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Teaching Climate Change Concepts and the Nature of Science: A Library Activity to Identify Sources of Climate Change Misconceptions

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Teaching climate change concepts and the nature of science: A library activity to identify sources of climate change misconceptions

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A library activity was developed in which students found information about climate science misconceptions from popular and scientific literatures. As part of the activity, students developed a rubric to evaluate the credibility and type of literature sources they found. The activity prepared students to produce an annotated bibliography of articles, which they then used to create a training document about a climate science misconception for staff at a local science center. Evaluation of annotated bibliographies showed that students were able to distinguish between popular and scholarly literature but struggled to identify primary and secondary sources within the scholarly literature. In the training documents produced four weeks later, students retained information literacy skills and demonstrated aspects of scientific literacy, using language that addressed common barriers to scientific literacy such as the idea of scientific consensus. In self-assessments, students felt that they could identify and evaluate information resources related to climate

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science.

Introduction

In May 2013, a news article titled, "Dinosaurs 'gassed' themselves to extinction, British scientists say," appeared in social media posts.[1] The news article, from a prominent American media organization, suggested that plant-eating dinosaurs might have caused their own demise by producing clouds of methane, a greenhouse gas, which increased the global temperature and led to catastrophic climate change.[2] The news article referenced a journal article from *Current Biology*, so the authors of this chapter, a librarian and a chemist, accessed the original article to learn more.[3] The journal article that attracted national coverage was two pages in length, contained only estimates of calculations, and was written by two biologists with little experience in climate science. The news article did not summarize a peer-reviewed research article, but distorted information from a letter published in the "Correspondence" section of a scientific journal. The author of the news article either misinterpreted the information presented by the scientists, or approached the reporting with deliberate bias. Either way, it is unlikely that casual readers, even those critical of the news story, would have located the original source to evaluate it and discover its context and content.

This news article about dinosaurs, and the work required to interpret the information behind it, inspired the authors of this chapter to design a new project for students in a course on the chemistry of climate change. Working together on the project led the instructors to explore the idea of improving scientific literacy and information literacy simultaneously by helping students overcome common barriers to these two inter-related types of literacy.

Scientific and information literacy

Scientists and the general public alike are bombarded with scientific information from a variety of sources. Interpreting this information requires some degree of scientific literacy. As such, improving scientific literacy is widely recognized as an important goal for K-12, post-secondary, and informal education in the United States.[4–7] An important aspect of scientific literacy is the ability to understand the nature of science: what science is, and how it is conducted and communicated.[5,8–10] In order to understand the nature of science, one must apply the core skills of information literacy – discovering and evaluating information and analyzing the context and processes in which the information was created.[11,12] Because information literacy and scientific literacy require some similar skills and cognitive abilities, integrating these literacies in class activities may be both efficient and meaningful.

Barriers to accessing and understanding science information

When readers approach scientific writing, they require skills in information literacy and scientific literacy. At a basic level, people need to understand the difference between popular and scientific literatures, but they also need to differentiate between primary and secondary sources in the scientific literature, determine the skill and training of authors who wrote the information, and identify whether data and/or opinions are expressed in an article. Even with these skills, it may be difficult for readers to access science articles due to their publication in academic journals with a high subscription cost. Finally, even readers with easy access to science articles and the necessary information literacy skills to evaluate them may still encounter barriers to understanding the scientific knowledge under discussion, including how scientists process that knowledge.

Sinatra, Kienhues, and Hofer describe three main challenges to public understanding of science: difficulty in understanding the process of scientific reasoning, misconceptions about the science, and unconscious biases.[9] Difficulties in understanding the process of scientific reasoning arise when non-scientists are unprepared to handle knowledge conflicts (epistemic knowledge) and/or they are more likely to be persuaded by arguments that appeal to self (personal pleas) rather than logic. In the context of climate change, the current scientific consensus is that climate change is caused by human-induced increases in atmospheric carbon dioxide, but cognitive conflict may arise when readers find alternate explanations. Arrhenius first proposed the link between global temperature and atmospheric carbon dioxide in the 1700s, but since then, other scientists argued that the earth's tilt, solar radiation, and volcanic dust have a greater effect on atmospheric temperatures than carbon dioxide.[13] Even today, a few leading scientists disagree with the consensus that carbon dioxide is the primary cause of climate change.[14] Most scientists understand the way that scientific consensus changes over time, and recognize the various knowledge conflicts in this process, but non-scientists may find it difficult to reconcile these competing arguments, especially when they appear in scientific journals. As such, the Yale Program on Climate Communication considers public misunderstanding of scientific consensus to be a "gateway belief" that may prevent people from accepting scientific arguments for climate change.[15]

The second barrier to public understanding of science relates to misconceptions about the science. Non-scientists reading about climate change may hold misconceptions about the science, which leads to confusion or misunderstanding. For example, many Americans erroneously believe that the ozone hole contributes to global warming (74% of American adults surveyed in 2010, according to one study).[7] This misconception, which conflates two separate concepts that both relate to gases in the Earth's atmosphere, may lead to the idea that Earth's temperature is increasing because the ozone hole allows more heat from the sun into the planet's atmosphere.[16] The ozone hole misconception could also lead people to believe that increasing atmospheric gasses may ‘plug’ the hole in the atmosphere and prevent further warming.[17] Misconceptions about important science concepts, such as these, may prevent students from interpreting information correctly or using appropriate search terms to find credible resources on complex scientific issues such as climate change.

Learning about science topics can also be hindered by the third challenge to public understanding of science, unconscious bias towards previous ideas/knowledge. Scientists and non-scientists alike may be motivated to find information that fits their world view. This type of bias, conscious or unconscious, is defined as motivated reasoning. For example, a person who believes that vaccinations cause autism may find information that disproves their belief, but they may be more likely to select and read articles that reinforce their beliefs. This bias in information selection may exist even if the science in the article with which they agree is not as strong as the science in the article that disproves their belief. Multiple studies have linked motivated reasoning and rejection of climate science, illustrating how individuals’ experiences and world views can influence what they believe about scientific information, or what information they choose to seek out and consume.[18–21]

Educators use many approaches to overcome these barriers that students face when trying to understanding science, including focusing on information literacy. Carefully constructed information literacy assignments can lead to improved scientific literacy in both those information literacy assignments and in later assignments.[22–28] Educational psychologists have shown that directing students to review the structure and source of a scientific text can improve understanding of scientific information.[29] In a non-major science class, students who were taught how to evaluate the reliability of sources of scientific information about Mt. St. Helens improved their ability to use online resources to find credible scientific information about other topics, including controversial topics.[22] Students who were instructed to find retracted publications also developed deeper understanding about the ethics associated with science.[26] When dealing with controversial topics like climate change, students may experience great difficulty in overcoming the barriers to understanding science. Therefore, it has been suggested that students should read articles explaining multiple sides of an argument so that they encounter the misconception and scientifically correct concept simultaneously.[27,30–32] In summary, multiple studies show that assignments can succeed in helping students overcome barriers to learning science by asking students to develop conceptual models of the source and type of scientific information and then providing opportunity to use those models to investigate other scientific topics.

This chapter builds on prior work by describing how information literacy and scientific literacy skills were developed in a chemistry class that focused on climate change. The assignment that the authors designed for the class utilized best practices for developing scientific and information literacy. Students developed a rubric (mental model) to differentiate between different article types, which they then used to identify specific articles for an annotated bibliography. Students then worked in groups to produce a training document about a climate science misconception for staff at a local science center. Assignments were carefully structured to address barriers to understanding science by asking students to determine the source and type of information, acknowledge biases that may have been present in the information, and discuss how the misconception may have come from misunderstandings of the scientific literature. The project described in this chapter focuses on the chemistry of climate change, as it was the focus of this particular course. However, the general principles discussed here can be extended to other topics.

Course description

Climate Change: Chemistry and Controversy was a five-credit course (quarter system) developed for non-science majors at a private comprehensive university. This 10-week-long course, described previously,[33] served 16 first-year (freshman) students. The goal of the course was to help students evaluate and communicate climate change misconceptions through development of foundational content knowledge in climate science concepts, development of critical thinking skills, understanding of the nature of science, and application of their skills to a service project. Throughout the course, students learned the chemistry behind climate science and were provided opportunities to learn how climate science data were produced and published. The course utilized outcome-based design, which meant that each outcome was paired with course activities and assessments.[34,35] The course had several learning outcomes but two outcomes were specifically related to information literacy. The relevant outcomes were:

Upon successful completion of this course, students will be able to:

(1) evaluate the reliability and interpretation of data from various sources to analyze the impact of climate change on society.
(2) locate scientific information from a range of paper-based and online sources.

In order to meet these goals, students participated in two course activities: a session with the science librarian culminating in the submission of an annotated bibliography and a group project to produce a training document that discussed a climate change myth for staff at a local science center. The final training document had to include a variety of references, including a source exemplifying the climate change myth. Students worked on the project for 6 weeks. Two two-hour class periods were dedicated to the project; one for the library activity and one for peer review of the project. Prompts for the annotated bibliography and final project are provided in Table 1. The rubrics used to evaluate the annotated bibliography and training document are included at the end of this chapter.

Table 1: Example Prompts for the Annotated Bibliography and Final Paper

Annotated Bibliography	Your objective is to identify at least one source of your assigned misconception (newspaper, TV show, government document, senate hearing, internet meme, journal article, etc.) and then explore the scholarly literature on the topic. When possible, identify the earliest source of the misconception and if you can, explain why it was made (incorrect interpretation of data, blatant misstating of data, something that was later disproved due to better instruments). You also need to find 3 peer-reviewed articles with data that disprove the misconception.
Final Project	Each group will prepare a document for staff at the science center. You will be evaluated based on your ability to: • identify climate change misconceptions • identify and use peer-reviewed data to disprove misconceptions • explain information that portrays the science correctly without oversimplifying or using overly complex language. • portray certainty/uncertainty in data. • propose ways of overcoming the misconception without being preachy. • write clearly and succinctly. The final draft should have 5-10 scholarly sources.

Library activity

The library activity took place four weeks into the academic term, a little less than halfway into the academic quarter, prior to the first exam. The placement of the activity was such that students had a basic understanding of climate and chemical concepts before starting their literature research. The library activity consisted of three parts: (1) creating a rubric to distinguish between types of literatures, (2) using the rubric to assess and categorize articles, and (3) creating an annotated bibliography of articles for the final project. Before the library session, the professor had provided a list of climate change misconceptions derived from a list at SkepticalScience.org.[36] Students had been assigned to form groups, select a climate change misconception, and prepare to find information related to the misconception.

The guided inquiry session, designed by the librarian and the professor, had the following goals:

At the end of the library session, students will be able to:

- Distinguish between articles from the scientific literature and those from the popular literature.
- Articulate the main difference between subscription databases and other search tools for the open web.
- Find the subscription databases on the library web site.
- Search for and locate articles in a subscription database.

Library activity part 1: Students create a rubric to distinguish between literatures

As a preparatory activity prior to the library session, the librarian and professor asked the students to examine, compare, and contrast three articles and determine distinguishing characteristics of each. The three articles were:

- "Dinosaurs 'gassed' themselves into extinction, British scientists say"[1]
- "Could methane produced by sauropod dinosaurs have helped drive Mesozoic climate warmth?"[3]
- "Enhanced chemistry-climate feedbacks in past greenhouse worlds"[37]

At the start of the 2-hour session, students were divided into groups and given the task of collaboratively examining the articles, building on the analysis they had done as homework. Without receiving prior instruction about evaluating information or distinguishing between popular and scholarly literatures, groups of students were asked to look for differences and similarities in the articles. They were told that one or more of the articles were "popular" and one or more were "scholarly" or "scientific," and instructed to work in small groups to develop a draft list of characteristics of scholarly and popular literatures based on the differences in the articles they observed.

Following the group work, the full class discussed the differences observed in the articles, shared their draft lists of characteristics, and compiled them in a shared document visible on a large screen. Class discussion, facilitated by both the faculty member and the librarian, led to a collaboratively-created list of characteristics of scientific/scholarly and popular literatures, such as: audience (is the language aimed at the general public or scientists/experts?), authors (what are the credentials/positions of authors?), design (is the article colorful or text-heavy?), references (does the article have a long list of references, or few, or none?), and more. This discussion led to brief coverage of broader concepts relevant to scholarly communication, such as the peer-review process. The librarian and professor also guided the discussion so that students could learn to distinguish the difference between primary sources within the scientific literature (e.g. research papers) and secondary sources within the scientific literature (e.g. commentaries and review articles). The students were then able to refer to these lists of characteristics, which they developed together (rather than receiving from the instructors), when they were seeking and evaluating articles for their project. The first part of this activity took 35 minutes of the class.

Library activity parts 2 and 3: Students locate and evaluate information resources on climate change

The first product required for the course's final project was an annotated bibliography of resources about their selected climate change misconception. Following the group activity, the librarian provided a brief overview of starting points for discovering resources for their annotated bibliography. These starting points included tools on the open web, such as a site for searching television news transcripts (TV News Archive: https://archive.org/details/tv), as well as library resources, such as a subscription database that includes science articles, news articles, and more. Rather than demonstrating all of the database’s features, she explained that they could construct their own understanding of the database by exploring it themselves, in small groups, and with help from the instructor as needed. Students working on similar misconceptions could work together to find appropriate resources but had to cite different resources.

For the remainder of the session (about 1.5 hours), students were given time to search for articles for their annotated bibliography, with the professor available to answer questions. Before leaving the session, students were required to find sources from the popular literature exemplifying their selected climate change misconception, as well as sources from the scientific literature providing evidence related to their misconception. As part of the activity, students were instructed to evaluate the credibility of all the literature sources they found, by determining if sources were written by expert scientists, contained real scientific data, and were written for a scientific audience. These criteria linked to the characteristics/qualities of scientific and popular literatures that the class had developed together at the start of the session. The activity prepared each group to produce an annotated bibliography of articles, which they then used to create a training document educating science center staff on the science behind a common climate change misconception.

Results: Student work and evaluations

We evaluated student attainment of the course's information literacy goals by looking at three types of evidence: student responses to the annotated bibliography assignment, resources used in the final project, and student self-assessment of learning. The results from each of these are described below. Evaluations described below are independent of the rubrics provided in the appendix. The data presented below are anonymized so that students can not be identified. This work was granted exemption from the university's Institutional Review Board (IRB).

Evaluation of annotated bibliographies

Students submitted their annotated bibliographies electronically one week after the library session. After grading the assignment, the instructor then anonymized the bibliographies and shared them with the librarian for evaluation. The librarian evaluated the bibliographies to determine whether students could correctly identify sources from the popular literature and scientific literature, as well as primary sources within the scientific/scholarly literature. The results listed below are from the librarian evaluation. The instructor grade was not known to the librarian and did not influence the evaluation described below.

The purpose of the annotated bibliography was to determine if the students could find and identify the types of information resources needed to complete their final project. In order to complete the assignment successfully, students needed to apply the skills they learned in the library activity. Each person was asked to find a minimum of three articles related to their climate change misconception: at least one article exemplifying the misconception in the popular media, and at least two research papers, or primary sources from the scholarly literature, that provided evidence related to the misconception. Students were asked to provide a brief description of the source that addressed the following questions.

- How do you know this is a credible source?
- How is the content of this article relevant to your topic?

- How do you expect to utilize the information in this article?
- Describe anything else that you think is interesting.

Results from the librarian's evaluation of annotated bibliographies are shown in Figure 1. In the annotated bibliographies, 100% of students (16) identified sources from the popular literature correctly. Over 80% of students (13) could identify sources from scholarly/peer-reviewed literature. Students struggled to identify primary sources within the scholarly literature, with only 69% of students identifying one primary source and 38% of students identifying two primary sources correctly.

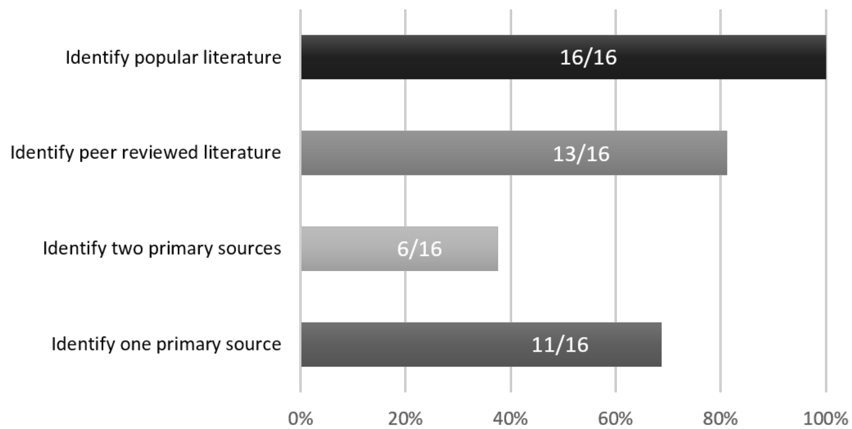

Figure 1: Percent of students able to correctly identify sources from the popular literature and the scholarly literature, directly after the library activity.

Students examined a variety of evidence to analyze their articles, but most of their evidence focused on three main points: whether the journal was peer-reviewed, the expertise of the people who performed the research described in the article, and whether the expertise of the author matched the content of the article. Here is an example from a student describing the identification of a peer-reviewed article.

> "This article is trustworthy because it is from the peer reviewed scientific publisher Journal of Climate, part of the American Meteorological Society. The authors are affiliated with climate and environmental physics, astrophysics, earth and ocean sciences, and research focusing on climate change. These qualifications would enable them to be well-versed in the area of climate change, temperature increase, and the causes and effects of these and the ramifications they imply for the future."

This response suggests that the student understood two issues covered in the library session: the concept of peer review and the critical evaluation of author expertise/authority with respect to the content of the source.

The students who were unable to correctly identify sources from the scholarly literature made two types of errors. One confused an editorial in a peer-reviewed journal with a peer-reviewed article; the other believed an article from a trade magazine was a peer-reviewed article from the scientific literature.

The first student provided reasoning that demonstrated awareness of peer review but failed to distinguish between editorials and research articles:

> "This article is credible because it comes from the academic journal, Pediatrics, which has been peer reviewed. Pediatrics is published by the American Academy of Pediatrics, and the article has listed its contributors."

In contrast to the first student quoted, this student neglected to check that the credentials of the author matched the context of the article. Additionally, the student did not analyze the structure or genre of the article. In this case, the journal is considered part of the scholarly literature because its research articles are written by scientists and are peer reviewed, but the editorial/commentary was not peer-reviewed, so it is not considered a scholarly source, which the student did not understand. The library session had covered the presence of non-peer-reviewed articles (such as editorials) in scholarly journals, but this student was not able to recognize such an article. This oversight indicates a lack of understanding of the concept that "authority is constructed and contextual," as described in the *Framework for Information Literacy in Higher Education.*[38] Even though the article is written by an expert in the field and is in a peer-reviewed journal, most scientists (including this course's instructor) would judge this article less authoritative than a research article, based on its context as an editorial. The student's error is similar to the error made by the journalist who wrote the news article claiming that methane-producing dinosaurs could have caused global warming.

Another student who incorrectly identified a scholarly article assumed that a trade journal, *Hydrocarbon Processing*, was part of the scholarly, peer-reviewed literature:

> "I believe that this article is credible on the grounds that it was published relatively recent, 2009. It was peer reviewed twice by Chemical Engineering Progress. Some background research on the Chemical Engineering Progress shows that it is the world's leading organization for chemical engineering professionals in over 90 countries and has a credible monthly magazine published."

The student states that the article was peer reviewed by *Chemical Engineering Progress*. However, *Chemical Engineering Progress* is a trade magazine, which typically does not publish peer-reviewed research articles. Additionally, the student does not correctly identify the source of the article, *Hydrocarbon Processing*, which is a trade magazine for the petrochemical industry, similar to *Chemical and Engineering News* for chemists.[39] To a non-scientist, a trade magazine may appear similar to a scientific journal because both contain technical information and significant amounts of jargon. However, it is likely that this student did not look at the magazine or take the time to read the full article, as they did not provide a date of the publication and they recorded an incorrect name of the article. The library session had not covered trade magazines and how they differ from scientific journals or popular magazines. This student's error suggested a point of improvement for future library session lesson plans.

Overall, the annotated bibliography assignment showed that students could identify and apply the criteria necessary to distinguish between scientific and popular literature. However, some students still struggled to apply all criteria with articles placed in an unexpected context, as exemplified by the choice of an editorial in a science journal or a jargon-filled article in a trade magazine.

Evaluation of science and information literacy in the final project

After the library session and annotated bibliography, students worked in groups of four to create an informative paper of two to three pages aimed at helping a science interpreter at the Pacific Science Center in Seattle respond to a frequently encountered misconception about global warming. Information literacy goals were explicitly part of the final assignment: students needed to identify at least 4-5 sources for their paper, including peer-reviewed articles with data directly related to the misconception. Before evaluation by the professor, the document was reviewed by students in the class and by staff at the science center.

For the quarter described in this chapter, students investigated four climate science misconceptions:

- Global warming is caused by the hole in the ozone layer.
- Carbon dioxide is not the most potent greenhouse gas, so there is no need to regulate it.
- Venus is also warming, so our planet is warming due to increased solar output.
- Human contribution to carbon dioxide is tiny, thus we cannot be the cause of increased levels of this gas.

Because students worked in groups of four, it is not possible to describe specific student performance. However, it is possible to determine if groups demonstrated an understanding of information and/or scientific literacy.

In their final projects, students provided narratives that directly discussed the three barriers to understanding science information discussed by Sinatra, et al.: scientific reasoning, misconceptions, and motivated reasoning.[9] All projects discussed the idea of scientific consensus, but two groups specifically discussed ways in which uncertainty in scientific information can be misreported in the media. One such example is from the group researching human contributions to carbon dioxide:

> "Misunderstandings in the general public regarding human contributions to carbon dioxide (CO_2) in the atmosphere have often resulted from scientific arguments. One such example was an article appearing in Forbes which claimed that human carbon emissions only accounted for ".9 of 1 percent" of the greenhouse effect (Hendrickson). Some scientists, particularly those whose primary focus of study is not on climatology or a related field, focus on data that they have heard before instead of the findings of more recent studies. For instance, many scientists refute the claim that mankind's burning of fossil fuels is impacting the climate by arguing that there have been temperature fluctuations long before humans were emitting CO_2 into the atmosphere. Articles appearing in scientific publications have made additional claims that the "average temperature has remained roughly level globally" while also acknowledging that human carbon emissions have increased in the last century (Paterson). While articles such as these [Forbes article] reference multiple scientific articles, they fail to address the science behind current trends. The media will often then misinterpret arguments such as this and accept them as truth, failing to provide data to support their claims."

One group provided a nuanced explanation of how misconceptions and motivated reasoning influence scientific understanding. In particular, this group discussed how skeptics can select specific studies in ways that contradict the general scientific consensus:

> "When encountering this misconception, it is important to note that much of the confusion is rooted in scientific errors that are often difficult to understand. Take the following graph from The Washington Times for example. In their article Global-warming fanatics take note; sunspots do impact climate, the misconception of the sun effecting climate change is supported by what seems like a well put together graph. However, if we look deeply into the sources of this data, we find that the entire study is called into question, as all the data reported came from locations about the poles of the earth. Basic scientific errors or biases are not taken into account, and it creates data that does not represent an overall trend…. there have been many studies taken using nearly the same

> techniques and the same instruments, but with unbiased methods that take the entirety of the earth's climate into consideration, show a very unrelated trend."

Other groups did not use specific language that demonstrated scientific or information literacy. However, in reflection papers assigned outside of the course, most students described ways in which they recognized unconscious bias, corrected their own misconceptions, or understood the process of scientific reasoning.[33] Additionally, student groups used language in their final documents that described the iterative process of scientific reasoning (such as the CO_2 example above) and ways in which unconscious biases and motivated reasoning lead to articles that contradict scientific consensus (such as the sunspots example above). Finally, in their projects, students provided a wide number of resources, both popular and scientific, showing that as a group, they could find and evaluate different types of information resources about climate science topics.

Student self-evaluation of information literacy outcomes

At the end of the course, students self-reported how well they met the information literacy outcomes of the course. The data are reported in Figure 2. Overwhelmingly, students felt that they met the two learning outcomes: the ability to locate scientific information from a variety of sources and the ability to evaluate reliability of data related to climate change. Only one student felt that they had not met the outcome, stating, *"For locating scientific information, we only focused on that for a very short period of time and I only used one source when actually looking."* As the survey was anonymous, we can only speculate that this student was unable to locate a wide range of sources and thus scored low on the annotated bibliography.

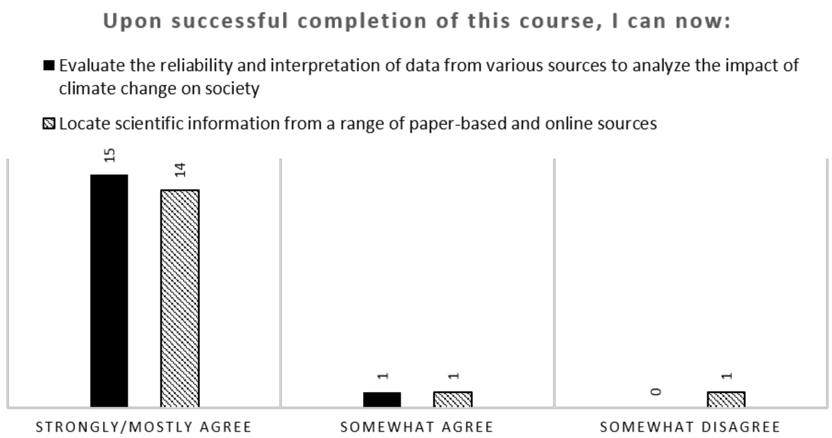

Figure 2: *Student evaluations of information literacy outcomes. (Survey data was collected on the last day of class using a 6-point Likert scale. The survey was issued one week after the final project due date, before students had received scores on their final project. The numbers above each column indicate the number of students who selected the option.)*

Discussion: Integrating science and information literacy

The data presented in this chapter suggest that science assignments incorporating information literacy learning outcomes can help students overcome a key barrier to scientific literacy — the difficulty in understanding scientific reasoning and the related assumption that scientific knowledge is certain. Assignments that ask students to consider the evolving nature and limitations of scientific truth[40] and help them overcome other common barriers to understanding science,[9,41–43] are necessary if students are to learn how to interpret scientific information.

The assignment described in this chapter approaches these barriers to understanding science in several ways. First, the assignment and library activity utilize a learning cycle approach, which reflects the nature of science and scientific reasoning with an emphasis on process, exploration, and discovery. This learning cycle approach, which has been shown to work effectively in many academic settings,[44,45] includes phases of exploration, concept development, and application. Approaching teaching and learning in this way also reflects the information literacy threshold concept of "research as inquiry," especially the idea that the research process may include "points of disagreement where debate and dialogue work to deepen the conversations around knowledge."[38]

By working with the chemist author on this chapter, the librarian leading the information literacy sessions incorporated this learning cycle approach, which engaged the students in exploration at the start of the activity. This approach contrasted with some of the previous information literacy sessions led by the same librarian, in which the instructional approach was more traditional, with students receiving a short lecture on scholarly and popular literatures before applying that information in an activity. With this focus on "research as inquiry" and an emphasis on the nature of science, the librarian and chemist designed the library activity to allow the students to construct and refine their own understanding of evaluating sources, and then provided opportunities to practice applying these concepts in multiple assignments, iteratively building up to the final project.[46] This learning cycle approach seemed successful, as all students seemed engaged during the activity in class and the majority of students were able to correctly identify the types of information required for the annotated bibliography assignment. Students also retained these skills in the final project four weeks later.

Assignments like the one described in this chapter can also help address misconceptions about science content, another barrier to understanding science. Educational researchers have suggested that the process of correcting misconceptions can be more difficult than learning concepts for the first time because students must break connections with old concepts before learning new concepts.[27,47,48]

In an attempt to help students work through the difficult process of un-learning misconceptions, this activity asked students to identify and analyze contradictory sources, which has been shown to lead to conceptual change.[33] Some of these sources upheld the climate change misconception, and others refuted it. In the final documents, all groups were able to provide both a popular source that described the misconception and a scientific source which related to the misconception. In addition, the majority of students also reported an ability to evaluate the reliability and interpretation of data from climate sources (Figure 2), suggesting that students believed that they were able to use these information literacy skills to critically approach misconceptions present in the sources they consulted. One student discussed misconceptions in her reflection, stating,

> "This class really opened my eyes to everything about global warming and how important it is to our future to correct misconceptions on global warming and learn the true facts before its [sic] too late."

By working with these contradictory sources, students focused on the misconception as well as the credible scientific information, rather than just ignoring the misconception. Confronting these sources also helped students learn about the complexities of research as an iterative process that may include contradictory findings. During class, the instructor often pointed out the uncertainty in climate change data and the process of scientific consensus building over time. The final documents that students produced suggested that they understood some of this process, and two groups explicitly discussed the role of scientific consensus in understanding these misconceptions.

Reflection and authentic audience as motivators for conceptual change

According to Sinatra and Danielson, “strong emotional reactions may be produced when prior knowledge, beliefs, and identity conflict with new information.”[49] They also argue that emotions may be heightened when discussing global challenges such as climate change, stating that “even students who understand and accept... climate change may find these ideas disheartening.”[49] Thus when encouraging students to seek out sources of information that conflict with each other and perhaps even conflict with the students’ assumptions about science or worldviews, instructors should consider ways to help students acknowledge and explore their own biases in a low-stakes way. Reflection papers and journaling can be effective in helping students deal with biases that are emotionally charged.[50]

In this course, students were asked to provide four short reflections (each 2 to 3 paragraphs long) through an informal blog to other students in the class.[33] In these reflections, students provided evidence that they were encountering their biases and beliefs during the course. This was particularly evident in one reflection from a student:

> “I distinctly remember during a presentation in my government class last year ... [where a government official] stated that her party did not even believe that global warming was happening, let alone that it was an issue that needed to be dealt with. Although I found that to be shocking, I disregarded the statement …[Now]… I can no longer dismiss this statement. Because climate change is a global issue, the government must intervene in order for change to happen.”[33]

This student mentioned a specific instance where her prior experience (high school class) was contradicted by her college experience. By noting the discrepancy between these experiences, she recognized how information provided in the prior experiences may have been biased.

Motivated reasoning, or bias (whether conscious or unconscious), has been described as another major challenge to learning science.[18–20] Teachers can avoid potentially singling out one “biased student” by designing assignments that require all students to identify articles that contradict the scientific consensus. This assignment required students to search for and evaluate multiple types of information, including articles whose arguments or data directly contradict each other, as discussed above. Engaging in this type of searching may teach students about the bias inherent in the search for information. In a reflection post one student provided an excellent description of bias in selecting sources:

> "As we have seen in class, scientists use different types of graphs and data to show the public what they "want" them to see and find ways to hide the ones that could be hurtful to their research/hypothesis. It is extremely important when doing scientific research to look at many different articles and at how valid/official they are before forming a final conclusion."[33]

Reflections such as this one, with its mention of "valid/official" with respect to articles, suggest that students not only learned about bias in searching, but they were able to connect the idea of bias and scientific authority. This comment about validity of sources connects to the information literacy threshold concept that "authority is constructed and contextual."[38]

To help motivate the students to do the intellectual work required to overcome common barriers to learning new science, the instructor decided to provide an authentic audience for the students' final projects. All of the student groups' final documents were provided to staff at the Pacific Science Center. The projects were to be used to train staff in further educating patrons about climate change misconceptions. Student comments on course evaluations suggested that the authentic audience was indeed a motivating factor. One student said, "Feeling I had a real impact on people's perceptions just motivated me to address this topic to a greater extent."[33] Staff at the science center found the documents interesting, but ultimately decided not to use the documents for training, because they were too dense with information. In future iterations of this course, we propose that students focus more on communicating this information effectively to an identified audience beyond the instructor or the classmates.

Conclusion

A general goal of information literacy instruction is to equip students with "the critical skills necessary to become independent lifelong learners."[12] Non-scientists reading scientific information or popular source summaries of scientific information, such as the dinosaur article that launched this project, may be able to better encounter and understand such information throughout their lives if they possess basic skills in information literacy, including the ability to evaluate information and to understand the context in which the information was created. Projects like the one described in this chapter can help achieve both scientific and information literacy goals in ways that are meaningful to non-science majors. Additionally, teaching the “nature of science - that is, what science is, how it is conducted, and what practices are or are not scientific,” including science communication practices and information literacy, may help educators “improve public understanding and acceptance of science” in important areas such as climate change.[49] By strategically combining information literacy and scientific literacy exercises, it is possible to successfully equip students with real-world application of these related forms of literacy.

Appendix – Rubrics

Rubric 1 - Rubric used by instructor to evaluate annotated bibliographies.
Rubric 2 - Rubric used by students to evaluate the work of other students.

Note: Rubrics are provided for pedagogical purposes. These rubrics were not used in the librarian-led evaluation of annotated bibliographies described in this chapter.

Rubric 1 - Rubric used by instructor to evaluate annotated bibliographies

Identify articles from popular sources and Academic Search Complete		
10 9 8	7 6 5 4	3 2 1 0
Meets assignment specs of finding at least one article from popular sources and one article from Academic Search Complete.	Generally meets assignment specs for using popular sources and Academic Search Complete.	Generally fails to meet assignment specs or show ability to use Academic Search complete.
Identify five articles/sources		
10 9 8	7 6 5 4	3 2 1 0
Meets assignments specs of finding at least five articles; one of them from the popular literature, two primary sources, two others.	Generally meets assignments of finding at least 5 articles but many miss one or more of the following; one from popular literature, two primary sources, two others; or incorrectly identifies articles.	Generally fails to meet assignment specs, explain search process, or show ability to use Academic Search complete.
Correct APA format		
10 9 8	7 6 5 4	3 2 1 0
Cites articles correctly using APA style for “Reference” list.	Generally follows APA style but with missing elements or some mistakes in ordering or punctuation of data.	Doesn’t follow APA style or provides no references.
Summary of Articles		
20 19 18 17 16	15 14 13 12 11 10	9 8 7 6 5 0
Complete, clear, useful summaries of articles; puts source's argument into writer's own words with minimal quotation; effective analysis of article's usefulness for writer's purpose.	Summaries are satisfactory, but less complete, clear, accurate, balanced, or idea-centered; may be less effective than a 16+ in analyzing each article rhetorically or analyzing its usefulness.	Summaries are too short, vague, or unclear to be useful. Reader can’t benefit from writer’s research; may be overly thin or not address required components of rhetorical analysis and evaluation of usefulness.

Rubric 2- Student Peer Review

Misconception #

Names of people reviewing this misconception:

<u>Statement of Misconception</u>

Text.

Professional	Insufficient	Unprofessional
Text is complete and concise. Misconception clearly explained.	Text is wordy or incomplete in some sections. Misconception not explained.	Text is missing. Contains no description of misconception.

Briefly describe the misconception:

Comments/suggestions for improvement.

Are references to sources of the misconception provided?

Professional	Insufficient	Unprofessional
Includes more than one non-technical source of the misconception. Link between misconception and initial source is clear.	Includes at least one non-technical source of the misconception. Or link between misconception and initial source is unclear.	Does not include non-technical sources of the misconception.

Briefly list the non-technical references used:

Comments/ Suggestions for Improvement:

<u>Discussion of Scientific Information</u>

Is Basic Terminology Explained?

Professional	Insufficient	Unprofessional
Text is complete and concise. Technical jargon is used sparingly and is well-defined/ explained.	Text is wordy or incomplete in some sections. Technical jargon is used often but some explanation is provided.	Text is missing or entirely technical. Contains no description of jargon.

Briefly list the technical jargon that is used and the definition of this jargon:

Comments/ Suggestions for Improvement:

Are the data/figures presented in a logical, organized, professionally formatted fashion.

Professional	Insufficient	Unprofessional
Presentation choice (table, graph, or figure) enhances understanding. Clear legends/captions are included.	Presentation confuses understanding of information. Legends/captions are vague or difficult to follow.	Presentation choice makes understanding the data impossible. Legends/captions are missing.

Briefly describe the format of tables and graphs. Do captions match the graphics?

Comments/ Suggestions for Improvement:

Does the data choice, data processing, figures support or contradict the misconception?

Professional	Insufficient	Unprofessional
Contain ample data that support or contradict the arguments made in the discussion. Contain no irrelevant or redundant data. Data are interpreted correctly.	Missing some critical data or contain some irrelevant or redundant data. Data are interpreted incorrectly in some places.	Missing most critical data or contain a large amount of irrelevant or redundant data. Data are interpreted incorrectly in most places.

Briefly describe the data that is contained in the discussion: Does the data support/contradict the misconception?

Comments/ Suggestions for Improvement:

Are the pictures described in the text?

Professional	Insufficient	Unprofessional
Ratio of pictures to text description is balanced. Pictures support the text and text supports the description.	High ratio of pictures to description. Description of figures is present but not adequate.	The ratio of pictures to description is high. Very little description of the figures is provided.

Briefly describe the text that is used to explain the figures. Does the text support the figures (and do the figures support the text?)

Comments/ Suggestions for Improvement:

Is discussion engaging?

Professional	Insufficient	Unprofessional
Discussion is presented in an engaging manner. Reader is encouraged to think about material as they read it.	Discussion is partially engaging. Reader is encouraged to read the material but it is possible to read without thinking about the material.	Discussion is not engaging. Reader is confused or bored by material.

Comments/ Suggestions for Improvement:

Is discussion persuasive?

Professional	Insufficient	Unprofessional
Effectively uses data to address misconception. Key data are interpreted correctly. Argument structure and quality logically leads to conclusions.	Relationship between data and misconception are sometimes muddled. Key data are not always interpreted correctly. Uses some unimportant data. Argument is sometimes weak or poorly structured.	Does not effectively use data to address the scientific aim. Key data are interpreted incorrectly. Fails to use the KEY data. Argument is generally weak or lacks structure.

Read through the discussion in its entirety, then summarize the key points of the discussion here.

Comments/ Suggestions for Improvement:

<u>How to refute the misconception (FAQs)</u>

Before reading this section, write down any questions you have about the misconception.

Now read the section. Were there any unanswered questions? Put a star next to the unanswered questions.

Are the sections on outreach consistent with scientific principles?

Professional	Insufficient	Unprofessional
Yes, sections on outreach are supported by data.	Mostly, sections on outreach are mostly supported by data.	No, sections are not supported by data.

Comments/ Suggestions for Improvement:

Is the Text sufficient?

Professional	Insufficient	Unprofessional
Text is complete and concise.	Text is wordy or incomplete in some sections.	Text is missing.

Comments/ Suggestions for Improvement:

References

Are references appropriate?

Professional	Insufficient	Unprofessional
Reference sources are appropriate. Number and variety of references indicate that authors have a high level of understanding of the subject.	Some reference sources are not appropriate for a scientific paper. Number and variety of references indicate that author has a moderate understanding of the subject.	Reference sources are inappropriate for a scientific paper. Small number of references indicate that author has little understanding of the subject.

Briefly list the references used for the scientific part of this paper:

Comments/ Suggestions for Improvement:

Are references formatted properly? (APA format)

Professional	Insufficient	Unprofessional
References properly cited in text and formatted correctly.	References not properly cited in text or formatted correctly.	References are improperly cited in text and formatted incorrectly.

Comments/ Suggestions for Improvement:

Overall Writing Style

Is the writing style appropriate for your audience?

Professional	Insufficient	Unprofessional
Sounds like a professional writer—clear, concise, persuasive. Language is clear without being too technical.	Sounds like a good student—somewhat clear, concise, and persuasive. Language is sometimes too technical.	Sounds like a student new to writing—not clear, concise, or persuasive. Language is technical without explanations.

Comments/ Suggestions for Improvement:

Writing Mechanics

Professional	Insufficient	Unprofessional
Grammar, punctuation, usage, and spelling enhance paper quality.	A few mechanical errors, but does not distract reader too greatly.	Many mechanical errors severely detract from meaning of paper.

Comments/ Suggestions for Improvement:

Writing Submission

Professional	Insufficient	Unprofessional
Document looks professional. Font, style, and formatting approach are not distracting.	Document is well-formatted but does not look professional. Formatting enhances text but distracts.	Document looks unprofessional. Font and figures are distracting to the reader. Formatting does not enhance the text.

Comments/ Suggestions for Improvement:

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