 2013). The first author initially identified and listed the content terms in each of these three texts; these terms were crossed checked for duplicates and/or missing terms and revised by the second author. Content terms were classified deductively into categories of analysis identified from our prior work on science concepts in graphic nonfiction and fiction (Guzzetti & Mardis, 2011) and from the

theoretical frame, as well as inductively based on new categories emerging from the data. Terms were tallied within these categories and frequency percentages were calculated within categories. The two coders conducted an analysis of discordance, reaching a 98% level of agreement.

We also analyzed the supplemental features, such as bibliographies for further reading and lists of other related websites; the visuals, such as photographs and satellite images; and the reading aids, such as advance organizers and pre-reading and post-reading questions embedded in the texts. We identified, categorized, and tallied these special features within each text. We also visited the three texts' supporting websites and examined their supplemental features, visuals, and concepts.

Finally, we conducted a cross-text analysis. This analysis enabled us to obtain a comparative overview of each text's conceptual load and range and determine how they conveyed concepts and supported learning. Supplemental features, visuals, reading aids, and concepts/terms in the two graphic nonfiction texts and their supporting websites were compared by type and/or frequency of occurrence to those in the textbook and its supporting website.

Findings

The Textbook's Treatment of Climate and Climate Change

The textbook, *Earth Science*, (Spaulding & Namowitz, 2005) was authored by two former earth-science teachers. This textbook devoted one 18-page chapter, "Climate and Climate Change", to changing weather patterns on a local and global scale.

Organization. The chapter was organized into three sections: Climate, Climate Zones, and Climate Change, all written as expository text. Each section had similar supplemental features, included visuals, and contained reading aides.

Supplemental Features. The textbook provided several types of supplemental features. These included embedded readings, such as a section on "Science and Society" describing El Niño, a chain reaction from weakening trade winds that causes erratic weather around the world. A subsection on climate controls included a "Summary Table" explaining how climate controls of latitude, elevation, nearby water, ocean currents, topography, prevailing winds, and vegetation impacted temperature and precipitation. Two key terms, "climate" and "climate controls," were highlighted in bold-face type. A sidebar, "Key Ideas" provided the definition of this climate and alerted students to two "Key Vocabulary" terms - climate and climate controls. A 25-minute mini lab on classroom microclimate directed students to take measurements with thermometers at different points inside their classroom to look for temperature variations.

Reading Aids. Multiple reading aids in the textbook served as guides for students' reading, reflecting content literacy strategies. For example, organizing statements were used as chapter previews or advance organizers, such as the statement, "climate is controlled by many factors, including elevation, latitude, topography and vegetation" (p. 21), four concepts/terms that related to climate controls. This page also included a query requiring students to compare and contrast, providing a pre-reading purpose for students' reading: "Why is the climate in the plains of southern Nepal so different from the climate in the mountains of northern Nepal?" (p. 21). The "Preview" page that followed included three additional pre-reading "Focus Questions" of literal recall to guide students' reading by asking students to read to define climate, list the factors that affect it, name the characteristics of climate, and identify the causes. The chapter's reading aids included other pre-reading and reading guides, such as a pre-reading title question, "What is Climate?" Two sidebars, called "Science Notebook", consisted of two critical thinking questions: "Are there any drawbacks to telling people that extreme weather is on the way?" and an

evaluative question asking students to determine if volcanism or plate tectonics has a greater effect on climate.

These reading aids were complimented by comprehension review activities, including "Review Topics" from prior chapters, such as "plate tectonics"; "heat budget"; "global warming"; and "temperature variations" and the page numbers in the textbook where those terms had been previously discussed. A "Reading Strategy" directed students to connect what they learned as they read to the climates in which they lived as an "Extension Activity." Students were also asked to complete a concept map on volcanoes' ejections as a "Graphic Organizer." The chapter also included four post -reading or section-review questions, two of which were recall and two of which required inferences. The chapter also included vocabulary and comprehension reviews, including, "A Summary of Key Ideas"; a "Vocabulary Review"; a "Concept Review"; a "Critical Thinking" section of questions and activities (e.g., "compare and contrast marine climates and continental climates"); and an "Interpreting Maps" activity on climate and latitude.

Visuals. At least one visual or graphic was included on every page of the chapter. These consisted of 15 color or black and white photographs (e.g., photos of weather buoys, rainforests, deserts, and ice fjords) that typically showed examples of concepts introduced in the expository text. Five illustrations (e.g., continents' and cities' locations on globes) elaborated on concepts. Three graphs (i.e., global temperature change from 1880-2000, Antarctic temperature for the past 420,000 years, and climate and latitude) traced climate change. One satellite image showed weather associated with high and low pressure systems. These visuals typically provided additional supporting information or provided illustrated examples of the concepts in the text.

Additional visuals were provided on the textbook's website to support the chapter. One of these two visuals was an interactive graphic - a map of the earth with strategically placed dots; clicking on the dots revealed photographs depicting the region's climate zone, emphasizing the concept that climate changes with geographical location. These were not frequent or customizable, however, so that students were typically not able to see photos of climate indicators (such as deserts or tundra) in their own locations. The other visual consisted of a caption, "How Nature Records Climate Change" with photographs of coral growth buds, tree rings, and ice layers, allowing students to recognize examples of indicators of climate change.

Website. At six strategic points throughout the chapter, readers were directed to the publisher's website, ClassZone.com (www.classzone.com) for interactive activities. Students were asked to use maps and local weather data to answer questions like, "What factors control your local climate?" (p. 467). Students were provided with a key code to enter on the website for these Investigation and Extension activities.

Internet Resources were also provided on the publisher's website. These were links to local resources, earth news, visualizations of climate zones, and climate change records. These supplements included information about and photographs of glaciers and ice cores, a graph showing warming trends over the past 165,000 years, and included interactive activities using data to plot and track earth's warming trends and increases in carbon dioxide.

Content Vocabulary/Concepts. As can be seen in Table 1, the textbook chapter included 95 content terms in 12 categories. These 12 categories (in order of frequency) were: climate influences; climate products; climate sub-zones; climate zones; climate measures; climate characteristics; climate controls; climate conditions; weather patterns; climate monitors; climate personnel; and climate regions. The largest category of terms was climate influences (19%) followed by climate products (17%) and climate sub-climates (12%). Together, these three categories accounted for about one half of the terms/concepts in the chapter. The next largest category was climate measures (11%). climate characteristics (9%), climate controls (8%), and climate zones (8%) accounted for the remaining terms.

Table 1. Vocabulary from *Earth Science*: Chapter 21 Climate (Spaulding & Namowitz, 2005)

Category	Term or Concept
Weather Patterns (n=3)	Climate; monsoons; El Niño
Climate Monitors (n=2)	Tai/Triton Array; Topex/Poseidon Satellite
Climate Professionals (n=2)	Meterologist; climatologist
Subclimates (n=11)	Tundra; ice cap; desert; semi-arid; tropical wet; tropical wet and dry; humid subtropical; marine west coast; Mediterranean Zone (ITCZ); humid continental; subarctic
Climate Zones (n=8)	Marine; polar; dry; humid/tropical; continental; highlands; midlatitude; intertropical convergence
Climate Measures (n=10)	Sea floor sediments; micro-organisms; tree growth rings; oxygen isotope analysis; fossils; pollen; corals; stalagtites; sand dunes; glacial sediments samples
Climate Conditions (n=6)	Local climate; global climate; climate change; global warming; global cooling; greenhouse effect
Climate Products (n=16)	Solar radiation; fog; ice cores; glaciers; floods; drought; sea levels; humidity; water vapor; frost; snow; thunderstorms; carbon dioxide; greenhouse gases; sulfur dioxide; glaciation
Climate Influences (n=19)	Leeward side; windward side; Horse Latitudes; poles; evaporation; earth motion; plate tectonics; sunspots; volcanoes; volcanic ash/gases; pollution; heat budget; solar radiation; deforestation; geosphere; hydrosphere; biosphere; stratosphere; troposphere
Climate Regions (n=2)	Rainforests; savannahs

Note. Categories and terms appear in the order in which they were identified in the text.

Most of the concepts in this chapter centered on climate influences, climate products, climate zones and sub-zones, and climate measures. The largest category of terms discussed climate influences, such as plate tectonics, volcanoes, sunspots, pollution, leeward and windward sides of mountains, solar radiation, deforestation, and the heat budget. Climate products included fog, humidity, water vapor, frost, ice cores, snow, and glaciers. Eight types of climate zones – marine, polar, dry, tropical, continental, highlands, mid-latitude, and inter-tropical convergence zones were discussed as were 11 climate sub-zones, including tundra, semi-arid, Mediterranean, sub-Artic, and humid subtropical. Climate measures included sea floor sediments, tree-growth rings, fossils, pollen, and isotope analysis.

The textbook paid little attention to climate personnel or climate monitoring systems and the weather patterns they assess, however. Only two terms were related to climate personnel (climatologist and meteorologist) or climate monitors (TAI Triton Array and Topex/Poseidon Satellite). Only three terms related to weather patterns (climate, monsoons, and El Nino).

Most content terms were explicitly defined. These included such terms as "savannas" ("grasslands with occasional trees" p. 472) and the "Intertropical Convergence Zone" ("where winds from the northern and southern hemispheres converge and hot, humid air rises, causing large amounts of precipitation to fall" p. 472). The meaning of other vocabulary that represented supporting details, such as "monsoon" typically could be inferred in context: "In Bombay, India, almost all of the rain falls in the four months of the summer monsoon" (p. 466).

Other key vocabulary, however, were not defined and their meanings could not be inferred from their use in the context of a sentence, such as the term "heat budget" that was introduced in the sentence, "Changes in the Earth's heat budget apparently need not be very large to trigger climate changes" (p. 474). Rather, students were required to remember from the list of terms in the

Review Topics on page 465 at the beginning of the chapter that they had been directed to refer back to pages 372-373 to review this concept. Other terms were never defined, referred back to earlier chapters, or used in a context that would allowed their meanings to be inferred, such as the term, "horse latitudes" in the Section Review sentence: "Explain why dry climates often exist on the leeward sides of mountain ranges and in the horse latitudes" (p. 473). Hence, this text required students' prior knowledge to understand key concepts.

The Super Scientist Graphic Nonfiction's Treatment of Climate and Climate Change

One of the two graphic nonfiction texts, *Understanding Global Warming with Max Axiom, Super Scientist* (Biskup, 2008), featured a superhero/super scientist as a narrator speaking in first-person voice in cartoon-strip format. Information about this character was presented at the conclusion of the text, including his physical traits, demographics, super intelligence, x-ray vision, and his abilities to travel through time and space and to shrink to the size of an atom. The back cover introduced this character:

> Meet Max Axiom, Super Scientist. Using powers he acquired in a freak accident, Max teaches science in ways never before seen in a classroom. Whether shrinking to explore an atom or riding on a sound wave Max does what it takes to make science super cool.

This character "speaks" to the reader in a mix of narrative and expository text. This narrator provides factual information in a story line as he travels from his greenhouse to a lab, a weather center, and a hospital. He dialogues with an environmental scientist, a meteorologist, and a physician, asking them questions and sharing information regarding climate change and its effects on humans and their environment.

Organization. This colorful text was divided into four chapters – "The Greenhouse Effect"; "Carbon Dioxide"; "Global Changes"; and "Looking to the Future." These 27 pages were presented in a cartoon strip format. A one and a half-page section followed these chapters, "More about Global Warming" and a half page, "More about Max Axiom." This character narrated 32 pages about climate and climate change, relating his personal experiences from inside his own greenhouse to describe the greenhouse effect. In the second section, he visited environmental scientists and had conversations with them about carbon dioxide and its effect on climate and global warming. In the third and longest section (12 pages), Max travelled around the world to illustrate the negative effects of global warming on earth's weather and climate, showing rising seal levels, shrinking glaciers, and diminishing habitats for wildlife and fauna. In the final section, the super scientist discussed solutions for environmental problems, such as wind turbines to generate electricity and alternative transportation to reduce pollution.

These sections were followed by almost two pages of additional information titled, "More about Global Warming." This section consisted of expository text providing supplemental details about major concepts. Two of these were: "The United States is responsible for more greenhouse gas pollution than any other country in the world" (p. 28) and, "Venus is the hottest planet in our solar system. Many astronomers believe its heat is due to a massive greenhouse effect" (p. 28).

Website. One of the last pages of *Understanding Global Warming with Max Axiom* directed readers to relevant websites by using the publisher's website, Facthound.com (www.facthound.com), described as "a safe, fun way to find Internet sites related to this book" (p. 31). Students were provided with a code to use on the site to select their grade level to locate age-appropriate sites and topic-related resources. Readers were directed to browse subjects by clicking on words or pictures.

Typing in the code for this book allowed site visitors to discover four other trade books on the environment and recycling. This site also listed three relevant websites on climate change. These included, *Doing Something about Global Warming*,

(http://www.alligatorboogaloo.com/kids/features/globey); *Global Warming Facts and Our Future,* (http://www.civildir.com/Environmental-Engineering/Climate-Change/Global-Warming-Facts-and-Our-Future-details-7343.html); and *What's Up with the Weather?* (http://www.pbs.org/wgbh/warming).

Visuals. The 27 pages of narrative contained eight colorful illustrations or photographs. Illustrations included drawings of four climate zones (dry, tropical, temperate, and polar) and the flora and fauna that habitat them; glaciers and melting ice sheets; and wind turbines. Two photographs - a black and white satellite image of Hurricane Katrina and a photo of crops impacted by global warming - supplemented these illustrations.

Graphs, diagrams, and a figure were also embedded within the narration. A graph illustrated the increase in carbon dioxide levels in the past 50 years. Three diagrams illustrated how the sun's rays warm the earth and how heat from the earth is radiated into space; how greenhouse gases result in more heat radiated back to earth; and how plants take up carbon dioxide and release oxygen in photosynthesis. A fourth diagram illustrated coastlines today compared to how much coastlines would shrink if Greenland's ice sheet melted. A figure listed the four greenhouse gases of water vapor, carbon dioxide, nitrous oxide, and methane.

Supplemental Features. Three notes to the reader provided supplemental information, including one about the benefits of global warming on cold regions and two that provided definitions of two terms (i.e., fossil fuels and deforestation). These five "Notes to the Reader" were embedded within the narration and were highlighted in bright red and yellow, drawing reader's attention to them.

Other supplemental features preceded and followed the narrative. A Table of Contents preceded the chapters. A sidebar in the text pointed out the positive impact of global warming on agriculture in typically cold regions, such as Canada and Russia by creating longer growing seasons. The last two pages of the book included a Glossary of 11 content terms (e.g., climate, drought, fossil fuels, ozone layer). A "Read More" bibliography of five books directed students to further reading. Readers were also directed to relevant "Internet Sites" via the publisher's website. An Index concluded the text.

Reading Aids. There were only a few content reading aids in *Understanding Global Warming*. Three content terms were defined in colorfully highlighted boxes next to the term as it was used in the narrative, such as defining fossil fuels next to the sentence, "carbon dioxide is released as we burn fossil fuels" (p. 8). Only three critical thinking questions were included; those were not directed to the reader, but were embedded in the dialogue among characters, such as Max asking a meteorologist if the world is getting warmer (p. 14) and asking a physician how higher temperatures will have an impact on human heath (p. 22).

Content Vocabulary/Concepts. As can be seen in Table 2, this graphic nonfiction included 56 content terms in 12 categories. These categories (in order of frequency) were: climate products; climate influences; climate impacts; climate conditions; climate interventions; climate zones, climate characteristics; climate personnel; climate measures; climate regions; sub-climates; and climate regions. The largest category of terms was climate products, accounting for more than one third of the vocabulary/concepts (35%). Climate impacts (13%) and climate influences (13%) accounted for about one fourth of the terms (26%), and together with climate products accounted for about two thirds (62%) of the terms in this text.

Table 2. Vocabulary from *Understanding Global Warming* (Biskup, 2008)

Category	Term or Concept
Climate Conditions (n=4)	Climate change; greenhouse effect; global warming; ice age
Climate Controls (n=1)	Ocean currents
Climate Zones (n=4)	Polar climate; tropical climate; dry climate; temperate climate
Climate Characteristics (n=2)	Average temperature; temperature
Climate Personnel (n=1)	Meterologist
Climate Products (n=19)	Nitrogen; oxygen; methane; water vapor; nitrous oxide; carbon dioxide; fossil fuels; heat wave; hurricane; drought; tropical storm; glaciers; polar ice; ice caps; ice sheet; sea levels; coastlines; arctic ice; crops
Climate Measures (n=1)	Rainfall patterns
Climate Impacts (n=7)	Species habitats; plant habitats; species adaptation; malaria; Lyme Disease; Rocky Mountain Spotted Fever; ozone layer
Climate Regions (n=1)	Rainforests
Subclimates (n=1)	Humid climate
Climate Interventions (n=5)	Solar panels; wind turbines; hydrogen engine; clean fuel; recycle
Climate Influences (n=7)	Ultraviolet rays; radiated heat; photosynthesis; deforestation; atmosphere; deforestation; chlorofluorocarbons

Note. Categories and terms appear in the order in which they were identified in the text.

Most of the terms represented concepts related to climate products, influences, and climate impacts. The largest category of terms, climate products, discussed polar ice, coastlines, sea levels, Artic ice, ice caps/ice sheets, hurricanes, glaciers, and tropical storms, as well as chemicals and gases. Climate influences included deforestation, radiated heat, photosynthesis, ultraviolet rays and chlorofluoride carbons. Climate impacts included species adaptation, species and plan habitats, and mosquito-carrying diseases, such as malaria and Lyme disease.

This superhero-narrated graphic nonfiction paid little attention to concepts related to climate personnel, climate controls, climate measures, climate regions and sub-climates, discussing only one term in each of these categories. Only two climate characteristics were mentioned (temperature and average temperature). Only four types of climate zones were discussed.

Content vocabulary terms were typically explained within the context of the narration. One example of this was the explanation of the term "greenhouse gas" in one cartoon frame that depicted the earth and listed the greenhouse gases in a nearby insert:

> Earth's atmosphere is made mostly of nitrogen and oxygen. It also contains gases that act like the glass panels of a greenhouse. These "greenhouse" gases help trap heat that that keeps the earth warm and able to support life (p. 5).

Content terms like this one were extended and related to other terms in brief sections as demonstrated by the next frame illustrating the super scientist wiping sweat from his forehead and standing near a thermometer, complaining:

> But, you can have too much of a good thing. The world is getting warmer due to increased amounts of greenhouse gases in the atmosphere. The rise in the average temperature of earth's atmosphere is called global warming (p. 5).

In addition to these devices, the glossary aided the reader's understanding by defining 11 key terms, including atmosphere, carbon dioxide, habitat, and photosynthesis. Although some of these terms were not defined in the text, typically readers could infer their meaning from the context, such as the term "habitats":

> Global warming affects more than just humans. It will change animal and plant habitats too. In fact, many species will have difficulty surviving in the regions where they now live. Global warming changes habitats faster than plants and animals can adapt. For instance, polar bears may go extinct if temperatures keep rising. Their hunting grounds are shrinking as the artic ice melts away (p.20).

The Graphic Nonfiction's Treatment of Climate and Climate Change

The graphic nonfiction, *Weird Weather: Everything You Didn't Want to Know about Climate Change but Probably Should Find Out* (Evans, 2006) consisted of 95 pages of black and white cartoons, cartoon-strips, and expository text devoted to climate and climate change. Cartoons and/or cartoon strips characterized every page of the text that had no story line, but emphasized expository presentation of ideas. Words were included on pages, not simply as straight lines or in paragraph form, but also appeared around illustrations, sometimes on a diagonal, and other times in a circular fashion. Varying font sizes, bold face type, and some words written in all capital letters characterized the text. Some key terms were bolded (e.g., methane, hexafluoride, sulfur dioxide, p. 11), but typically these vocabulary words were not defined nor used in a way that would allow readers to infer their meanings.

The writing style in this text was geared toward a mature audience. This text contained expletives in the introduction and sarcasm or satire (e.g., "CFCs [a term that was never defined] are emitted by vital socially necessary life enriching soft drink dispensers" (p. 13). In conveying humor, unrelated terms were also used, such as vocabulary presented, but not defined in a conversational frame where a man considered moving to England and another man remarked, "But that will make you a refugee" and he responded, "Oh no, no; it makes me an expatriate" (p. 37).

Teasers were included on the book's front and back covers to induce readers. On the front cover, the author was introduced with a comment that spoke to her humor rather than her content knowledge: "Kate Evans is one of the most original talents in comics I've seen in a long time." An "About the Author" section described the author as an environmental activist who researched, wrote, and illustrated the text that was first published as *Funny Weather* (Evans, 2006). The back cover featured brief reviews of the book, including two from newspapers, two from other authors of other texts on climate, and one from a scientist at a climate research center who wrote, "Very well researched…scientifically well informed and entertaining, too" (Jones, 2006).

Organization. This graphic nonfiction began with four additional but brief reviews of the book by climate authors and scientists, promising the text to be "really funny" and a "brilliant resource" (p. 4). A page of cartoons followed, including one depicting a person reaching for a set of car keys in one hand and an inhaler in the other and an illustration of a person turning off a radio report about millions facing starvation in Africa due to drought. A second page of cartoons preceding the narrative depicted a flood resulting from carbon dioxide increases due to vehicle emissions.

An introduction by the author of a book on global warming, *Heat*, (Monbiot, 2006), explained two reasons why climate change is not the largest political issue in the world today – because everyone is responsible for global warming and because people are enjoying less frigid climates. This Introduction was followed by the main text characterized by both expository and narrative passages and was divided into four chapters. The first and longest chapter (35 pages), "So What Is This Greenhouse Effect?" discussed the causes of greenhouse gasses and effects of global warming on plants and human and nonhuman animals; the second chapter, "Feedbacks" presented current and impending impacts of global warming on the earth; the third chapter, "What Are We Doing?" related current practices that impact the environment and climate; and the

fourth chapter, "What Are We Going to Do?" addressed future practices and recommendations, including alternative energy sources and modes of transportation.

Supplemental Features. Several special features were used in this text, including an Index and a Table of Contents. The Table of Contents included a note to the reader directing attention to the scientific references at the end of each chapter. Interspersed in these narrative pages were supplemental expository passages. These typically listed descriptive statistics, such as an insert on page 21 providing the numbers of deaths and injuries in various countries caused by typhoons, hurricanes, tornadoes, cyclones, blizzards, thunderstorms, avalanches, tropical storms, mudslides, and floods or numerical figures describing carbon dioxide emissions (p. 63). Another insert explained the effects of carbon dioxide on climate change (p. 11).

Ninety-eight numbered footnotes or "Notes" ranging from of one to three pages followed the chapters, providing references, elaboration on figures, or supplemental information. Often, these footnotes provided reference support for statements made in the narrative. *The No Nonsense Guide to Climate Change* (Godrej, 2001) was one text often referred to as a source in these footnotes.

This graphic nonfiction also referred readers to other resources, including six websites for information about climate change (e.g., www.climatewire.org; www.climatechangenews.org). A section, "Take Action", listed four websites for environmental organizations and regional groups (e.g., www.greenpoeace.rog; www.pollutionprobe.org) and directed readers to another website to view Al Gore's documentary, *An Inconvenient Truth* (www.climatecrisis.net). Readers were referred to the websites for two interactive online games, *Climate Challenge* and *Greena, the Worrier Princess* and to three other websites to calculate the amount of carbon dioxide they emit each year. An annotated bibliography provided recommendations to 15 books for further reading. The text concluded with a metric conversion chart and an Index.

Website. At the conclusion of the text, readers were directed to two websites – the author's website at www.cartoonkate.co.uk and a website that supported the book, www.funnyweather.org. (Readers were also invited to e-mail the author and were given her e-mail address to share their opinions about this graphic nonfiction). The author's website contained no information related to the text or to climate change, but rather promoted or sold her flash animations and cartoons as screen-printed shirts.

The website for *Funny Weather, Funny Pictures and Stories about Weather*, included multiple types of humorous texts about climate primarily intended for British audiences with statements like, "Britons spend six months of their lives discussing the weather" and descriptive statistics from British weather records. This website was populated with jokes about weather, "Funny Weather Snippets", such as, "What is the Mexican weather report? Chili today and hot tamale." This site also included myths, such as one about forecasting - that cold weather could be predicted by the amount of wood collected by Native Americans of the Great Lakes region. The website also featured "tales of strange climates and fun weather" consisting of humorous stories about weather, cartoons and poems about weather, and pictures of weather conditions, like strange cloud formations. Factual information included indicators of weather of wind direction or force.

Visuals. Five diagrams supplemented the black and white cartoon-strip narration, such as one illustrating cold patches in the north Atlantic impacting its hot, salty water (p. 36), the rate of carbon emissions (p. 43), carbon dioxide sinks in soil (p. 44) and the cycle caused by dissolving carbon dioxide acidifying the ocean (pp. 46-47). Two graphs illustrated variations of the earth's surface temperature during the years 1000 to 2100 (p. 11) and rising carbon dioxide levels from 1958 to 2005 (p. 43). Seven black and white sketches of political and religious leaders were presented in cartoon format with their quotes regarding climate change (p. 14-15).

Reading Aids. *Weird Weather* included two types of reading aids. Three pre-reading questions in chapter 1 asked: "So, what is this greenhouse effect?"; "Where do greenhouse gases come from?" and, "Who says climate change is really happening?" that provided a purpose for

reading. The titles of chapters three and four asked, "What are we doing [about climate change]?" and, "what are we going to do?' Seven critical thinking questions interspersed throughout the book posed inferential and evaluative questions, such as, "Ask yourself, will your greenhouse be affected?"; "How much more global warming can we get away with?" and, "What about the effects on wildlife?"

Content Vocabulary/Concepts. As can be seen in Table 3, this graphic nonfiction contained 84 terms in 11 categories. These categories in order of frequency were: climate products; climate influences; climate interventions; climate impacts; climate patterns; climate agencies; climate regions; climate personnel; climate controls; climate measures and climate characteristics. The largest category of terms, climate products, accounted for 40% of the terms followed by climate influences (16%) and climate interventions (15%). Together, these first two categories accounted for more than one half of the terms and these three categories accounted for 75% of the terms/concepts.

Table 3. Vocabulary from *Weird Weather* (Evans, 2006)

Category	Term or Concept
Climate Conditions (n=4)	Climate change; greenhouse effect; global warming; ice age
Climate Controls (n=1)	Ocean currents
Climate Zones (n=0)	
Climate Characteristics (n=1)	Global temperature
Climate Personnel (n=2)	Forecasters; climate modelers
Climate Products (n=34)	Carbon dioxide; methane; nitrous oxide; sulfur dioxide; fossil fuels; heat energy; water vapor; wind; cyclones; hurricanes; tropical storms; rain; snow; hail; Albedo effect; drought; heat wave; natural disaster; ice sheets; glaciers; ice plain; sea level; Amundsen Popsicle ice plain; Larsen B Choc ice shelf/sheet; flood; stagnant pools; ice caps; oxygen; permafrost; carbonic acid; calcium carbonate (chalk); tsunamis; ice crystals; methane hydrates
Climate Measures (n=1)	Carbon dioxide monitoring stations
Climate Impacts (n=8)	Ecosystem; extinction; coral reefs; food chain; climate chaos; viruses; bacteria; parasites
Climate Regions (n=3)	Flood plain; deserts; rainforest
Subclimates (n=1)	Arctic
Climate Interventions (n=12)	Biodiesel; wind farm; solar energy; Kyoto Protocol; carbon credits; emission quotas; recycle; green energy; shale tar sands; biofuels; carbon rationing; solar panels
Climate Influences (n=12)	Pollution; sulfur hexafluoride; atmosphere; deforestation; sunspot cycles; volcanic activity; CFCs; fertilizer; CO_2 emissions; high and low pressure; gulf stream; aerobic decomposition
Climate Agencies (n=3)	United Nations; Inter-governmental Panel on Climate Change; OPEC

Note. Categories and terms appear in the order in which they were identified in the text.

This text provided uneven presentation of content concepts. The largest categories of terms - climate products, climate influences and climate interventions - discussed concepts related to weather forms, gasses, earth's natural and human-made occurrences, and environmental precautions. Climate products included cyclones, hurricanes, tsunamis, tropical storms, heat waves, drought, snow, rain, and hail. The role of gasses, such as carbon dioxide, methane nitrous oxide, sulfur dioxide, and oxygen in climate change was also discussed. Climate influences included deforestation, sunspots, volcanic activity, and pollution. Climate interventions included

biofuels, wind farms, solar and green energy, and carbon rationing. Little attention was given to climate patterns, climate monitors, and climate regions with only two or three terms in each of these categories. This text did not include information about climate zones and only one sub-climate, the Artic, was mentioned. Only climatologists and meteorologists were described for careers in climate.

Content vocabulary was typically not defined in this text (e.g., "we can buy carbon credits from abroad", p. 62), but sometimes terms were bolded. Occasionally, a term was used in a context that allowed the reader to infer its meaning or partial meaning, such as the term "Gulf Stream" in the sentence, "our mild climate is due to the Gulf Stream which brings warm, tropical water over from the Caribbean" (p. 36). The referent to "our" is made clear in the frame above this one with the dialogue, "Here in England it will be balmy" (p. 36). There was no glossary to refer to for unknown terms.

Cross -Text Comparisons

Content Concepts. The textbook contained more conceptual terms and categories than did either of the graphic nonfiction texts, and almost twice as many terms were used in the textbook (n = 95) as in one of the graphic texts (n = 54). Only the textbook described the role of climatologists and the climate-monitoring devices they use. In addition, the textbook was the only text that described all eight types of climate zones and provided more information about climate zones and sub-zones than did the graphic nonfiction. Although the textbook presented more information, this conceptual density illustrates the criticism that textbooks contain too many concepts that can overload students (Daniels & Zillman (2004).

Despite these differences, there were similarities across the three texts in their presentations of concepts. The most frequently discussed key concepts in all of the texts were climate products and climate influences. Each text devoted intensive attention to climate products by describing the observable results of climate change. All of the texts thoroughly addressed influences on climate change.

There were also common omissions in content within and across the three texts. Each text mentioned at least one relevant vocation, but none of the texts presented a thorough treatment of careers in weather and climate change despite calls for early interventions to encourage youth in further science study and careers (e.g., Turner, Steward, & Lapan, 2004). None of the three texts addressed students' misconceptions about climate and climate change, a common criticism of science textbooks (Budianski, 2001) that the alternative texts did not compensate for in their presentations of concepts. Only the graphic nonfiction presented concepts about preventing climate warming and discussed both the benefits of global warming and the negative consequences, however.

Supplemental Features, Reading Aids, and Writing Style. There were similarities and differences in the graphic nonfiction compared to the textbook in terms of reading aids, writing style, and supplemental features, as well. Each of these texts contained useful supplements (i.e., Tables of Contents, Bibliographies, and Indexes). The textbook contained the most supplemental features, however, and content vocabulary words were more likely to be defined in context in the textbook. The textbook also offered the wisest variety of content literacy aids (i.e., graphic organizers, pre-reading and post-reading questions, critical thinking questions, concept maps, reading strategies, key ideas, and chapter previews) in opposition to the limited use of only pre-reading and critical-thinking questions in the two trade books.

The quality of the writing style also varied among the three texts. One of the graphic nonfiction texts, *Weird Weather* (Evans, 2006), included dense text in tiny type, distracting satire and sarcasm, unfamiliar referents to unrelated constructs, difficult to follow patterns of words

written around margins and illustrations, and contained expletives. This text was written primarily for a British audience using unfamiliar referents to British measurements, places, and politics. The supporting website for *Weird Weather* also contained distracting information and satirical ideas. In contrast to this trade book and the textbook, *Understanding Global Warming* was the most reader friendly by including only a few content terms on each page.

Yet, in terms of supplemental features, *Weird Weather* was the only text of the three that included an annotated bibliography of relevant video games, media that typically appeal to adolescents and can be motivating for learning content concepts (Gee, 2003), particularly in science (Guzzetti, 2009). This text was also the only text to offer websites for organizations to assist students in protecting the environment and stabilizing climate change.

Visuals. The textbook chapter contained the most visuals. *Earth Science* had almost twice as many visuals (24) compared to the 14 in *Weird Weather* and four times as many as compared to the eight visuals in *Understanding Global Warming.* The textbook chapter included 15 photographs compared to none or only one in the two graphic nonfiction texts. The textbook also contained the most visuals included on one page.

The visuals across the three texts conveyed varying types of knowledge. The figures, graphs, and diagrams tended to provide additional information and extended ideas in the written text. The photographs and satellite images tended to offer examples of the scientific concepts that illustrated the concepts/vocabulary thereby assisting readers to recognize or picture key concepts.

Discussion

These findings illustrate the range of quality found in graphic nonfiction and call for teachers' critical analysis when selecting these alternative texts. Like Crowson and Hopper (2002) found in their investigation of nongraphic trade books, we discovered that appropriateness of the writing style and the scope and treatment of supporting concepts varied among graphic nonfiction titles. Like the textbook, the graphic nonfiction did not address misconceptions or promote conceptual change through refutation text structures as is recommended by researchers in science education (e.g., Mikkila-Erdmann, 2001) and literacy education (e.g., Guzzetti & Mardis, 2011). Therefore, educators cannot assume that graphic nonfiction will be more informative for or appealing to adolescents than textbooks.

Graphic nonfiction provided the same emphasis on key concepts as did the textbook, however. In addition, these alternative texts were more likely than a textbook to present varying perspectives on an issue. Presenting both sides of an issue could prompt students' critical thinking and debate in a discussion where students take a stance and find evidence from text to support their positions, fostering thinking like scientists (Alvermann, Phelps & Gillis, 2010). Graphic nonfiction also provided background knowledge when supporting concepts were not well explained in the textbook.

In addition, the cartoons and graphics accompanying the graphic nonfiction assisted by providing a context for abstract ideas (Rice, 2002). The textbook contained by far the most photographs that allowed for visualization of scientific terms/concepts, but typically these photos were embedded among other graphics, figures, supplemental features, and reading aids that were together on a single page. Textbooks have been criticized for their presentation of too many visuals and supplements appearing together that can distract and confuse students (Daniels & Zellman, 2004).

Our comparative analysis demonstrates the utility of graphic nonfiction for teaching and learning scientific concepts. This study supports including graphic nonfiction along with other types of trade books as a supplement to textbooks in a multiple-text approach (Stahl & Shanahan, 2004) that allows for constructing knowledge through a cross-text comparison. Graphic nonfiction,

through its visuals and conversational style, can assist in deepening understandings of content concepts and serve as an appropriate resource for science instruction, research, and enrichment.

References

Alvermann, D.E., Moon, J.S., & Hagood, M.C. (1999). *Popular culture in the classroom: Teaching and researching critical media literacy.* Newark, DE, and Chicago, IL: International Reading Association and the National Reading Conference.

Alvermann, D.E., Phelps, S., & Gillis, V. (2010*). Content area reading and literacy: Succeeding in today's diverse classrooms, 6th ed.* Boston, MA: Allyn & Bacon.

Biskup, A. (2008). *Understanding global warming*. North Mankato, MN: Capstone Press.

Buckingham, D. (2003). *Media education: Literacy, learning, and contemporary culture.* Malden, MA: Polity

Budianski, S. (2001, February). The trouble with textbooks. *Prism.* Retrieved from http://www.project2061.org/publications/articles/articles/asee.htm

Butler, K. (2010). Comic books as journalism: Ten masterpieces of graphic nonfiction. Retrieved from http://www.theatlantic.com/entertainment/archives/2011/08/comic-books-as-journalism-10-masterpieces-of-graphic-nonfiction/243351

Cope, B., & Kalantas, M. (2000). *Multiliteracies: Literacy learning and the design of social futures.* London, England: Routledge.

Crowson, A.F. & Hopper, P.F. (2009). The use of trade books in science classrooms. *National Forum of Teacher Education Journal*, *19*(3). Retrieved from http://www.nationalforum.com/Electronic%20Journal%20Volumes/Hopper,%20Missy%20The%20Use%20of%20Trade%20Books%20in%20Science%20Classroom.pdf

Daisey, P. (1994). The value of trade books in secondary science and mathematics instruction: A rationale. *School Science and Mathematics*, *3*, 130-137.

Evans, K. (2006). *Weird weather: Everything you didn't want to know about climate change but probably should find out.* Toronto, Canada: Groundwood Books.

Gee, J.P. (2003). *What video games have to teach us about learning and literacy*. New York, NY: Palgrave-Macmillian.

Guzzetti, B.J. (2009). Thinking like a forensic scientist: Learning with academic and everyday texts. *Journal of Adolescent and Adult Literacy, 53*(3), 192-203.

Guzzetti, B.J., & Mardis, M. (2011). Thinking with forensic science: A content analysis of fiction and nonfiction graphic novels. In D.E. Alvermann & K. Hinchman (Eds.) *Re-conceptualizing adolescent literacy, 3rd ed*. (pp. 92-111). Mahwah, NJ: Lawrence Erlbaum.

Farland, D. (2006). Trade books and the human endeavor of science. *Science and Children*, *44*(3), 35-37.

Ford, D.J. (2006). Representations of science within children's trade books. *Journal of Research in Science Teaching, 43*(2), 214-235. doi: 10.1002/tea.20095

Lankshear, C., & Knobel, M. (2006). *New literacies: Everyday practices and classroom learning, 2nd Ed.* New York, NY: Open University Press and McGraw Hill.

Madrazo, G.M. (1997). Using trade books to teach and learn science. *Science and Children*, 34(6), 20-21.

Miles, M., & Huberman, M. (2013). *Qualitative data analysis: A methods sourcebook, 3rd ed*. Thousand Oaks, CA: Sage.

Mikkila-Eerdman, M. (2001). Improving conceptual change concerning photosynthesis through text design. *Learning and Instruction*, 11, 3, 241-259.

Mitchell, W. J. (1995). *Picture theory: Essays on verbal and visual representation*. Chicago, IL: University of Chicago Press.

New London Group. (1996). A pedagogy of multiliteracies: Designing social features. *Harvard Educational Review*, *46*, 60-92.

Patton, M.Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, CA: Sage.

Rice, D. (2002). Using trade books in teaching elementary science. *The Reading Teacher, 55*, 552.

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

Shanahan, C., Shanahan, T., & Misischia, C. (2011). Analysis of expert readers in three disciplines: History, mathematics, and chemistry. *Journal of Literacy Research*, *43*(4), 393-429. doi: 10.1177/1086296X11424071

Sibanda, J., & Sibanda, L. (2013). Visual literacy development through the mediation of grade 4 English textbooks. *Journal of Visual Literacy*, 32, 2. Retrieved from http://www.questia.com/library/journal/1G1-357473144/visual-literacy-development-through-the-mediation

Spaulding, N.E., & Namowitz, S.N. (2005). *Earth science.* Evanston, IL: McDougal Little.

Spiro, R., Coulson, R.L, Feltovich, P.J., & Anderson, D. (2004). Cognitive flexibility theory: Advanced knowledge in ill structured domains. In R.B. Ruddell (Ed.), *Theoretical models and processes of reading, 5th ed.* (pp. 602-616). Newark, DE: International Reading Association.

Spoehr, K.T., & Spoehr, L.W. (1994). Learning to think historically. *Educational Psychologist*, 29, 71-77. doi: 10.1207/s15326985ep2902_2

Stahl, S.A., & Shanahan, C. (2004). Learning to think like a historian: Disciplinary knowledge through critical analysis of multiple documents. In T.L. Jetton & J.A. Dole (Eds.), *Adolescent Literacy Research and Practice* (pp.94-116). New York, NY: Guilford Press.

Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief exploratory study. *Science and Communication*, *8*(4) 1-17, Retrieved from http://www.scienceinschool.org/2010/issue14/web

Tatalovic, M. (2010, April 29). Science comics and cartoons. *Science in School*, 14. Retrieved from http://www.scienceinschool.org/2010/issue14/web

Turner, S.L., Steward, J.C. & Lapan, R.L. (2004). Family factors associated with sixth grade adolescents' math and science career interests. *Career Development Quarterly*, *53*, 41-52.

Yarden, A. (2009). Reading scientific texts: Adapting primary literature for promoting scientific literacy. *Research in Science Education*, *39*, 307-311. doi: 10.1007/s11165-009-9124-2

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