RADICAL SCIENCE WRITING: AN INTERDISCIPLINARY BOOK ARTS APPROACH

by Danny Long, Susan Guinn-Chipman, Barbara Losoff, Leanne Walther, and Deborah Hollis

CURRENT LITERATURE IN SCIENCE EDUCATION recommends that students combine what they know with what they discover through research to create original work.[1] In response to this recommendation, we, a science-writing instructor and a team of librarians at the University of Colorado Boulder (CU Boulder), have developed a unique partnership.[2] Using materials from Special Collections and Archives (SCA) and the Government Information Library (GIL), we seek to empower students to be stewards of their own learning, since they "will retain their learning when they claim ownership of it."[3]

SCA's past instructional model consisted of a single class session in the SCA Reading Room, during which students were introduced to rare materials that complemented a course's time period or subject matter. Although this approach, sometimes referred to as a "one-shot lecture" or "show-and-tell," would generate student interest, it frequently left students with too little time to engage with the rare works. Consequently, few students would return to use these rare works in class projects. In the early 2000s, however, CU Boulder humanities faculty expressed a desire for their students to curate Reading Room exhibits using special subject collections.[4] This proved to be the first step toward making rare materials a significant feature in course curricula.

The SCA pedagogical approach now resembles a learning lab, with students returning to the Reading Room three to five times during the semester to study and analyze rare works and artists' books.[5] Yet SCA is not just a learning lab; it is also a stage, complete with rare props and interactive class sessions that fuel creative student responses. SCA has consequently adjusted its focus from student-curated exhibits to faculty collaborations that give students the means to demonstrate their knowledge and skills visually, verbally, and tactilely through books they make themselves. To be sure, SCA personnel have observed that when confronted with rare materials and artists' books, students inevitably ask questions about book history, book anatomy, and bookmaking. The physical act of turning the pages of an early printed work or an arresting artists' book sparks students' curiosity:

ABOUT THE AUTHORS

Danny Long is an instructor of writing and rhetoric at the University of Colorado Boulder (CU Boulder). In his science-writing courses he partners with his colleagues in the CU Boulder Libraries: Susan Guinn-Chipman, Barbara Losoff, Leanne Walther, and Deborah Hollis. Together they create lessons that allow students to study, use, and interact with artists' books and rare materials.

“How did they do that?” It was precisely this student-sprung interest that encouraged Danny Long to approach CU Boulder life sciences librarian Barb Losoff for help in putting together dynamic classroom assignments for his science-writing course, Writing on Science and Society, an upper-division course that fulfills the core writing requirement for students majoring in, among other scientific disciplines, engineering, biology, integrated physiology, chemistry, physics, mathematics, or astronomy.

But if SCA’s current educational approach is a flexible one, suitable to students from all disciplines, why the emphasis on science writing? Why not writing in business or philosophy, English or Spanish? Why not, indeed. Effective educational practices need not be confined to particular subject areas. Yet in science, especially in engineering, students are often asked to think so intently about *how* that they sometimes miss the opportunity to ask, “So what?” A design works, or it doesn’t. A theory explains something, or it doesn’t.[6] This emphasis on doing science is, of course, central to undergraduate science majors’ education, for which reason we are not criticizing it. We are merely suggesting that getting students to examine the implications of scientific research and discovery may make them better scientists. Exploring science means delving into the nature of science, which consists of those integral, intriguing, and often overlooked principles that are science’s foundation: “its realm and limits, its level of uncertainty, its biases, its social aspects, and the reasons for its reliability.”[7] If students learn about the nature of science, there is a greater chance science will become humanized, accessible, appealing. If they do not, then the “notion that scientific ideas just drop from the sky or are known all along and just waiting for confirmation”[8] will persist, particularly among laypersons, who rely on scientists to be their teachers. Thus we apply an active-learning educational model to create assignments that acquaint our students with the nature of science by integrating two supposedly discrete ways of knowing: science and the arts.

SCIENCE AND THE ARTS

Scholars are challenging the prevailing academic model that has separated the arts from the sciences.[9] This new paradigm poses the question: “Could art instruction help produce more innovative scientists?”[10] Emerging pedagogy specific to writing in the STEM disciplines (science, technology, engineering, and mathematics) explores the use of visual imagery as an “instructive bridge . . . between seeing and saying.”[11]

In a process that we describe as one part seduction and two parts immersion, students are drawn into an assortment of special collections and government information materials selected to promote inquiry-driven study and to ignite scholarly, scientific conversations across time.[12] The pairing of the classical and the modern, the ancient philosopher and the undergraduate, casts the students as scientists and philosophers with stories to tell, the most recent voices in a lively, centuries-old conversation.

Students’ artistic interpretations of scientific thought draw upon a long tradition of exchange between the two disciplines. This interrelationship has been studied extensively by Martin Kemp, who notes that “many artists ask ‘why?’ as insistently as any scientist. For the artist, as for the scientist, every act of looking has the potential to become an act of analysis.”[13] Further, “If we look at their processes rather than end products, science and art share so many ways of proceeding: observation, structured speculation, visualization, exploitation of analogy and metaphor, experimental testing, and the presentation of a remade experience in particular styles. In these shared features, the visual very often has a central role."[14]

Early modern and modern scientists acknowledged the value of this union. Sixteenth-century physician and anatomist Andreas Vesalius wrote that "illustrations greatly assist the understanding, for they place more clearly before the eyes what the text, no matter how explicitly, describes."[15] Galileo relied upon his knowledge of perspective and foreshortening—"in virtù di prospettiva"—to illustrate and to describe the light and dark areas evident on the surfaces of the sun and the moon.[16] Seventeenth-century natural philosopher Robert Hooke, too, was "sharply aware of the problems with seeing, knowing, and representing."[17] In *Micrographia* (1665), Hooke writes of the flea:

> The strength and beauty of this small creature, had it no other relation at all to man, would deserve a description. . . . But, as for the beauty of it, the *Microscope* manifests it to be all over adorn'd with a curiously polish'd suit of *sable* Armour, neatly jointed, and beset with multitudes of sharp pinns, shap'd almost like Porcupine's Quills, or bright conical Steel-bodkins; the head is on either side beautify'd with a quick and round black eye.[18]

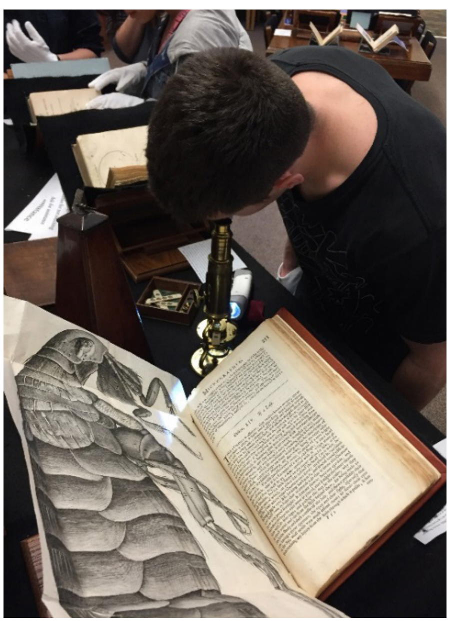


Figure 1. Student using Culpeper-type microscope.

Like seventeenth-century members of the Royal Society, their patrons, and their readers, today's students are privileged to enter into Hooke's "world of form and space"[19] (fig. 1).

Images have long played a key role in "the making of natural knowledge" and in that capacity continue to provide students with a window into the scientific and medical practices of the past.[20] One of the first printed publications of anatomical illustrations, Johannes de Ketham's *Fasciculus medicinae* (circa 1500), pictures "Wound Man," "Pregnant Woman," and "Zodiac Man," the latter reflective of fifteenth-century thought on the role of the planets in human health. Centuries on, the graphic illustrations of Edward Jenner's *An Inquiry into the Causes and Effects of the Variolae Vaccinae; a Disease Discovered in Some of the Western Counties of England, Particularly Gloucestershire, and Known by the Name of the Cow Pox* (1798) drive home the benefits of vaccination against deadly disease. *Physicians' Anatomical Aid* (1888), designed to instruct and guide physicians in daily use, offers students a similar glimpse into the strata of an unseen natural world.

More recently, US government publications offer a multidisciplinary smorgasbord of modern scientific and visual materials, many of which afford students a view into the more divisive issues that confronted twentieth-century scientists.[21] Government documents on the atomic bomb allow students to explore the original research that led to its development, the moral dilemma of its use, and, thanks to photojournalism, the human suffering in its aftermath. Once directed at a broad Cold War–era audience, the highly illustrated *Operation Doorstep* (1953) and *Facts about Fallout* (1955), published by the Federal Civil Defense Administration, and *Just in Case Atom Bombs Fall* (1951), published by the Civil Defense Office of Denver, Colorado, illuminate for students governmental and public concern over the potential for nuclear fallout during the 1950s and 1960s. Government photography from NACA (National Advisory Committee for Aeronautics) and later NASA shed light on the early years of the space program, including the experimental flight, in 1961, of the first chimpanzee in space, Ham (named after the Holloman Aerospace Medical Center).

The natural interdependence of art and science facilitates student adoption of the artists' book as a vehicle for their responses to these rare early modern and modern scientific works. Though artists' books have been described as a "quintessentially twentieth-century form," Johanna Drucker reminds us that it is a form rooted in the centuries-old print traditions of Aldus Manutius, late-fifteenth-century Venetian printer of Aristotle.[22] Characteristics of contemporary artists' books echo such antecedents. Clive Phillpot, former library director of New York City's Museum of Modern Art and founder and curator of the museum's extensive collection of artists' books, places the interdisciplinary, "mongrel" form "provocatively at the juncture where art, documentation, and literature all come together."[23] Anne L. Burkhart concurs, noting that "artists' books not only correspond with interdisciplinary and integrated approaches, they often embody and deftly demonstrate them. Their hybrid status as both an artwork and a book connects them to art and, depending on the book's focus, cultural practices and areas of knowledge such as history, literature, medicine, science, religion, as well as other art."[24] For Burkhart, this interdisciplinarity renders the form particularly effective in transcending the boundaries of art and in integrating multiple disciplines. Such permeability and exchange, Amanda H. Brown, Barbara Losoff, and Deborah Hollis note, produce a "cross-fertilization of intellectual and creative inquiry."[25]

For our purposes, the hybrid nature of artists' books echoes characteristics of the centuries-old tradition of scientific illustration—a tradition of works simultaneously artifact and repository of intellectual content—and suggests to students creative approaches for depicting scientific thought in images and text.[26] Displaying five periods of rare and governmental scientific illustration together with a selection of science-themed artists' books helps students appreciate how these modern creations are frequently "direct outgrowths of historical works."[27] Charles Hobson's *Fresnel's Tower* (1997), Julie Chen's *Panorama* (2008), Karen Hanmer's *Most Excellent Canopy* (2008), and Sara Press's snake-shaped *Evolve = Unroll* (2013) rest side by side with Isaac Newton's *Opticks* (1704) and Charles Darwin's *On the Origin of Species* (1859), inviting an invigorating cross-germination of scientific ideas.[28] Fueled by the history of science and imbued with artistic interpretation and personal narrative, these interdisciplinary artists' books play a key role in inspiring our students.

Figure 2. Students with life sciences librarian.

Students' artists' books, like those of well-known artists working in the field, embody a materiality that is especially instructive (fig. 2). As Burkhart has noted, the form is "uniquely sensory, material, and experiential. . . . You can touch, handle, smell, and even, in the swish of their pages and the clop of the covers, hear many artists' books."[29] This physicality informs encounters between the completed artists' book and its readers. The physical nature of the artists' book also plays a role much earlier in the process, informing encounters between artists and their own work during the process of creation.[30] The tactile creative process informs kinesthetic learning throughout, reinforcing and processing scientific thought in new ways. Cognitive aspects of process and product have been identified by Wendy J. Strauch-Nelson, who writes: "The serial and linear order of the traditional book causes both the creator and the user to reflect in a sequenced manner. The artist/author must organize and prioritize data to fit the format while the viewer is required to reflect upon the part to whole relationship."[31] For the artist, it is a problem of "spatial management" that requires the collection of data, organization, prioritization, sequencing of thoughts, and analysis.[32]

Our collaboration casts the students enrolled in Writing on Science and Society as scientists and artists, each assigned with drawing upon a centuries-old tradition of exchange between the disciplines to spark inquiry and craft new narratives.

GOALS AND ASSIGNMENTS

The Colorado Commission on Higher Education lists the following objectives for upper-division writing courses, such as Writing on Science and Society:

1. Extend rhetorical knowledge.
2. Extend experience in writing processes.
3. Extend mastery of writing conventions.
4. Demonstrate comprehension of content knowledge at the advanced level through effective communication strategies.[33]

In our version of Writing on Science and Society, these objectives inform each course assignment's design. That is, they serve as curricular starting points, not as destinations. The destination, as implied above, is for our students to examine the nature of science through the stereoscopic, and rhetorically stimulating, science-art lens. The assignments are therefore meant to guide students toward this end. We will focus on two of these assignments here: the "what if?" project and the children's book. The "what if?" assignment is organized according to five time periods: pre-Galileo, pre-Enlightenment, pre-Darwin, pre–atomic bomb, and post–atomic bomb.[34] For this project, students can do one of three things. One, they can place themselves in one of these time periods and consider what life was like before a significant scientific discovery. What would it have been like, for instance, to criticize the biblical account of creation before Darwin published *On the Origin of Species*? Or how would a person have studied the cosmos before telescopes became widespread? Two, they can set themselves in the present and investigate the implications of scientific or technological research. How did refining and perfecting the technology of glass—so that, as in the case of microscopes, the tiny could be rendered large—influence modern medicine?[35] Three, they can envision an altered present by assuming that an important historical event in the sciences either did not happen or happened differently. How would modern politics be altered if the Soviets had beaten the Americans to the moon? To complete this assignment, students must work through challenging questions: Where does knowledge come from? How do science and society influence each other? How are scientific fields developed? Questions like these are the first steps toward understanding the nature of science.

The children's book project is more straightforward in concept though no less valuable to students' growth as writers and scientists. Using original stories and illustrations—evocation, not direct instruction—students create books for Stephanie Briggs's first graders at Bear Creek Elementary School in Boulder, with the purpose of teaching those first graders simple lessons in math or science.[36] This assignment (as well as others in Writing on Science and Society) gives students experience in conveying science to nonscientists. Such experience is important partly because of curricular differences. In their major courses, students discuss science with scientists—their professors and peers—and consequently receive little practice in sharing their expertise with those outside the know. This experience is also important because their ability to share science with the public may prove critical to students' careers. For example, in its grant-proposal guidelines, the National Science Foundation (NSF) requires that applicants explain the potential social outcomes of their proposed projects, including “increased public scientific literacy and public engagement with science and technology.”[37] The American Association for the Advancement of Science, which believes so strongly in the science-society connection that in 2004 it established the Center for Public Engagement with Science and Technology, echoes the NSF, stating that “scientists can discover ways to make their work more relevant to society *if they engage in two-directional dialogues with the public*.”[38] The children’s book project allows students to engage in this two-directional dialogue.

Both assignments naturally raise questions about genre—a concern in composition studies—and medium. By its very nature the “what if?” project demands writing that does not fit into the traditional research essay, a genre that would prove inappropriate and ineffective, for example, for a student who wanted to explore the thoughts of a teenage skeptic seeking an explanation for life’s complexities before Darwin published *On the Origin of Species*. Although this student would have to do a considerable amount of research to gain an understanding of pre-Darwinian society and beliefs, the research-essay form would foil and spoil her message. A diary might serve better, yet how would the student in question create the archival effect—visual and tactile—of a nineteenth-century diary being read in the twenty-first century? What would be her medium? She could not simply drive to the nearest bookstore and buy a brand-new leather-bound journal; its newness would be its fraudulence.[39] Moreover, how should the children’s books be constructed? To be authentic, the books cannot look like business proposals held together with plastic sleeves, or last-minute essays stapled in their top-left corners, or coloring books with illustrations drawn on pages containing already-printed words. The children’s books need to look, feel, sound, and act like children’s books. In other words, both projects require that students blend genre and medium, with each enhancing the other.

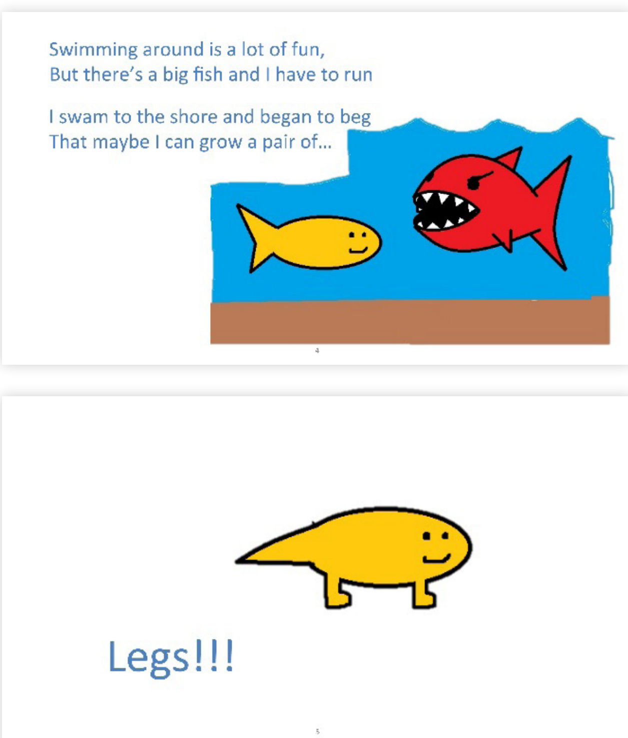
After being familiarized with artists’ books, students tackle these questions, not in, but *with* their work. Below, we provide examples and analyses of this work. We begin, though, with a brief explanation of how the students learn to bind books.

BOOKBINDING WORKSHOP

While the process of immersion into centuries of scientific materials (as described above in “Science and the Arts”) is essential to the final product, so too is the building of technical skills needed for the production of artists’ books. Students begin with a fifty-minute introduction to basic bookbinding skills. SCA staff and members of a local nonprofit, the Book Arts League, prepare packets with materials and printed instructions for pamphlet, accordion, Japanese stab stitch, meander, and pop-up construction techniques. They instruct a host of colleagues who, in turn, lead small groups of three or four students within each section of Writing on Science and Society. Though the Japanese stab stitch has proven to be by far the most popular technique because (we surmise) of its name, a number of students have adopted the pamphlet style or meander book as a means of replicating in a simplified form the structures of rare manuscript journals or early printed works.

CHILDREN’S BOOKS

The students’ children’s books benefited directly from the bookbinding workshop. *Bob the Blob* (2015), a treatise on evolution by Jesse Janzen, Ashley Zimmerer, and Zachary Jones, invites young students to read along responsively from one page to the next. With its beautiful stab stitch binding and unfussy illustrations, nothing detracts from the message. *The Lost Wolf and the Sleepy Moon* (2016) by Will Golding, Christopher LeSueur, Hanadi Salamah, and Perry Soderstrom features a pamphlet-style binding and luminescent watercolor illustrations that track the phases of the moon. *Halley* (2015) by Lucy Wilkinson, Girish Narayanswamy, Christina Clementz, and Eric Brown stitches a pamphlet-style cover together with a folded interior that expands to more than four feet, vividly illustrating Halley's comet on her recurring encounters with the friendly planets of our solar system and visually depicting the expansiveness of space. *The Adventures of Reggie and Frankie* (2016), a book about the water cycle by Brock Bylovas, David DeHerrera, and Nicci Hines, borrows *Halley*'s binding style but to a different end. Its elongated accordion fold circles back upon itself, creating a three-hundred-sixty-degree panoramic image that symbolizes the water cycle (figs. 3,4,5).



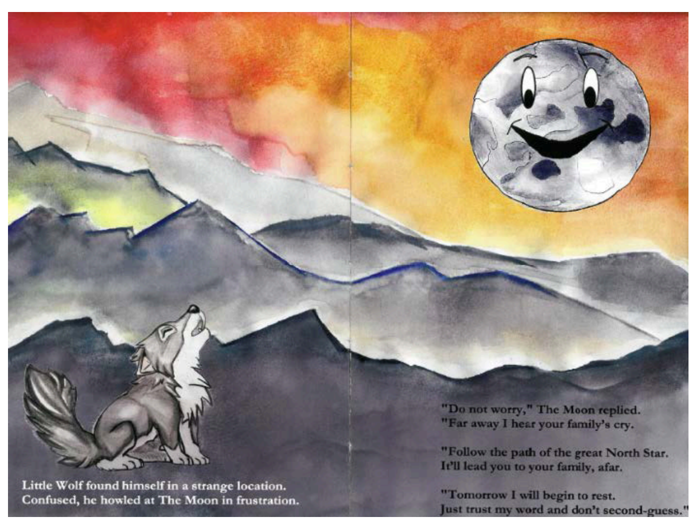


Figure 3, top. Halley*'s elongated accordion fold.*
Figure 4, left. Two consecutive pages from Bob the Blob.
Figure 5. A page from The Lost Wolf and the Sleepy Moon.

"WHAT IF?"

Students' "what if?" projects have profited from the inherent hybrid nature of artists' books. Karina Simon's *Thanks to Penicillin . . . He Will Come Home!* (2015) describes the accidental discovery of penicillin by Alexander Fleming in 1929 and its development by an Oxford team in 1941 into a drug ready for use by soldiers during World War II (fig. 6). Working closely with government information librarian Leanne Walther, Simon compared data detailing soldiers' deaths due to infection during World Wars I and II. With text rolled into empty medicine capsules rather than constructed into the form of a codex, Simon's *Thanks to Penicillin* pushes the boundaries of what we think of as a book, powerfully integrating the medium and the message: the book does not just discuss medicine; metaphorically, it *is* medicine.

Figure 6. Karina Simon's Thanks to Penicillin . . . He Will Come Home!

Joe Torres's *Journal of Thomas Johannes* (2015) narrates a fictional fourteenth-century physician's account of the arrival of the pestilence in Venice and his failed effort to discover a cure (fig. 7). Torres reminds the reader of the sociological and economic consequences of the plague and its role in the formation of the modern world. Suggestive of a centuries-old journal that, like its fourteenth-century author, survived the Black Death, this small meander book has been fried in a pan, baked in an oven, and kicked along the street—in short, aged and distressed.

Like scientific illustrators and book artists before them, the students in Writing on Science and Society have learned from the natural exchange between science and art. They likewise have profited from the hybrid nature of book arts, which allows these works to transcend disciplinary boundaries in ways that speak to students and scholars of divergent fields. These characteristics enable students to distill complex scientific thought in ways that engage young readers and to explore with creativity the thought-provoking scenarios presented by the "what if?" project.

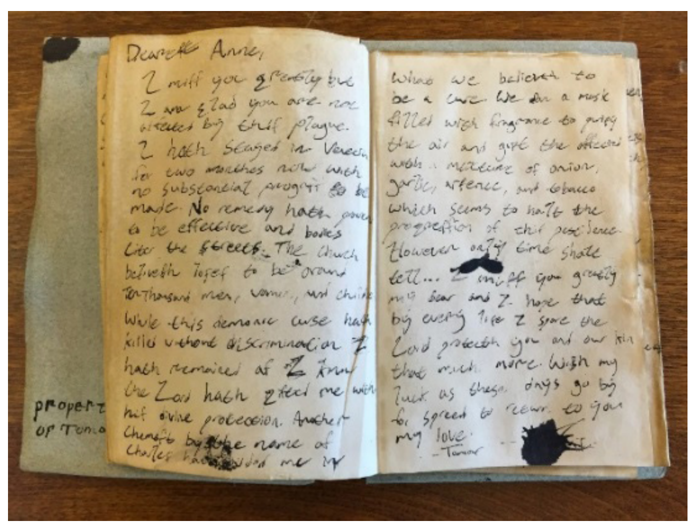


Figure 7. Joe Torres's Journal of Thomas Johannes.

STUDENT RESPONSES

Students are key participants in the educational exchange—active agents, not empty vessels. As such, they have an important role to play in our summative assessment of learning outcomes. Over the past two years of this collaborative venture, we have at the end of each semester invited students to fill out an optional survey, asking whether their work with SCA informed their understanding of course concepts; if so, how; and what they thought was important about this work. These are some of the more thoughtful responses from Spring and Fall 2015 students:[40]

> The biggest contribution that special collections made to this course for me was being able to see how our information delivery methods have changed throughout history. . . . Special collections makes this easy to see. (Dane Ballou, mechanical engineering)

> The old ways bookbinding and printing from 1400 on can be appreciated as an art form in today's society. (Chris Bean, mathematics)

> My favorite part was how [SCA] illustrated how culture-based hard science is. It expanded my perception of "fact" and made me more confident to argue my ideas. (Second-year electrical engineering major)
>
> It's important to remember where you come from, especially with science, since there have been a lot of mistakes and tragic consequences before, and it's good to remember when looking to the future. (Fourth-year biochemistry and molecular, cellular, and developmental biology major)
>
> Just like in law, science sets precedents, and there's a quote I like by Isaac Newton. It goes, "If I have seen further it is by standing on the shoulders of giants." I think that about sums it up. (Anonymous)
>
> I think that special collections is a cool way to look into the past. Searching for everything on Google kind of desensitizes the subject; you can't comprehend how old something is until you really see it. (Cody Gondek, aerospace engineering major)
>
> The most important part to me was the "awe" aspect. I thought it was just friggin' awesome to see work from Einstein, Galileo, Leonardo, as well as the more ancient items and things from the atomic age. It was inspiring, but also felt like a little walk through history. (Jeff Thomas, electrical and computer engineering major)

The vocabulary here is revealing: "information delivery methods," "art," "culture-based hard science," "precedents," "desensitizes," "awesome," "tragic consequences." This language focuses on the nature of science, providing a glimpse of what the students learned: that science has a tangible past, that the means of sharing it are forever in flux, and that it can be communicated in imaginative ways. This last point places our students firmly within current trends in science education. In *Multimodal Teaching and Learning: The Rhetorics of the Science Classroom*, for example, Gunther Kress and his colleagues argue that

> science education (and science) no longer relies on verbal language alone (particularly language-as-writing) in its efforts to describe the material interactions of people in the natural world. Implicit in this argument is the assertion that visual, actional and linguistic modes of communication have been refined through their social usage to make meaning in different ways and to produce different meaning-making potentials.[41]

Worth noting is that if the words "science education (and science)" did not appear in this passage, Kress et al. could be describing artists' books. It would seem, then, that educators are already envisioning the commingling of art and science, whether they say so explicitly or not.

A RADICAL APPROACH

Because they indicate an awareness of the mutually enriching relationship between art and science, as well as a newfound interest in the nature of science, our students' books and responses to SCA materials serve as evidence, in our estimation, of a successful learning exercise. Perhaps we are biased. Others may look at our students' work and see something else, and indeed at least one person has. Upon reading the first round of children's books, *Bob the Blob* among them, a colleague in the CU Boulder Program for Writing and Rhetoric described them with the help of a word we did not expect: "radical."[42] While his intention was not to censure—nor, for that matter, to praise—the word caught us off guard (fig. 8). After giving it some thought, however, we realized that our colleague had hit the mark, not only for the children's books but for the "what if?" projects and, in fact, our entire pedagogical philosophy as well. In modern parlance "radical" often means new or progressive. This is likely the definition our colleague meant to invoke. Admittedly, some may hear this definition and conclude that deeming these projects radical is a bit of a stretch. Were we discussing such subjects as history, art, or education, we would agree. But because we are discussing a science-writing course, we maintain that we are using "radical" neither inaccurately nor hyperbolically but precisely, for artists' books and archival research do not figure prominently in such courses: the "what if?" and children's book projects are indeed somewhat novel.

Figure 8. Writing instructor Danny Long admiring Halley *with CU Boulder chancellor Philip DiStefano.*

Paradoxically, moreover, "radical" may mean just the opposite of new, deriving as it does from the Latin word *radix*, or "root." Besides signifying novelty, in other words, "radical" can refer to that which is foundational, fundamental, or inherent to.[43] This both/and nature of "radical" thus renders it a suitable adjective and metaphor for the kind of work we are espousing in this essay. By asking students to create artists' books, we are involving them in a time-honored (i.e., foundational) process: bookmaking; and by presenting students with historical scientific documents and government information we are putting them in conversation with the past but with the added aim of getting them to reflect upon the present. We, and consequently our students, are merging the old with the new, the fundamental with the progressive.

This approach is itself arguably progressive. Traditionally, artists' books and special collections materials have been regarded as fertilizer to the living organism otherwise known as the college course: sprinkle some here, a little more there, and watch that course flower and flourish. This treatment is positive; it celebrates special collections and artists' books, placing them at the receiving end of much faculty and student praise. Unfortunately, though, it also externalizes them (fig. 9).

Figure 9. The cyclical panorama of The Adventures of Reggie and Frankie.

We are offering an alternative instructional model for STEM courses generally and for science-writing courses particularly. Our partnership, and the student writing that has emerged therefrom, has been effective not because we have sprinkled special collections and artists' books over Writing on Science and Society but because we have made them vital to it. They are not its fertilizer; they are its roots. In our case these roots have nourished the splicing of the sciences with the arts, the archival with the contemporary, the scientist with the society in which he or she works. We call this splicing "radical science writing." It is writing that connects rather than separates, binds rather than sunders; writing that places "inter-" in front of "disciplinarity" and "active" in front of "learning." It inspires and instructs, tells stories and teaches lessons. In the words of biological anthropologist Jonathan Marks, "Humanistic knowledge is . . . at least as crucial to the scientist as scientific knowledge is for the masses."[44] Radical science writing supplies STEM majors with a method of obtaining this humanistic knowledge, knowledge that can help them to grow into thoughtful scientists capable of doing science well, sharing science with "the masses," and examining their role in society—past, present, and future. ■

NOTES

1. King, "Sage on the Stage," 30. Also see Bobek and Tversky's "Creating Visual Explanations" and Bahde, Smedberg, and Taormina's edited collection, *Using Primary Sources*.

2. This partnership would not have been possible without the help of many individuals. Our thanks to Megan Lambert, Gregory Robl, Michael W. Harris, Cheryl Koelling, Sean Babbs, Kay Moller, Mónica González, Fernanda Iwasaki Cordero, Hillary Jones, Yashmin Yacubu, Olivia Schlueter, Zander Carrie, Ilena Johnson, Alyssa Cavalier, Jordan Johnson, and Dakota Jutzi, Alex Kaaua, Nhi Lai, Winter Roibal, Allyssa Jewel, Kelsey Turner, Katy Zeigler, Taylor Chouinard, and Katelyn Cook for their energetic assistance in the bookmaking process. Book artists Megan Lambert, Gregory Robl, and Kay Moller of CU Special Collections and Archives and the Book Arts League have been especially helpful in leading sessions and facilitating the instruction process. We would like to extend still another thank you to Gregory Robl for reading a draft of this paper with the eyes of a hawk, the patience of a lion, and the understanding of an old friend. We would also like to thank Vicky and Bill Stewart for their encouragement, and Glenn Koelling of the University of Denver Libraries for her help in finding an elusive source. Finally, we would like to thank our fellow CBAA conference attendees for their helpful suggestions and good humor.

3. Foyle, ed., *Interactive Learning*, 118.

4. Graduate students curated an exhibit featuring rare works from the Enlightenment period. Students selected, researched, and wrote captions aimed at a general audience. See Schmiesing and Hollis, "Special Collections Departments," for an explanation of the pedagogical rationale and outcomes. Word spread and CU Boulder faculty and their students curated *The Printed Page and Early Modern Italy* and *ATTN: Selected Works from the Lucy R. Lippard Artists' Book Collection*, exhibits that met with rave reviews.

5. Bahde, "The History Labs," 178. In this article Bahde argues that the laboratory metaphor is not accurate: "Many of these uses of the laboratory metaphor in the literature leave out an important component of the pedagogical notion of laboratory. On the whole, they do not take into account the frequency of laboratory coursework and the cumulative learning inherent to the laboratory model. Within science or language classes using a traditional laboratory format, students visit this space frequently, often once or twice a week, to practice ongoing observation and experimentation in groups," 178. See also Mitchell, Seiden, and Taraba, *Past or Portal?*

6. Anthropologist Jonathan Marks puts it this way: "The great paradox of modern science is that scientists are not trained to think about science; they are trained to *do* it, to carry it out." See *What It Means*, 266.

7. Flammer, "The Nature of Science?"

8. Herreid, "Chicken Little," 9.

9. See Gurnon, Voss-Andreae, and Stanley, "Integrating Art and Science," 1–4; and Wallace, Vuksanovich, and Carlile, "Work in Progress." Also see Harvard professor of biomedical engineering David A. Edwards's *Artscience* and *The Lab*, both of which advocate breaking down disciplinary boundaries to propel innovation.

10. Gurnon, Voss-Andreae, and Stanley, "Integrating Art and Science," 1. Also, we do not use the words "new paradigm" lightly or accidentally, aware that the concept of the paradigm shift emerged from the backdrop of science writing—namely, Thomas S. Kuhn's *The Structure of Scientific Revolutions*. Kuhn defines paradigms as scientific achievements and practices that garner widespread acceptance among scientists. By establishing a paradigm, Kuhn argues, an area of research becomes legitimate or normal. It is fair to say, then, that the challenge leveled against a paradigm—the separation of the arts from the sciences—warrants Kuhn's terminology.

11. Faflik, "Light Writing," 52–64. Faflik notes that "as images evolve, the visual today accordingly functions as an instructive bridge: conceptually, between seeing and saying; intellectually, between the sciences and humanities; and temporally, between the classical practices of rhetoricians in the past and our current image-centered methods of making meaning," 52.

12. For interpretations of scholarly conversations within the context of information literacy, see "ACRL Visual Literacy." See also Mazella and Grob, "Collaborations," 476–87, for inquiry-

inspired uses of rare works in a special collections setting. Thanks to CU Boulder instructor Carol Byerly for characterizing our process as "seduction."

13. Kemp, *Visualizations*, 3.

14. Ibid., 4.

15. Vesalius, *Fabric*, trans. Richardson and Carman, lvi. Daniel Garrison and Malcolm Hast translate this sentence differently in their online edition of *Fabric*, published by Northwestern: "How much pictures aid the understanding of these things and place a subject before the eyes more precisely than the most explicit language, no one knows who has not had this experience in geometry and other branches of mathematics," 4r. Though it does so more subtly, this translation essentially comes to the same point: illustrations bring written text to life. In a letter of dedication from 1538, Vesalius reported some limitations to illustrations: "I believe it is not only difficult but entirely futile and impossible to hope to obtain an understanding of the parts of the body or the use of simples from pictures or formulae alone, but no one will deny that they assist greatly in strengthening the memory in such matters." See Saunders and O'Malley 1950, 233, quoted in Kemp, "Temples of the Body," 45.

16. Galilei, *Opere di Galileo Galilei*, 99, 416; Kemp, "Temples of the Body," 80. See also Galilei, *Sidereus Nuncius*.

17. Kemp, *Visualizations*, 42–43. Kemp, "Taking It on Trust," 131–32.

18. Hooke, *Micrographia*, 210.

19. Kemp, *Visualizations*, 42–43.

20. Smith, "Art, Science, and Visual Culture," 87. See also Topper, "Towards an Epistemology"; Ashworth, "Martin Gheeraerts"; and Kemp, "Taking It on Trust."

21. Federal Depository Library Program.

22. Drucker, "Concepts of Production," 2.

23. Phillpot, "Books by Artists," 33.

24. Burkhart, "Mongrel Nature," 264.

25. Brown, Losoff, and Hollis, "Science Instruction," 198. Published in 2014, this collaboration, also at the University of Colorado Boulder, introduces a confluence of illustrated science works and artists' books. Dissipation of disciplinary and institutional boundaries has also been promoted in the sciences. See Edwards, whose notion of "artscience" stresses interdisciplinarity as "catalytic for innovation." Edwards, *Artscience*, 5.

26. Despite clear benefits to a dynamic learning process, the underlying interdisciplinarity of art and science raises important questions. The primacy of text in the arena of science and, conversely, the primacy of image in the arts present the reader/viewer with distinctly different modes of expression. Brian S. Baigrie has noted the conviction that in the realm of science, "human thinking takes place in words," and that "pictures in science are psychological devices that serve as heuristic aids when reasoning breaks down." See Baigrie, *Picturing Knowledge*, xviii.

27. Taraba, "Artists' Books," 111.

28. On the important conceptual role of the sciences in the creation of artists' books, see Seigel and Chen, "A Conversation," 30–35.

29. Burkhart, "Mongrel Nature," 262.

30. Strauch-Nelson, "Book Learning," 7.

31. Ibid., 9.

32. Ibid., 14–15.

33. Colorado Commission on Higher Education (CCHE), "Content: Communication," 1–3. Because CCHE employs such language as "appropriate audiences," "variety of technologies (writing and research tools)," "adapt genre conventions," and "adapt content and style to respond to the needs of different audiences and rhetorical situations," these goals can arguably be narrowed down to one: increase rhetorical flexibility.

34. One reason we formed these admittedly Western-male categories is their recognizability. The names Galileo, Enlightenment, and Darwin create clear chunks of time in students' minds without the aid of vague, impersonal dates. "Enlightenment" is more concrete than "eighteenth century," at least in the context of scientific history. Another reason is students' awareness of the significance behind these names. For instance, undergraduates may not be fluent in the intricacies of Galileo's work, but they do know that after Galileo the world was never the same. The names themselves help students to grasp the "what if?" assignment's driving purpose. However, a student interested in the pre-Galilean world is not obligated to research Galileo himself, nor is a student fascinated by pre-Darwinian society forced to focus solely on Darwin or his famous theory. And neither of these students is restricted to studying male scientists or Western scientific history. Our students are aware of the wide-open range of possible topics, and this awareness has led them to ask some intriguing questions that reveal just how complicated the science-society relationship can be, questions like "What if Albert Einstein had been a woman?"

35. Steven Johnson performs a version of such "what if?" research in *How We Got to Now*. Johnson considers glass, cold, sound, cleanliness, time, and light through the lens of what he calls the hummingbird effect, named after the coevolution of nectar in flowers and the unique traits of the hummingbird's wing. We find Johnson's work important, not to mention gratifying, because it brings both legitimacy and interest to the "what if?" assignment's guiding methodology.

36. Though in theory it should not matter which school, teacher, and first-grade students we partner with, we mention them by name here because Bear Creek Elementary is a STEM-oriented school. Many of the kids' parents are scientists themselves, which means a book on, say, evolution—whether or not the word "evolution" appears on any of its pages—is less likely to fall on hostile ears. Having a sympathetic audience has been crucial to getting this project off the ground floor. Once it picks up momentum, we may try expanding to different schools. Also, in "Kids Weave Tales," Clint Talbott nicely summarizes just how important the children's book project has been to the first graders' developing skills in reading, writing, and researching, inspiring them to write science books of their own.

37. National Science Foundation, *Proposal and Award Policies*, 19.

38. American Association for the Advancement of Science, "Why Public Engagement Matters," emphasis added. Another, more recent, more local reason for asking Writing on Science and Society students to write science for public audiences has to do with CU Boulder campus initiatives. In his October 2014 State of the Campus address, Chancellor Philip DiStefano invited students, faculty, and staff to create "a collaborative campus environment in which earth and space sciences, engineering, business, law, social sciences, and humanities come together" to "explore and shape how space-based innovations and technologies impact business, law, and society." In response to this Grand Challenge, as it has come to be known, a steering committee was put together consisting of twenty campus administrators, among them Waleed Abdalati, professor of geography and director of the Cooperative Institute for Research in Environmental Sciences, and Steven Leigh, dean of the College of Arts and Sciences and professor of anthropology. See DiStefano, "Chancellor's Corner" and "State of the Campus Address."

39. Authenticity is critical not only to the "what if?" and children's book assignments but to the Writing on Science and Society curriculum as a whole, as it stems directly from the rhetorical appeal of *ethos*, commonly translated as "credibility." Budding scientists owe it to themselves to think about credibility—where it comes from, how to establish it, how to use it persuasively and ethically, etc.

40. Some of these statements were copyedited for readability.

41. Kress et al., *Multimodal Teaching and Learning*, 20–21.

42. How could we have expected it? Children's books are a lot of things—cute, fun, adventurous, adorable, creative, artistic, succinct, beautiful, gutsy, uncanny, scary, bright, cheerful, bittersweet, educational, dreamy, realistic, abstract, metaphorical, concrete, colorful, diverse, poetic, powerful, punchy, pithy. But radical? *Radical*?

43. *OED*, 2nd ed., adjective and noun, "radical."

44. Marks, *What It Means*, 288.

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