3.2 A NEWTON STORY: OVERCOMING BARRIERS TO COMMUNICATING SCIENCE TO THE PUBLIC

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ABSTRACT

Communication barriers between scientists and the public hinder the public understanding of science. An educated public is empowered to make well-considered policy decisions, participate in informed public debate, and direct support toward promising scientific developments. For example, stifling polarization with respect to the debate on climate change may be a consequence of ineffective communication. We know scientists need to be able to communicate science to nonscientists without compromising the quality of the message. Part of each scientist's professional responsibility is to promote the public understanding of science, yet most undergraduate writing instruction is focused on writing for the specialist, and we need to prepare future scientists to communicate effectively outside of academia. In the fall of 2010, content course faculty and writing faculty at the Pennsylvania State University collaborated to develop curriculum in meteorology to teach their students to write for a variety of audiences. A general discussion of audience accommodation, and a specific example of audience accommodation—narration—is presented to provide practical, hands-on approaches and examples from the atmospheric sciences to help begin rethinking current assignments, instruction, and evaluation methods for the classroom to overcome barriers to communicating science to the public.

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1. INTRODUCTION

It turns out the apple story is true. One of the most familiar anecdotes of science has Sir Issac Newton sitting under the branches of an apple tree thinking about the mysteries of the universe, when *boink*, an apple hits him on the head, and he comes up with the theory of gravitation. In the archives of London's Royal Society, the manuscript of William Stukeley, one of Newton's first biographers, published in 1752, verifies that Newton relayed these events to Stukeley ("Newton's Famous," 2010). As of May of 2010, the Royal Society made the digital facsimile of the manuscript available online.

The apple story illustrates two key points concerning communicating in the sciences. First, technology has brought information about science into our daily lives. With a click of a mouse, we have access to a twelve course meal of scientific information in the form of original manuscripts, journals, conference proceedings, dissertations, and more. We can choose the fast food versions too: popular science magazines, websites, and blogs. And there is good news. According to the Science and Engineering Indicators published by the National Science Foundation, thirty years of data consistently show Americans believe in past achievements of science, are optimistic about the promise of science and technology to provide solutions, and favor increasing investment in the sciences (2010). Americans are aware that science is important and relevant to their lives.

Second, the way science is communicated often influences whether or not the public is aware of the science. Almost 300 years have passed since Newton was knocked on the head. Why are so many of us familiar with this event? It is a science story that has been communicated well. Science writer Issac Asimov believed that public hostility and suspicion take hold if scientists are not effective communicators (Asimov, 1980; Gregory & Miller, 1998). If so, the stifling polarization witnessed with respect to scientific debates on issues such as climate change, embryonic stem cell research, the safety of vaccinations, genetic engineering, and the teaching of evolution appear to be a consequence of ineffective communication. Clearly, Americans need concise, accessible, and reliable information to make decisions in the democratic process. Part of each scientist's professional responsibility is to promote the public understanding of science. Yet most undergraduate writing instruction does little to prepare future scientists to effectively communicate outside of academia. Exactly what can we do to prepare our students—or future scientists—to overcome the barriers associated with communicating to the public when writing?

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2. EVIDENCE BARRIERS EXIST

Communication barriers between scientists and the public exist. In July 2009, the Pew Research Center and the American Association for the Advancement of Science issued a report titled, "Public Praises Science; Scientists Fault Public, Media." It profiled America's scientific illiteracy. For example, only 54 percent of Americans responding to the survey knew antibiotics do not kill viruses; only 52 percent knew stem cells can develop into many types of cells, and only 46 percent knew electrons are smaller than atoms. Additionally, the gap between scientists and the public with respect to controversial scientific issues is even more revealing. Scientists overwhelmingly (87 percent) say humans and other living things have evolved over time and that evolution is the result of natural processes such as natural selection. Only 32 percent of the public accepts this as true. On the question of global warming, 84 percent of scientists say the earth is getting warmer because of human activity, but just 49 percent of Americans think human emissions are causing global warming.

Also according to the report, despite the general agreement among scientists on the issues of evolution and climate change, substantial minorities of the public say scientists do not agree: 28 percent say that scientists *do not agree* on evolution and 35 percent say that scientists *do not agree* that the earth is warming because of human activity. In other words, the public's perception of a lack of consensus among scientists is inaccurate. If scientists were communicating effectively to the public, it is likely the viewpoints of scientists and the public would be more similar.

3. WHY SHOULD WE CARE?

Public understanding of science matters. In May 2009, the New York Academy of Sciences hosted a symposium to recognize the fiftieth anniversary of C.P. Snow's Cambridge University's Rede Lecture and to stimulate discussion of the barriers to effective science communication ("A Dangerous Divide," 2009). Snow's argument stated there were "two cultures"—literary intellectuals and scientists—and they were separated by a "gulf of mutual incomprehension (Snow, 1959). The 2009 symposium of scientists, journalists, entrepreneurs and teachers examined the "two cultures" of modern day. NOVA executive producer Paula Apsell summed the participants' sentiments well; she stated, "The gap between the two cultures today is much less between scientists and literary intellectuals, as it is between science and the public" ("A Dangerous Divide," 2009).

Specifically, why should we care? According to Durant, Evans, and Thomas in "The Public Understanding of Science," there are four concise reasons (Nature, 1989).

> First, science is arguably the greatest achievement of our culture, and people deserve to know about it; second science affects everyone's lives, and people need to know about it; third, many public policy decisions involve science, and these can only be genuinely democratic if they arise out of informed public debate; and fourth, science is publically supported, and such support is (or at least ought to be) based on at least a minimal level of public knowledge (p. 11).

The public needs to be informed. Scientists need to be able to communicate science to nonscientists without compromising the quality of the message. Scientists and educators in the classrooms on the front lines need to instruct future scientists how to do this effectively.

4. EXPLORATORY INTERVIEWS: ESTABLISHING A STARTING POINT

Do content course faculty (i.e., those who teach the science content as opposed to those who teach writing) instruct their students on how to communicate with both specialists and public audiences? And if so, how do content course faculty teach this skill? Public audiences are defined as those with a wide range of interests, needs, and educational backgrounds (Penrose & Katz, 2010, p. 198). Exploratory e-mail and phone interviews of ten senior scientists and faculty at the Pennsylvania State University, University Park, Pennsylvania in the fall of 2010 identified the types of writing assignments required of students; faculty perception of student writing skills; faculty role in helping students develop academic writing skills; and the importance of writing. The purpose of these exploratory interviews was to identify areas of writing instruction content course faculty emphasized, and to explore whether or not they included assignments, instruction or feedback that is specifically designed to address communicating with public audiences. Questions were open-ended, and were adapted from a previous study that examined business and engineering faculty views on writing instruction (Zhu, 2004).[1]

Nine of the ten surveyed responded. All nine respondents commented about the importance of instructing students to write well, yet no responses included gearing assignments, instruction or feedback *specifically* to prepare students to write science for the public. Additionally, focus on audience accommodation or using narration as a way to adapt to communicating with a public audience was not specifically mentioned in the responses. It should be noted that none of the questions included the terms audience or narration, so responses were not prompted to consider these concepts.

Interviewees were selected because they taught the writing intensive first-year seminar during the fall 2010 to freshmen in the College of Earth and Mineral Sciences. The first-year seminars are typically taught by seasoned teaching veterans with vast research experience within their disciplines. Of the nine responses, eight are full professors and one is an assistant professors. The disciplines are diverse; however, they are all within earth sciences: two in geosciences, one in geography, one in materials science, two in meteorology, two in energy and mineral engineering, and one in petroleum and natural gas engineering. All are content course faculty as opposed to writing instruction faculty.

Additional highlights of the survey results are the following:

1. Faculty expressed that writing is important (100 percent). Typical comments include "I wish writing skills and reading skills were stressed

[1] Interview questions found in Appendix A.

more in the sciences," and "Science that is not communicated well is of little use."

2. Two types of assignments were mentioned most often: short essays and term reports (78 percent). One faculty stated he uses online discussion boards and another one includes journal entries.
3. The general perception of faculty is students' writing ability is varied (78 percent). Typical comments include "The quality of the writing varies a great deal. I suspect that the variation is a function of native aptitude rather than any targeted training," and "I'm not as concerned about writing for freshmen. It's okay for my purposes. I'm more concerned about the lab reports of the juniors and seniors."
4. Three weaknesses in student writing were mentioned often: clarity, conciseness, and organization (67 percent). One response mentioned the need for students to "make the transition to proper formatting for technical and scientific writing."
5. When asked about their role in helping students develop writing skills, 67 percent mentioned they find themselves burdened by other concerns. Responses such as, "I feel that I cannot take that [developing writing skills] on as a major responsibility in light of other things they must learn in my courses," were typical. One faculty member commented, "Especially being not a native speaker, I see my ability to be limited in this regard."

We know scientists need to be able to communicate science to nonscientists without compromising the quality of the message. Part of each scientist's professional responsibility is to promote the public understanding of science, yet most undergraduate writing instruction is focused on writing for specialists and may not prepare future scientists to effectively communicate outside of academia.

In the fall of 2010, content course faculty and writing faculty at the Pennsylvania State University collaborated to develop curriculum in meteorology to teach their students to write for a variety of audiences. A general discussion of audience accommodation, and a specific example of audience accommodation—narration—is presented to provide practical, hands-on approaches and examples from the atmospheric sciences to help begin rethinking current assignments, instruction, and evaluation methods for the science classroom.

5. KEY WRITING PRINCIPLES TO OVERCOME COMMUNICATION BARRIERS

5.1 Audience Accommodation *(Pretest)*

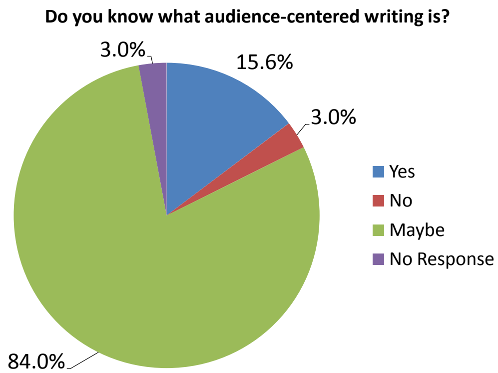
Even though the American public is science attentive, they are not knowledgeable (Shortland, 1991). Students need to be instructed to adapt their messages to accommodate audiences who may be interested but not informed. Audience accommodation is crucial to ensuring science is communicated in a way the public comprehends (Barrass, 2002; Blakeslee, 2001; Goldbort, 2006; Gregory & Miller, 1998; Shortland & Gregory, 1991; Sivey & Lee, 2008, Tichy, 1988).

To explore if students were able to define audience accommodation and recognize ways to incorporate this writing principle into their communications, two upper-level meteorology classes participated in a non-experiment design (Trochim, 2006); one class was Weather Communications (n=23) and the other was Advanced Atmospheric Dynamics (n=9). A true experimental design with a pretest-posttest control group was not possible because it requires random assignment of subjects to experimental control groups (Langenback, Vaughn & Aagard, 1994), and students had self-selected their courses at the beginning of the semester. It is also recognized that research using a pretest (some form of measurement that precedes a treatment or experience), may result in the test itself having an impact on the subjects (McMillan & Schumaker, 1997, p. 186). All respondents (N=32) were meteorology majors in their junior or senior years.

In the pretest, students were asked 1.) if they knew what audience-centered writing was, 2.) to write a definition if they answered "yes" or "maybe," 3.) to list strategies to adapt their writing to achieve audience centered writing, and 4.) to give an example of something they had read that was audience centered.[2]

As can be seen in Figure 1, the most frequent response to question 1 was "maybe" (84 percent; Weather Communications, n=18; Advanced Atmospheric Dynamics, n=9), followed by "yes" (15.6 percent; Weather Communications, n=4; Advanced Atmospheric Dynamics, n=1), and lastly by "no" (3 percent; Weather Communications, n=1; Advanced Atmospheric Dynamics, n=0). Thirty-one responses were recorded, and there was one "no response" (Weather Communications).

[2] Pretest found in Appendix B.



Responses (n=31)
Weather Communications (n=23)
Advanced Atmospheric Dynamics (n=9)

Figure 1. Pretest: Question 1

When students were asked to define audience-centered writing in their own words, responses were varied, but 90 percent indicated some awareness of their reader, and only 10 percent answered incorrectly (e.g., “writing suitable to be spoken,” “writing for a well-educated audience,” “making your viewpoint the highest priority”). Students had the most difficulty answering, *list strategies you use to adapt your writing to achieve audience-centered writing*. The most common correct response was to adapt vocabulary or terminology to the audience (n=9, 28 percent). No response (n=8) and vague responses (n=15), such as “engage in the mentality of the audience” and “write details” represented 72 percent of the responses in the pretest. Examples of texts students had read that were audience-centered included scientific articles (n=11), weather blogs (n=7), textbooks (n=4), newspapers (n=9) and other (n=1).

After the pretest, students participated in an activity designed to achieve the following five core competencies:

1. Writing, speaking and/or other forms of self-expression.
2. Practice information gathering, such as the use of the library, computer/electronic resources, and experimentation and observation.
3. Using collaborative learning and teamwork to problem solve.
4. Participating in activities that promote and advance scholarly conduct and community responsibility.
5. Using strategies that modify the comprehension and engagement of scientific information for the general audience.

Particular attention was paid to this fifth core competency in the activity piloted at Penn State University this fall.

5.2 Audience Accommodation *(Activity Description)*

To explore specific strategies writers can use to adapt scientific discussions to a variety of audiences, students in the two upper-level meterology classes read and compared four articles on one topic. For example, the meteorology students read about the topic of wind chill. The articles used are as follows:

1. Cauchon, D. (2000, February 11). Accuracy of wind chill questioned. *USA Today*. Retrieved from: http://www.usatoday.com/weather/news/2000/windchill.htm
2. Engber, D. (2008, December 22). Wind chill blows: it’s time to get rid of a meaningless number. *Slate.* Retrieved from http://www.slate.com/id/2207326
3. Quale, R.G. & Steadman, R.G. (2008). The Steadman wind chill: An improvement over present scales. *Weather and Forecasting,* 13(4). 1187-1193.
4. National Oceanic and Atmospheric Administration (November 1, 2001). New wind chill temperature index: new formula will provide more accurate warnings for North America. Retrieved from: http://www.noaanews.noaa.gov/stories/s800.htm

Working in small groups of 3-4, students used a scale of 1 (general audience) to 5 (most specialized audience), to rank attributes of each article. The Student Audience Accomodation Activity Handout found in Appendix C was used to guide students in their analysis of eight specific attributes: *content, level of detail, vocabulary/word choice, organization/arrangement, tone, visuals, format/structure*, and *readability.*[3]

Students recorded examples from the articles to support their rankings. At the completion of the activity, with guidance from faculty, students particpated in a large group discussion to compare their observations.

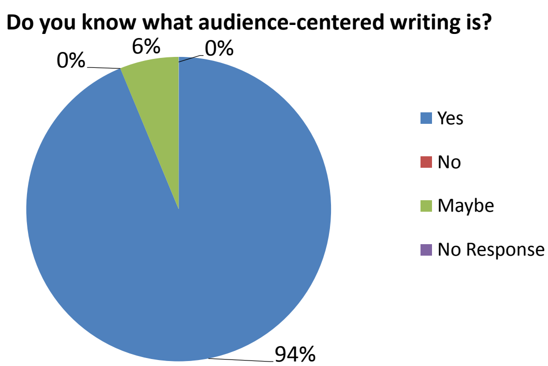
[3] Student Activity Handout found in Appendix C.

The activity and discussion is designed to help students recognize how each of the attributes contributes to the engagement and comprehension of the material to a specific audience.

5.3 Audience Accomodation (Posttest)

In the posttest, students were asked 1.) Do you know what audience-centered writing is? 2.) If "yes" or "maybe," what do you think audience-centered writing is? 3.) Which of the following are strategies for effective audience-centered writing (check as many choices as appropriate), and 4.) give an example of something you've read that is audience centered.[4]

As can be seen in Figure 2, for the posttest, the most frequent response (94 percent) to question 1 was "yes" (Weather Communications, n=21; Advanced Atmospheric Dynamics, n=9). Only 6 percent of the respondents answered "maybe," and no respondents indicated they did not know what audience-centered writing was or gave no response.



Responses n=32
Weather Communications n=32
Advanced Atmospheric Dynamics n=9

Figure 2. Posttest: Question 1

When students were asked to define audience-centered writing in their own words, all responses indicated some awareness of their reader. Fifty-six percent (n=18) included the concept of "adapting your writing to the specific audience through content, detail, tone and visuals." In other words, the responses were accurate and more developed than those of the pretest.

As shown in Table 1, students indicated the following with respect to identifying strategies for effective audience-centered writing (n=32):

(n=32)	Adapt length to the level of interest of readers
(n=31)	Include comparisons to explain unfamiliar concepts
(n=31)	Use visual presentations that are focused on the needs and expectations of the readers
(n=30)	Anticipate readers' interests in scope and development
(n=30)	Adjust technical information to the level of knowledge of the reader
(n=28)	Incorporate examples that are based on readers' experiences
(n=26)	Consider readers' perspectives in organization and arrangement
(n=26)	Provide reader desired (formal or informal) references to support claims
(n=24)	Use appropriate appeals (ethos, pathos, logos) to connect and engage readers
(n=23)	Use bias-free language
(n=19)	Establish rapport through good standards of etiquette
(n=0)	Other (write out)

Table 1. Strategies for Audience Accommodation

Adapting the length to the level of interest of the reader was viewed as the most recognized strategy of effective audience-centered writing. Perhaps this concept was particularly evident because the scholarly journal article students read and analyzed was 2,180 words compared to the other three articles that were between 625 – 950 words.

Examples of texts students had read that were audience-centered included newspapers (n=9), scientific articles (n=8), websites (n=6), weather blogs (n=5), textbooks (n=4), and other (n=0). These results are similar to the pretest with the exception of the addition of websites in the responses. One of the articles on wind chill used in this lesson was from a NASA website and may have influenced this response.

[4] Posttest found in Appendix D.

	Article 1 (Cauchon)	Article 2 (Engber)
Content	Accuracy of wind chill; basic description of Bluestein's new model & problems with the old one; brief summary of the development of the old model; current one "overstates" how cold feels—Bluestein's more accurate measure of "heat transfer"; Kessler's (former director of National Severe Storms) call to replace it	Wind chill is used to make weather exciting; history--Siple and Passel's development; forecasters turned it into "what it feels like"; Osczevski & Bluestein pointed out problems—assumptions presented; additional flaws; build a new one
Level of Detail	~ 950 words; broad statements about problems and new models; e.g., "scientists say," "account for big differences," "index overstates" ; wind chill charts are based on *this* formula (no specific formula); "half a dozen other researchers"	~ 750 words; moderately broad statements of "the equation…expressed in watts per square meter"; includes example of calculation—"for example, the rate of loss in 5-degree weather"; sidebar to explain Osczevski & Bluestein's calculation
Vocabulary/Word Choice	Accessible vocabulary and includes well known clichés, "crying wolf"; Kessler is quoted, "this whole *romance* with the wind chill factor is just a bunch of *hype* so the TV weatherman can scare you"	Title, pun (irreverent); use of analogy—"wind chill is its PR agent; title!; stylish use of adjectives & verbs, "gaudy negative numbers" "trot out these arctic pumped-down numbers"; "algorithm" "ambient"
Organization/Arrangement	Intro provides audience engagement--Bluestein shoveling driveway and main idea—flaw of current model; front loaded information; paragraphs of 1 or 2 sentences; simple and compound sentences used	Intro engages audience by telling them why they should care about wind chill-- being manipulated by "weathermen"; more detailed descriptions of the assumptions of Osczevski and Bluestein; sophisticated journalistic style with longer paragraphs and more sentence variety
Tone	Informal--scientist as "everyman"--Bluestein described as shoveler, mechanical engineer, and finally "a professor"; focuses on why the reader should care, "as a practical matter…tell people how warmly to dress"	Conversational, "well, I've been out…"; informal, use of first person, use of dashes; more inflammatory—negative portrayal of weather forecasters
Visuals	Two abbreviated tables (Current wind chill index & Weather revisions may warm up cold)	One sidebar to explain how Osczevski & Bluestein developed their wind chill table
Format/Structure	Shoveling used to engage audience—everyday occurrence; easy main point in headings, the problem, short proposal to "Get rid of it"	Web-based print includes "click here," ads on page; no subheadings
Readability	Easy	Moderate

Table 2. Audience Accommodation and Attribute Comparison Wind Chill Articles 1 & 2

	Article 3 (Quale & Steadman)	Article 4 (NOAA)
Content	Discussion of a more "realistic" wind chill calculation-- "Steadman wind chill"; more focus on the body's heat generation; explains specific calculations & statistical tests; provides equations; proposal—adopt Steadman model, revise NWS	Announcement of new method to compute wind chill; touting success of "science, technology & computer modeling"; brief description of how the new wind chill was developed; bulleted list of 6 specific changes; mention of "protecting lives"; original model covered in only one sentence
Level of Detail	~2180 words; scope is narrower (one model) with greater detail; includes specific emphasis on providing the reader with reproducible results—"as our basic starting point we employ the complete Steadman tables…"; "using second-order multiple-regression analysis"; "independent variables"	~625 words; more details on NOAA less on the problems of the previous model and proposed solutions; includes statement from Jack Kelly (director of NOAA's NWS); establishes who was involved in developing the new model but doesn't give individual credit; e.g., "scientists," "experts from the academic community"; includes additional NOAA web site links
Vocabulary/Word Choice	Assumes familiarity with meteorological jargon; "with an rmse of 0.31°F; we have carried the marginal notations regarding the warming effect of 100 W m ^{2}"	Includes acronyms but explains less familiar; e.g., "Joint Action Group for Temperature Indices JAG/TI"; includes some lesser known vocabulary: e.g., "anemometer" "calm wind threshold," "skin tissue resistance"
Organization/Arrangement	Conventional technical and scientific writing-- abstract provided first, followed by introduction, then the specific calculations and suggestions; paragraphs of greater than 6 to 8 sentences; sentence variety with more reliance on simple and complex structure;	Leads with emphasis on NOAA's accomplishment; direct quotation to support this point, and develops specific changes made to the new index; moves from specific info on wind chill to general info on NOAA and related web sites
Tone	Formal; credibility of authors established by providing their organization & university connections	Congratulatory and upbeat; "NWS operates the most advanced weather and flood warning and forecast system in the world, helping to protect lives, property, and enhance the national economy."
Visuals	Used extensively for specific details of complex data; 6 tables, 1 illustration, 1 diagram	One aggregated photo of various weather conditions; more info available outside of article at links
Format/Structure	Includes IMRaD, references; in-text parenthetical citations, numbered headings	Title and no subheadings; resembles body of internal memo format
Readability	High	Moderate

Table 3. Audience Accommodation & Attribute Comparison Wind Chill Articles 3 & 4

5.4 Audience Accommodation Summary

Students engaged in a large group discussion within the context of these questions:

1. Did you find similarities among the articles? Give examples.
2. Are there differences too? What are they?
3. Do any of the articles contain simplifications or generalizations? Do these simplifications or generalizations compromise the accuracy of the information presented?
4. What observations have you made about audience-centered writing?

Faculty encouraged students to consider the attributes of *content* (breadth or scope), *level of detail* (development or depth), *vocabulary* (word choice and jargon), *organization/arrangement, tone, visuals, format/structure*, and *readability* in their comparisons among the four articles. Tables 2 and 3 show the specific points of comparison developed for these four articles.

Students were encouraged to consider that to communicate well is to engage in self-interest because the ability to write and speak effectively to a variety of audiences will either aid or hinder the perceived importance or validity of the science itself. After the general discussion of audience accommodation, a specific example of audience accommodation—narration—was introduced in the next Weather Communications class.

6. AUDIENCE ACCOMMODATION: NARRATIVES

A narrative is one way to convey difficult concepts in the sciences. Research indicates that by creating narratives, audiences identify with the science, and it becomes accessible (Katz, 1992). Furthermore, studies show stories are basic to the formation of scientific knowledge (Barass, 2001; Katz, 1992; Polkinghorne, 1988). Narratives and scientific discourse are well suited to each other because the scientific method is at its core describing what happened and what it meant, and this is exactly what is done when a story is told.

To develop audience accommodation more thoroughly through the use of narration, one upper-level meteorology class (Weather Communications) at Penn State in the fall of 2010 participated in an exploratory collaborative group writing project. After discussing audience accommodation in the previous class, students were presented with a brief lecture on how to make science relevant to a general audience using narration. The elements of a story (narrative hook, theme, plot, characters, setting, and point of view) were introduced and reviewed. To make connections to the reader, students were instructed to use rhetorical appeals such as ethos, pathos, and logos. (Ramage, Bean, & Johnson, 2007), and also to consider the appeals of “wonder” and “application” as defined by Fahnestock (1986). *Wonder* emphasizes the sense of surprise and joy of the science, and *application* emphasizes the practical benefits of the science; both are effective in engaging the public when communicating science.

For this exploratory collaborative writing project, students were given the following seven facts adapted from NOAA’s website on how a thunderstorm forms (“A severe weather,” 2006).

Thunderstorm Facts

1. Three basic ingredients are required for a thunderstorm to form: moisture, rising unstable air (air that keeps rising when given a nudge), and a lifting mechanism to provide the "nudge."
2. The sun heats the surface of the earth, which warms the air above it. If this warm surface air is forced to rise -- hills or mountains, or areas where warm/cold or wet/dry air bump together can cause rising motion -- it will continue to rise as long as it weighs less and stays warmer than the air around it.
3. As the air rises, it transfers heat from the surface of the earth to the upper levels of the atmosphere (the process of convection). The water vapor it contains begins to cool, releasing the heat, and it condenses into a cloud. The cloud eventually grows upward into areas where the temperature is below freezing.
4. Some of the water vapor turns to ice and some of it turns into water droplets. Both have electrical charges. Ice particles usually have positive charges, and rain droplets usually have negative charges. When the charges build up enough, they are discharged in a bolt of lightning, which causes the sound waves we hear as thunder.
5. Thunderstorms have a life cycle of three stages: The developing stage, the mature stage, and the dissipating stage. The *developing stage* of a thunderstorm is marked by a cumulus cloud that is being pushed upward by a rising column of air (updraft). There is little to no rain during this stage but occasional lightning. The developing stage lasts about 10 minutes.

6. The thunderstorm enters the *mature stage* when the updraft continues to feed the storm, but precipitation begins to fall out of the storm, and a downdraft begins (a column of air pushing downward). The mature stage is the most likely time for hail, heavy rain, frequent lightning, strong winds, and tornadoes.
7. Eventually, a large amount of precipitation is produced and the updraft is overcome by the downdraft beginning the *dissipating stage*. At the ground, the gust front moves out a long distance from the storm and cuts off the warm moist air that was feeding the thunderstorm. Rainfall decreases in intensity, but lightning remains a danger.

Students were instructed to write to a general audience, one that is educated, but is unlikely to have a specialist's knowledge of the concepts. The specific directions given were as follows:

> *DIRECTIONS: To practice an adaptation strategy, you will collaboratively write a one-page narrative using the following facts on how a thunderstorm is formed. (They are taken from the National Oceanic and Atmospheric Administration (NOAA) website. Some sentences and illustrations have been omitted for brevity.)*
>
> *Your audience is similar to a group of your educated friends who are not meteorology majors, and may not even be science majors. Your purpose is to help them understand the formation of thunderstorms, so you may exclude any facts you determine are not relevant to your purpose. It may be helpful to think of your narrative title along the lines of "A Day in the Life of a Thunderstorm." Be creative and make sure the science is accurate.*

The collaborative aspect of the activity is designed to foster debate and discussion during the process of writing. At its best, it should expose students to various points of view and help them work through obstacles they may not be able to overcome on their own. In the next class period, students gathered in a large group to share what difficulties they encountered and make observations about the process of using narratives to communicate science to the public. Students were engaged during this lesson; however, they found it difficult. In particular, when surveyed, students mentioned the following obstacles: making sure the parts of the story were cohesive, keeping it concise, making it entertaining, figuring out what facts were necessary and what ones to omit, getting a "thesis" or theme written in a non-traditional way, using creative comparisons that adequately expressed the scientific aspect of the topic. These obstacles are useful in planning follow-up activities.

Allowing students to share their narratives provides an awareness of how their work compares to that of their peers and gives them additional insight into how to approach writing narratives in the future. Each group's work was posted to an electronic bulletin board. Excerpts of student narratives are found in Appendix E; audience accommodation follow-up assignments are found in Appendix F. Follow-up homework assignments are useful to the art of narrative writing.

7. CLOSING THE GAP BETWEEN SCIENTISTS AND THE PUBLIC

Scientists understand science. They have the power to inform the public, to educate new scientists, and to encourage political and financial support for science. Publication in peer-reviewed journals plays a major role in distributing new findings in science, and scientific journals are emphasized in undergraduate writing in science. Reaching out to the public is not always rewarded in the scientific community (Shortland and Gregory, 1991). Yet the landscape is changing and opportunities are developing for increased pollination of ideas between scientists and the public. New informal media are available—websites, blogs, wikis, discussion boards, online social networks. These outlets should help scientists reach a broader section of American citizenry. Yet to use these tools to their potential, future scientists must be provided with the skills to bridge the gap and communicate well to those outside of their circle.

A quick fix approach is not likely to have success. The solution, like the problem, is multi-faceted. Those of us who interact with future scientists must convey the responsibility of all scientists to act as liaisons between science and society. We must rethink our current assignments, instruction, and evaluation methods to provide opportunities *in the classroom* to write for *outside of the classroom* and not to concentrate solely on writing for an academic audience. We must give students practice making their science stories personally meaningful to their audiences using accommodation, narration and the vast array of rhetorical tools. Most importantly, we must share our tips that work, so we can make overcoming communication barriers a collective enterprise.

The public *is* interested. Does anyone have a Newton story to share?

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Appendix A. Content Course Faculty Interview Questions (Adapted from Zhu, 2004)

1. What type(s) of writing assignments are required in your courses and discipline? What guidance do you provide on student writing? How do you comment on and evaluate student written work?

2. What do you think about your students' writing? What kinds of strengths and/or weaknesses do you see in your students' writing? What aspect of writing do you think your students need to work on?

3. How important is writing in your courses? Program? and field?

4. What do you think is the role of content course instructors, such as yourself, in helping students develop writing skills? What are some of the things that have helped your students improve in terms of their writing? How can writing courses (e.g., composition courses) better prepare your students for writing tasks in content courses? How do you think writing for your discipline is similar or different from writing in another discipline?

5. Is there anything that I did not ask but you would like to add?

Appendix B.

Pretest Audience

Do you know what audience-centered writing is? Yes___ No___ Maybe___

If Yes or Maybe,

What do you think audience-centered writing is?

List strategies you use to adapt your writing to achieve audience-centered writing

Give an example of something you have read that was audience-centered.

Appendix C. Student Activity Handout (Audience Accommodation)

Directions: To explore specific strategies writers can use to adapt scientific discussions to a variety of audiences, compare the following articles on the same topic. You'll find they are clearly intended for different audiences. As you read, think about who these pieces are intended for, and what publications they are likely to appear in.

Rank each of the characteristics according to the level of specialized knowledge assumed on the part of the audience. Use a scale of 1 (general audience) to 5 (most specialized audience). Keep track of your group's consensus and the contrasting examples to illustrate each feature.

ARTICLE ANALYSIS:

Article Score Sheet

	Article 1	Article 2	Article 3	Article 4
Content				
Detail				
Vocabulary				
Organization				
Tone				
Visuals				
Format/Structure				
Readability				
TOTALS				

Appendix D. Post test Audience

Do you know what audience-centered writing is? Yes___ No___ Maybe___

If Yes or Maybe,
what do you think audience-centered writing is?

Which of the following are strategies for effective audience-centered writing?
(check √ as many choices as appropriate)
Establish rapport through good standards of etiquette
Use bias-free language
Adapt length to the level of interest of readers
Anticipate readers' interests in scope and development
Adjust technical information to the level of knowledge of the reader
Incorporate examples that are based on readers' experiences
Consider readers' perspectives in organization and arrangement
Use appropriate appeals (ethos, pathos, logos) to connect and engage readers
Include comparisons to explain unfamiliar concepts
Use visual presentations that are focused on the needs and expectations of the readers
Provide reader desired (formal or informal) references to support claims
Other____(write out)

Give an example of something that you have read that was audience-centered.

Appendix E. Excerpts of Student Narratives to Explain How Thunderstorms Form

This group selected an unusual angle for the narrator: a bird

> A wonderful day awaits my arrival on the other side of the seemingly endless corn field where the rest of my flock awaits. My wings are heavy after a long migration south, and I am anticipating the end of my journey soon. It is a relatively humid day, and the sun is shining brightly on the green abyss below me. Few clouds hinder the sunshine, and the temperature is rising fast. It almost feels as if my stomach is warmer than my back, meaning the air below me is warmer than the air above me. I have felt this sensation before, and in normal circumstances I would turn around because I sense instability, but my journey is almost over and I want to see my flock. It is difficult to fly in a level plane, and I notice myself steadily rising. In the distance there is a dark, anvil shaped cloud, probably because the sun is behind it.

This group selected the format of a recipe.

> Ingredients: ½ cup of sunlight, 2 ½ cups of air, a wallow of water vapor, a whisking nudge, one updraft
>
> Directions: Preheat sun to about 6000^{0} C. Prepare the air for rising by adding a wallow of water vapor. For better lifting results, apply recipe over a mountainous region. Place air under heated sun; let the air bake for about half the day. Once air is warmed, it will start to rise and transfer heat from the surface to the upper levels of the atmosphere, a process known as convection. As the parcel of air reaches an appropriate level, the water vapor will cool and a cloud is formed. At this point, adjust the temperature to below freezing, and some of the water vapor will turn to ice and others will turn to water droplets. Allow the opposite charges found in water droplets and ice particles to build up, and finally spark the development of lightning bolts and sound waves we hear as thunder. The cooking process is complete.

This group used common figurative language.

> The cold front is the first key ingredient needed to produce the forecasted weather. However the process of creating thunderstorms starts at the surface with the afternoon sun warming the air around us. Bubbles of moist air receive energy from the sun and start to rise from the surface. Unfortunately cold fronts are the air bubbles' worst enemy…Just like a car that runs on gasoline, thunderstorms need fuel in the form of rising warm moist air. The rising motions at the surface may start out small, but when combined with a forceful cold front, Mother Nature's has what she needs to produce a spectacular light and sound display.

Appendix F. Follow-up Audience Accommodation Assignments

1. Evaluate the introductory paragraphs from meteorological scholarly journals provided. Select and analyze a *general audience* for which this topic may be appropriate. Consider your subject from the perspective of your readers. In particular, answer the following questions.

    - What expectations does your audience have about your subject? About you as a writer?
    - What is your audience likely to know about the topic?
    - What firsthand experiences is your audience likely to have with the topic?
    - What terms are likely to be unfamiliar to your audience?
    - How will your audience likely use the information on this topic? What do they hope to learn?

    Adapt the paragraph for your chosen audience using the adaptation strategies we have studied. Be sure to specify the intended audience (by publication, background, age, interests, and goals). Compare your adaptation with the original, and explain the similarities and differences.

2. Compare www.weather.gov to www.weather.com. Are the audiences likely to be the same for these two sources of weather information? In a one-or two-page paper, identify and describe the audience adaptation strategies being used, and assess their effect on you as a member of the audience.

3. Creative comparisons, (i.e., similes, metaphors, and analogies) are useful to explain difficult scientific concepts to non-specialists. Using comparisons, a scientist is able to illustrate how a phenomenon is similar to or different from other phenomena.

    For example, in *Windswept,* (de Villiers, 2006) a book about the wind and the weather, Marq de Villiers's introductory passage describes the wind as follows.

    > The search for an understanding of wind and the weather it brings has been a constant of human history, for wind is a changeling that can bring blessings but also hard times. Wind can be soft and beguiling, seductive; the caress of a gentle breeze stroking the skin is one of the great pleasures of the human adaptation to our natural world. But sometimes wind can be deadly, intensifying violently into a kind of personal malevolence. Like a short-tempered and belligerent god, the wind has a power that can appear arbitrary, excessive, overwhelming, devastating, uprooting trees, wrecking houses, sinking ships, battering people, scarring psyches (pp.2-3).

    The author uses a simile to communicate the capriciousness and power of the wind.

    Accuracy and familiarity of the comparison are important when using this adaptation strategy. Although more precise terms may need to be replaced with less technical terms, strive to ensure the comparisons are <u>scientifically accurate</u>. Your goal is to simplify the writing, not the science. Select comparisons that gain the audience's interest and comprehension. (Often writing about meteorological phenomena is easier than in other science fields because of the general public's greater awareness of weather as compared to other technical fields.) In fact, many wind-related expressions are part of our everyday vocabulary: strong as the wind, moves like the wind, winds of change, and even in Bob Seger's lyrics--Runnin' against the wind.

    In "Violent Past" (Science News, May 26, 2007), Ron Cowen uses creative comparisons to explain scientific data about the sun's formation and the effects of massive winds. Read the article below. In a one-or two-page paper, identify the creative comparisons and provide an analysis for how the language of the article makes the information more accessible. Give specific examples. Also consider the numerous uses of creative comparisons with the sun in our everyday speech. Give examples of these familiar expressions. What conclusions can you draw about the use of creative comparisons in technical writing for a general audience?

Violent Past

***Ron Cowen*. Science News. Washington: May 26, 2007. Vol. 171, Iss. 21; pg. 323, 1 pgs**

A big bully pummeled our sun in its infancy, fatefully alluring the composition and evolution of the solar system, a new study suggests. The heavy, in this case, was a nearby, massive star. First, the massive star pounded the young sun with fierce winds. Then, the tyrant exploded, blasting the sun with shock waves that suffused it and its embryonic planets with iron.

Evidence for this early, violent episode comes from meteorites-rocky leftovers from the planet-forming process. Martin Bizzarro of the University of Copenhagen and his colleagues set out to determine the amount oi iron in the early solar system. To do so, they measured niekel-fio, a decay product of iron-fit, in eight meteorites known to have formed at different times during the first 3 million years of the solar system.

The meteorites that formed more than about a million years after the start of the solar system contain significantly more nickel-60 than do those that formed earlier, the team found. In a neighborhood of young stars, only a supernova could have produced iron-60, the parent of that nickel.

In contrast, all the meteorites, regardless of age, contain about the same proportion of aluminum. That element doesn't require a supernova source.

These findings drastically revise a 30-year-old story line for the origin of the solar system, the researchers say in the May 25 Science. In that scenario, a supernova triggered the collapse of the ball of gas and dust that became the sun. But the new data suggest that the sun had already formed about a million years before the supernova explosion.

The sun acquired its aluminum at birth or immediately afterward, Bizzarro says. The tact that all the meteorites had about the same amount of that element suggests that its source was a copious wind expelled by a massive star. The star had to be about 30 times as heavy as the sun, Biyyarros team calculates. Within a million years, that behemoth--which would have resided only about a light-year from the newborn sun--went supernova, driving grains of iron-60 into the sun as well as into surrounding material that would eventually form planets.

"This is a convincing argument that you had an injection of iron-d'O about 1 to 2 million years after the birth of the sun," comments Steve Desch of Arizona State University in Tempe. The only source for that iron "that makes any sense whatsoever is a nearby supernova," he adds.

Massive stars tend to be born in clusters, and the study suggests that the sun and its explosive neighbor were products of a starmaking factory that might have yielded thousands of stars some 4.5 billion years ago.

It may seem surprising, Desch says, that a massive star could explode so close to the newborn sun without destroying it. But work by Desch and his Arizona State colleagues Jeff Hester and Nicolas Ouellette, to be reported in an upcoming Astrophysical Journal, indicates that a newborn star could survive a supernova that pops off as close as a third of a light-year away.

Still, theorist Frank Shu of the University of California, San Diego cautions that a nearby, massive supernova might generate a host of additional effects on the young sun.
The Orion star-making factory is one of the closest stellar nurseries to Earth. New evidence suggests that the sun was born in such a factory and that a massive neighbor exploded soon after the sun's birth.

4. Review publications on a topic within meteorology written for educated non-specialists (e.g., *Scientific American, National Geographic, Science News).* Select an article that uses creative comparisons to communicate to this general audience. In a one-or two-page paper, identify the creative comparisons and provide an analysis for how the language of the article makes the information more accessible. Include several specific examples.