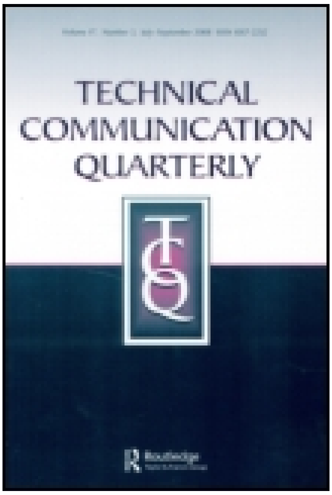

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Toward an Ethical Rhetoric of the Digital Scientific Image: Learning From the Era When Science Met Photoshop

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Toward an Ethical Rhetoric of the Digital Scientific Image: Learning From the Era When Science Met Photoshop

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Over the past two decades, scientific editors have attempted to correct ''mistaken'' assumptions about scientific images and to curb unethical image-manipulation practices. Reactions to the advent and abuse of image-adjustment software (such as Adobe Photoshop) reveal the complex relations among visual representations, scientific credibility, and epistemic rhetoric. Perelman and Olbrechts-Tyteca's model of argumentation provides a flexible system for understanding these relations and for teaching students to use scientific images ethically and effectively.

Keywords: digital image manipulation, ethics, rhetoric of science, visual rhetoric

Scientific research misconduct often involves visual components, and such misconduct can ruin scientific careers, delay the development of new therapies, and derail the research agendas of other scientists. New visualizing technologies and their digital processing have arguably increased the prevalence of image-based misconduct. Digital tools have made it easier for otherwise upstanding scientists to approach—or cross—ethical limits, and analyses of misconduct reports from the Department of Health and Human Services' Office of Research Integrity suggest an alarming trend. In 1990—Adobe Photoshop's debut year—less than 3% of allegations of research misconduct involved images; that figure jumped to 25% by 2001, to 44% by 2006, and to almost 70% by 2008 (Krueger, 2002, 2007, 2011). Of course, allegations are not convictions, and only a few inappropriately modified images represent intentional fraud (Krueger, 2007). In most cases, accused scientists used digital tools to make their images clearer, more appealing, and presumably more persuasive—not to fabricate results. But as the contrast adjustments in Figure 1 demonstrate, there can be fine lines between cleaning up an image for publication (section B2) and unethically modifying it (sections B3 and B4).

The inappropriate composite image represented in Figure 2 might seem a more obvious case of fraud; however, well-intentioned scientists might have created such a collage in an attempt to show more cells in a small space. Moreover, as the following description of a similar collage suggests, scientists do not always see their images as readers see them:

> A member of [a] biologist's lab had created a collage of images. Editors of the journal in which it was published, tipped off by a reader, deemed the collage unethical because it was presented as a single picture. A correction was subsequently published, noting that the modification, although inappropriate, did not affect the paper's conclusions. ''We thought it was obvious that it was a collage,'' says the biologist, adding that he vehemently opposes altering images. (Couzin, 2006, p. 1867)

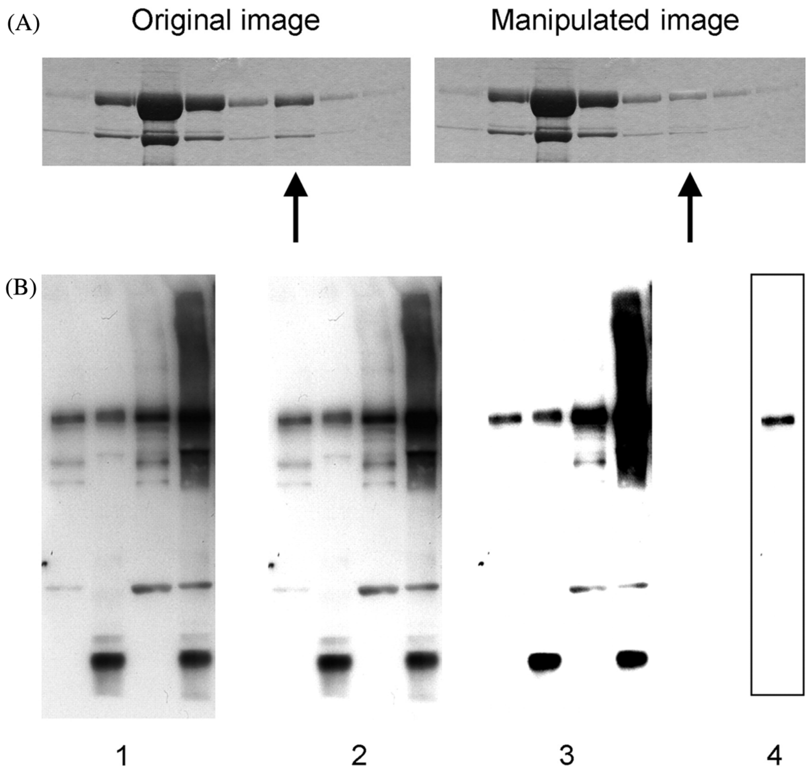

FIGURE 1 Brightness and contrast adjustments can be used ethically and unethically. Figure 3 from Rossner and Yamada (2004) demonstrates how brightness and contrast adjustments can clarify and falsify image data. In Part A, important visual data (signaled by their arrows) is unethically dampened through a brightness adjustment. In Part B, original data (B1) is altered through contrast adjustments (B2 and B3) and cropping (B4). B2 is an ethical enhancement of the entire image that does not destroy data. In B3, contrast adjustments have obliterated visual data. B4 is a cropped selection of one lane of B3 that is also an unethical adjustment. From ''What's in a Picture? The Temptation of Image Manipulation'' by Mike Rossner and Kenneth Yamada. ©2004 Rockefeller University Press. Originally published in *The Journal of Cell Biology, 166*, 11–15.

As this story suggests, different stakeholders approach images with different assumptions. The editor and reviewers initially ''approved'' the image. Did they see it as a collage? Or did they merely fail to notice? Regardless, some readers of the published piece found the image inappropriate; it needed elements to divide the visualized objects presented together. The biologist and his team failed to consider the expectations of readers, which is more of a rhetorical failure than an ethical lapse. Preparing ''objective'' scientific images has always been a rhetorical problem (Daston & Galison, 2007; Freedberg, 2003). But digital tools created new opportunities and challenges for scientists, which forced scientific editors to respond.

This article offers a rhetorical account of what happened when Science met Photoshop. Published reactions to digital image manipulation reveal scientists' typically unstated beliefs about the rhetorical features and functions of images. Statements about images and ethics from

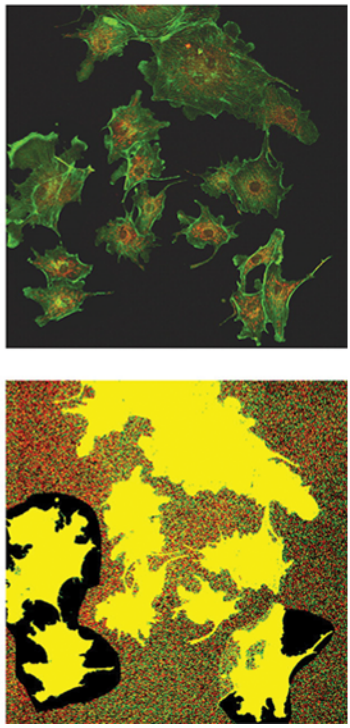

FIGURE 2 An unethical digital collage revealed by adjusting contrast. Figure 6 from Rossner and Yamada (2004) demonstrates how misrepresentations of image data can be revealed through digital forensics; it also demonstrates the fine line between image enhancement and fraud. In this case, a collage of cells was created by pasting images of cells together in a single field. Although these cells might have been from the same experiment, the image is a fabrication because the image does not provide clear lines between the compiled pieces. From ''What's in a Picture? The Temptation of Image Manipulation'' by Mike Rossner and Kenneth Yamada. ©2004 Rockefeller University Press. Originally published in *The Journal of Cell Biology, 166*, 11–15. (Color figure available online).

scientific editors and scientists themselves reveal networks of conceptual relations involving imaging technologies, mutable value hierarchies, and presumptions about scientific character and skill. Understanding these relations can aid technical communicators in helping scientists and future scientists develop effective and ethical multimodal arguments. By analyzing these reactions and relations with tools adapted from Perelman and Olbrechts-Tyteca's *The New Rhetoric* (1958/1969), I demonstrate how their system of argumentation can help us to understand scientific images and why their system provides a productive framework for teaching ethical visual communication practices to science-writing students. After reviewing previous studies on scientific images and digital images from the fields of rhetoric, technical communication, art history, information studies, and science studies, I summarize key features of Perelman and Olbrechts-Tyteca's (1958/1969) theory of argumentation. I then use their system to analyze reactions to digital image manipulation. Last, I discuss the implications of this analysis for technical communication pedagogy.

LITERATURE REVIEW

Researchers in the fields of rhetorical studies and technical communication, art history, information studies, and science and technology studies have advanced our understanding of historical and contemporary scientific visuals; however, the logical and ethical ramifications of digital scientific images for scientific arguments warrant additional attention.

When Gross, Harmon, and Reidy (2002/2009) charted the four-century history of the scientific article, their quantitative sampling convincingly demonstrated the increasing importance of images in 20th-century arguments. As they noted, ''the interaction of the verbal and the visual . . . constitutes the heart of scientific argumentative practices at the end of the 20th century'' (p. 213). More recently, Gross (2009) analyzed this essential visual-verbal interaction by applying separate analytical vocabularies for textual features (rhetoric and narrative) and visual elements (Peirce's semiotics and Gestalt psychology). Similarly, Whithaus (2012) applied Toulmin's system of argumentation to account for multimodal claim-evidence patterns in environmental science reports. Both Gross (2009) and Whithaus (2012) offered productive approaches to the analysis of multimodal artifacts, but neither addressed the historical and rhetorical problems of digital imaging.

In addition to semiotic and argument analysis, researchers have applied qualitative methods to visual work in scientific contexts. Graves' (2005) ethnographic study of physicists demonstrated how rhetorical figures, such as analogy and metaphor, can guide the interpretation of images and the invention of multimodal arguments. Northcut (2011) examined the complex rhetorical invention of scientific illustrations produced by professional illustrators for paleontologists; her interviews with illustrators revealed how their reconstructions of prehistoric life reflect Platonic, dialogic, collaborative, or collectivist models of invention. Richards (2003) combined a diachronic sampling of visuals in botany articles with a reader-response study involving a former journal editor. Her study confirmed that scientists value the aesthetics of visuals in addition to their functional properties, and she identified a reciprocal relation between ethos and images. Good images increase the credibility of an argument; an author's good scientific reputation can improve a reader's reaction to deviations from imaging norms. These studies and others (e.g., Hutto, 2008; Prelli, 2006; Wickliff, 1996) have increased our understanding of the visual rhetoric of scientific images in a variety of contexts; however, only a few scholars of rhetoric or technical communication have addressed the effect of digital media on the multimodal rhetoric of science.

Winn's (2009) case study of the controversy over the ivory-billed woodpecker exemplifies how digital images participate in scientific argumentation in a field that has come to terms with digital photography. In this case, rival ecologists developed arguments for and against the existence of a bird species thought to be extinct. These arguments depended on visuals that used drawings, models, photographs, and Photoshop to make meaning from 4 seconds of grainy digital video. The ecologists modified frames of the digital video by ''inserting brackets; employing zooming, flipping, and cropping techniques; and adjusting for contrast and brightness with Photoshop'' (p. 355). For ecologists, methodical (and documented) enhancement of marginal digital evidence was unproblematic and normal; however, researchers in other fields have reacted differently to image-editing tools. Technical writing teachers must chart these differences, so we can help students from every field become effective and ethical communicators.

Writing about digital media's effect on science more broadly, Lunsford (2007) described the remediation of scientific journals as a socialization process. The transition from print publications to networks of interactive digitized assets forced journal editors to articulate new norms of scientific publishing for their editorial staff and contributors. For Lunsford, ''the shift to electronic media, by disrupting typified practices, has made this work highly visible because values and practices must be articulated to be re-negotiated.'' Comments and journal policy statements about image manipulation suggest a similar renegotiation of values and practices, and we can learn from these visible activities.

Rhetoric and technical communication are not the only fields concerned with the implications of digital imaging. Art historian W. J. T. Mitchell's (1992) *The Reconfigured Eye* contrasted chemical photography's highly standardized processes and well-known representational commitments with the less standard processes of digital images: ''These [digital] processes are much less subject to institutional policing, offer more opportunities for human intervention, and are far more complex and varied in their range of possible representational commitments'' (pp. 221–222). Ritchin (2008) offered a similar account of the shift initiated by digital imaging, but he also considers the implications of Internet-enabled technologies that did not exist when Mitchell first published *The Reconfigured Eye*:

> Eventually, digital photography's relationship to space, to time, to light, to authorship, to other media will make it clear that it represents an essentially different approach than does analog photography. It will also become clear that to a large extent this emerging cluster of strategies will be forever linked with other components in the interactive, networked interplay of larger metamedia. This new paradigm, which has yet to fully emerge, can be called ''hyperphotography.'' (p. 141)

These comments about the transition from traditional photographs to digital photographs and ultimately to ''hyperphotography'' have parallels in scientific contexts. Over two decades, journals developed new procedures to standardize and police digital image-making. Although many reactions to image manipulation software reflect an attachment to the representational commitments of analog imaging, technical developments are changing the scientific image. We can use comments about digital imaging and ethics to track these changes.

Researchers in information studies and human–computer interaction have examined the effects of digital technologies on research collaboration (e.g., Olson, Zimmerman, & Bos, 2008), publishing infrastructure (e.g., Owen, 2007), and reading habits (e.g., Tenopir & King, 2008); however, these studies do not often focus on the construction and use of digital images. In a notable exception, Meyer (2007) demonstrated how digital cameras transformed specific fieldwork practices of marine mammal researchers. Meyer's (2007) participants, however, did not encounter the representational and ethical crisis experienced by experimental fields (such as cellular biology), perhaps because these marine mammalogists rarely publish photographs as data. Instead, they quantify their image collections through other types of representations (p. 251). These disciplinary differences highlight the need for a rhetorical understanding of both images generally and for images in specific disciplines.

Scholars in science and technology studies have a longer history of investigating digital images in astronomy (Lynch & Edgerton, 1988), cell biology (Cambrosio & Keating, 2000), nanotechology research (Daston & Galison, 2007), and clinical fields such as radiology (Burri, 2008). Most recently, Frow (2012) analyzed responses to digital image manipulation; that is, she addresses the same case (and some of the same documents) examined in this study. Frow (2012) read the most formal responses to image manipulation in the biosciences—new journal guidelines and policies—as attempts to clarify four ambiguities: ''the line between image production and image processing; the line between 'innocent' and fraudulent image alteration; the relationship between authors and readers of journal articles; and the meaning of objectivity in the digital age'' (p. 376). Frow (2012) concluded that guidelines are often contradictory and define ''appropriate'' practices ambiguously; nevertheless, guidelines ''can be understood as tools that help to (re)structure and make explicit relationships of accountability among authors, editors, and readers of journal articles, when it comes to making, interpreting and validating images in publications'' (p. 386). But guidelines are necessarily general, and they often lag behind rapid advances in technologies.

Scientists, technical writing teachers, and their students need flexible tools to account for the complexity and contingencies of arguing with digital scientific images. *The New Rhetoric* can provide particularly productive terms for describing these images as well as other technical visuals.[1]

APPLYING *THE NEW RHETORIC* TO SCIENTIFIC IMAGES

Perelman and Olbrechts-Tyteca's *The New Rhetoric: A Treatise on Argumentation* (1958/1969) is well-suited for analyzing multimodal scientific arguments for two reasons: its agreement-oriented approach to argumentation and its classification of arguments based on their relation to reality, the subject of scientific inquiry. This article considers the implications of the first of these features; specifically, how do scientific images function as (and depend upon) agreements between authors and their expert audiences?

For Perelman and Olbrechts-Tyteca (1958/1969), contestable arguments depend on the coordination of uncontroversial *objects of agreement*—notions no member of the audience would find objectionable. Arguers and audiences share two types of agreements: (a) agreements about the real (facts, truths, and presumptions) and (b) agreements about the preferable (values, hierarchies, and loci (*topoi*)). Through argumentation, rhetors arrange objects of agreement to form the premises of contestable claims. For example, a policymaker might make the following argument: ''Greenhouse gasses accelerate climate change; therefore, we should implement policies to reduce carbon emissions regardless of the increased costs incurred by consumers and businesses.'' This argument coordinates a number of facts, such as greenhouse gasses, carbon emissions, consumers and businesses are all ''things'' existing in the world. The speaker knows that the gasses accelerate climate change and that reducing them entails costs. The argument also rests on ''truths,'' such as the network of facts entailed in the concept ''climate change.'' This argument attempts to establish a hierarchical arrangement of values; that is, ecological values are positioned as more important than economic values. The success of the argument also depends on specific presumptions. For example, audiences typically presume the honesty of a speaker.

Of course, objects of agreement can and do lose their ''agreed upon'' status. For example, as Perelman and Olbrechts-Tyteca (1958/1969) observed, ''a fact loses its status as soon as it is no longer used as a starting place, but as the conclusion to an argument'' (p. 68). Moreover, rhetors can undermine objects of agreement when attempting to refute an argument. For example, someone could challenge the argument for carbon-emission restrictions by undermining the definition of ''greenhouse gas,'' the causal connections between those gases and climate, the status of the term ''climate change,'' the honesty of the speaker, the relative value of the environment, etc.

Although Perelman and Olbrechts-Tyteca (1958/1969) categorized the objects of agreement to account for spoken and written arguments, they can also account for persuasive visuals. The next two sections describe the objects of agreement in greater detail and relate them to scientific images.

IMAGES AND AGREEMENTS ABOUT THE REAL: FACTS, TRUTHS, PRESUMPTIONS

Scientists use verbal and visual elements to make claims about reality. To develop effective multimodal arguments, they must coordinate what Perelman and Olbrechts-Tyteca identified as ''agreements about the real.'' That is, a new claim is ultimately based on uncontroversial notions about reality accepted by all members of the audience. This section describes how Perelman and Olbrechts-Tyteca's taxonomy for describing the agreements of the real—facts, truths, and presumptions—can be applied to scientific visuals. These terms help to explain the multiple levels of agreement at work in scientific images.

In *The New Rhetoric*, facts are references to reality that all members of the audience accept: ''we are confronted with a fact only if we can postulate uncontroverted, universal agreement with respect to it'' (p. 67). For example, the existence of something called ''air'' is a fact. The United States (as a political and geographic entity) is a fact. Boyle's Law is a fact. Of course, these items were not always facts; at some point, each was argued into place. For example, Boyle's experiments with gasses in contained vessels resulted in the arguments establishing the inverse relationship between the pressure and volume of a contained gas at a constant temperature. Without agreement about facts such as ''pressure,'' ''temperature,'' ''volume,'' and ''gas,'' Boyle could not have established this claim as a fact.

Like facts, truths are agreements about the ''real,'' but ''the term 'truths' is preferably applied to more complex systems relating to connections between facts'' (p. 69). For scientific audiences, the theory of evolution is a truth. This truth rests on a network of facts, such as the constituents of the fossil record, evidence of natural and artificial selection, and so forth. Rhetors use facts to generate truths and truths to validate facts. Perelman and Olbrechts-Tyteca (1958/1969) described this reciprocal relationship:

> In most cases, facts and truths (scientific theories or religious truths, for instance) are used as separate objects of agreement, between which there are, however, connections that enable a transfer of the agreement to be made: certainty of fact A combined with belief system S leads to the certainty of fact B . . . (p. 69)

This approach to facts and truths comports well with established notions about fact-making in scientific contexts (e.g., see Fleck, 1935/1979; Kuhn, 1962/1996; Latour & Woolgar, 1979).

Presumptions are agreements based on the ''normal and likely'' (p. 71). For example, we presume ''any statement brought to our knowledge is supposed to be of interest to us'' (p. 71). Similarly, we typically presume a speaker is sane and honest. Audiences will presume these ''normal'' states apply to a situation unless given reasons to believe otherwise.

In scientific arguments, images often function as facts and depend on truths and presumptions. For example, before the proliferation of image-manipulation software, scientific photographs had a relatively stable epistemic status. The photographic process (not necessarily any specific photograph) was a *truth*—a network of physical and chemical facts producing representations of real things. The factual status of a scientific photograph is also supported by presumptions about images themselves, the events they capture, and the character of the scientists who create them.

Before digital image manipulation was widespread, the presumptions attached to the scientific image itself were similar to the premises Finnegan (2001) identified as empowering documentary photographs (such as newspaper photographs) from the predigital era. Such photographs succeed as ''naturalistic'' arguments—that is, as representations of the real world—when three unstated premises are acceptably satisfied for the audience. Finnegan labels these premises as (a) ontological, (b) representational, and (c) mechanical realism. A photograph succeeds as an argument about reality when viewers have no reason to doubt that (a) the photograph depicts a scene that really existed, (b) the scene depicts the subject the author claims it depicts, and (c) human intervention has not interfered with the ''normal'' production of the image (p. 143). A challenge to any of these presumptions can refute a photograph's claim to represent reality.

Finnegan's (2001) observations about documentary photographs can extend to scientific images; however, there are key differences between documentary images and scientific images, and especially digital images. First, mechanical realism—as Finnegan (2001) described it for documentary photographs—requires a camera capturing a candid moment. Photographs in her study were criticized because the photographer moved elements of the scene to take a better picture. In contrast, many scientific photographs are ''staged,'' especially in experimental contexts; thus, the mechanical integrity of the ''real'' scientific image depends on staging and on the accepted assumptions of the integrity of the imaging process. Second, the processes for making scientific images are numerous, and therefore the premises underwriting mechanical realism can be more complicated. For example, a 2010 review of technologies used to visualize cells and organisms described 13 classes of microscopes, 8 classes of magnetic-resonance imagers, and a plethora of tools for generating two- and three-dimensional images from the data these instruments collect (Walter et al., 2010). Unlike viewers of documentary photographs, scientific readers must recognize and sort images by their means of creation, and each type of imaging has specific constraints. For example, dozens of variables can affect the quality of images rendered through fluorescence microscopy, the imaging technique shown in Figure 2 (Pawley, 2000). Nevertheless, viewers of such images still expect that data—regardless of the source—have been collected and transformed into visual form according to accepted principles. For example, most forms of microscopy depend on mathematical transformations to turn detected signals into visualized evidence (Elkins, 2008, pp. 117–155). In short, mechanical realism still applies; it's just more complicated. Third, the documentary photograph and the scientific image can differ in their relationships with time and novelty. A ''naturalistic'' documentary photograph can only represent a singular moment in time. The scientific visual can depict a specific moment; however, many scientific images tacitly promise to be reproducible. For most experimentally derived visuals and many observationally derived visuals, viewers assume the same visual artifact would result from similar conditions. In other words, unlike documentary photographs, which must be ''unique'' to be real, many scientific images cannot be unique to be received as real. Nevertheless, for scientific audiences at the end of the twentieth century, the traditional photograph was an epistemologically reliable process—until digital image manipulation destabilized it.

In addition to presumptions about the realism of an image, scientific images activate presumptions about the character of the image maker and the thoroughness of the scientific work. These presumptions are sometimes revealed in editorial commentaries on digital imaging and ethics. For example, in an oft-cited editorial, Rossner and Yamada (2004) alluded to the presumption that a good scientific image represents the skill of the scientists and the reproducibility of the results:

> The quality of an image has implications about the care with which it was made, and a frequent assumption (though not necessarily true) is that in order to obtain a presentation-quality image you had to carefully repeat an experiment multiple times. (p. 11)

These comments reflect a common presumption which is particularly relevant to discussions of images and scientific ethos: ''The quality of the act reveals the quality of the person responsible for it'' (Perelman & Olbrechts-Tyteca, 1958/1969, p. 70). In scientific contexts, the quality of the image reflects on the quality of the science and hence the scientist. A ''clear'' or ''faultless'' image represents precise scientific practices and hence a conscientious scientist; a sloppy image entails sloppy science and hence a less credible scientist. In the case of scientific photographs, a ''presentation-quality'' image can serve as an index not just of a single experiment but also of the multiple replications of it. Thus, the ''clear'' image can indicate the thoroughness required to obtain a presentation-quality image. As the next section demonstrates, the network of presumptions attached to scientific images are closely related to the numerous values used to judge them.

IMAGES AND AGREEMENTS ABOUT THE PREFERABLE: VALUES, HIERARCHIES, AND LOCI

The rhetorical power of scientific images depends on agreements about the real, but it also rests on the agreements about the preferable—values, hierarchies, and loci. As this section demonstrates, scientific images are valued for many different features, these values can be contradictory, and scientists use lines of reasoning to establish and rank the important features in an image. Scientists not only draw on these agreements when selecting and creating visuals but also coordinate them to argue about the ethics and pragmatics of image modification.

In defining values, Perelman and Olbrechts-Tyteca (1958/1969) observed the following:

> Agreement with regard to a value means an admission that an object, a being, or an ideal must have a specific influence on action and on disposition toward action and that one can make use of this influence in an argument, although the point of view represented is not regarded as binding on everybody. (p. 74)

In short, values do not have the universal agreements of facts, but these agreements are still useful components of arguments. Values include abstract values and concrete values. Abstract values, such as beauty or justice, are not linked to specific objects. Concrete values are attached to specific groups, people, or objects. For example, the terms *clean air* and *American* can function as a concrete values. Even if speakers and their audiences share multiple values, they may disagree over their relative importance for a specific situation. Hierarchies and loci enable people to argue about competing values.

Hierarchies are agreements describing relations between competing values; for example, values pertaining to people are generally ranked as superior to those related to things (Perelman & Olbrechts-Tyteca, 1958/1969, p. 80). In a policy debate, the concrete value ''clean air'' might rank as more or less important than an industry's profits depending on established hierarchies or the loci used to adjust them.

Loci are generic premises rhetors use to establish values or to justify the hierarchical relations between values. Although there are many ways to classify these rhetorical strategies, Perelman and Olbrechts-Tyteca (1958/1969) outlined six major categories: loci of quantity, quality, order, the existent, essence, and the person.

Loci of quantity establish value through quantitative reasoning; for example, policies benefiting many people are of greater value than those benefiting only a few (Perelman & Olbrechts-Tyteca, 1958/1969, p. 87). In contrast, loci of quality establish value by focusing on the specific attributes of a thing, such as its rarity (p. 89). Loci of order establish value according to time relations; for example, ''the superiority of that which is earlier over that which is later'' or vice versa (p. 93). Loci of the existent ''affirm the superiority of that which exists, of the actual, of the real, over the possible, the contingent, or the impossible'' (p. 94). The maxim ''A bird in hand is worth two in the bush'' exemplifies this relation. The locus of essence assigns value to a specimen based on how it represents the essential characteristics of its class. For example, ''we immediately value highly a rabbit which exhibits all a rabbit's qualities: we consider him a fine rabbit'' (p. 94). Last, there are ''loci derived from the value of a person, concerning his dignity, his worth, his autonomy'' (p. 95). For example, a gain resulting from hard work might be valued more highly than some gain that is not.

Comments about digital images activate loci to define what is valuable about images; for example, authors invoke loci of essence when characterizing the ideal scientific image. According to one orthodontic surgeon, ''The ideal picture is easily recognised [*sic*] with its main area of interest sharply focused against a background free from distractions such as blood, cement or other intrusive debris'' (Hogg, 2004, p. 87). However, the ideal image will vary from field to field, context to context, and over time. Arguably, new digital image policies were efforts to redefine the ideal image in the light of technological change.

Students should learn to assess the contingencies that influence the values of images and the agreements that underwrite those values. And scientists value many properties of scientific images. In addition to an image's verisimilitude—its resemblance to phenomena in the world—images can be valued for their novelty or beauty (Richards, 2003); for aesthetic features (Lynch & Edgerton, 1988), for their uniqueness as ''golden events'' (Galison, 1997, p. 22); or for their objectivity, beauty, representativeness, or utility as a teaching tool (Daston & Galison, 2007, p. 164). Comments about digital images suggest scientists also value an image's ability to be modified (Gaffney & Mynes, 1995; Johnson, 2012) as well as its economic and logistic traits—such as efficient storage and reproducibility (Buonaquisti, 1994). Comments about digital imaging also demonstrate how specific technological developments affect relations between values.

With digitally generated and manipulated images, values of verisimilitude and clarity could compete for hierarchical supremacy. Before the proliferation of digital manipulation, these two values were inseparable or at least coincident in the minds of the scientists. For viewers, the clear or ''faultless'' scientific photograph accurately recorded a scene as it existed. As one editorial observes, available composing technologies reinforced the link between an image's clarity and verisimilitude:

> In days gone by, whether we liked it or not, data acquired at the bench were not much different from what was published. In a biomedical lab, for example, samples that had been radio-labeled and separated on a gel were recorded on X-ray film. Composite figures were assembled, with lettering carefully placed around the mounted film. If a control was forgotten or a gel was uneven, the graduate student or postdoc was sent back into the lab to get it right ''for publication.'' If a speck of dust on the film obscured data in the original photograph, another picture was taken. Slicing films to rearrange the order of samples, or to splice in a control group that was actually part of another gel, was not common because it took almost as much skill to do that as to rerun the experiment. (''Not picture-perfect,'' 2006, p. 891)

Digital tools decoupled the value of verisimilitude from the value of clarity, which allowed these values to be arranged (consciously or unconsciously) into a hierarchy. In ranking these values, some scientists place clarity above verisimilitude. They remove ''artifacts'' not contributing to their arguments even if these features are relevant or contradictory parts of the scene (e.g., section B3 of Figure 1). The rhetorical project of many scientific editors has been to re-establish verisimilitude as the preferable value in the hierarchy. The following comment from an editorial in *Nature Cell Biology* exemplifies such efforts:

> There is a myth that editors only like clean data that show striking effects. What we actually like is solid data that provides striking conceptual advances. Effects may be small, but statistics and controls are needed to make them believable. Data should be clearly presented and concise, but not at the expense of important information. Let's celebrate real data—wrinkles, warts and all. We want to publish gritty documentary movies, not digitally beautified yarns! (Appreciating Data, 2006, p. 203)

This comment distinguishes the values of ''clarity,'' ''concision,'' and ''visually striking'' from the preferable values of ''solid'' and ''conceptually striking.'' ''Gritty'' minimally processed images are valued more highly than manipulated images, and this hierarchical relationship rests on a common locus of existence: facts are superior to fictions. This articulation of values is representative of a swarm of similar editorials, news stories, and feature articles published between 1993 and 2012 (see Table 1). Although specific policies and position statements vary over time and between fields, these documents activate similar loci in attempting to articulate what scientific communities should value and presume about images in the Photoshop era. The next section uses these documents to reconstruct the history of the digital scientific image. Like Wickliff's (1996) account of 19th-century scientific photographs, this history of digital photography reveals how scientific communicators encountered the rhetorical problems and possibilities of a new visual communication tool.

IMAGES AND AGREEMENTS IN THE DIGITAL AGE

As the previous section explained, the taxonomy of agreements from *The New Rhetoric* can account for the features and functions of images in epistemic rhetorical situations. This framework is useful for analyzing specific multimodal arguments and attitudes toward specific

TABLE 1
Documents That Discuss Digital Images and Research Ethics (1993–2012)

Year	*Article Title*	*Journal*
1993	''Electronic Manipulation to Enhance Medical Photographs''	*Mayo Clinic Proceedings*
1994	''Easy-to-Alter Digital Images Raise Fears of Tampering''	*Science*
1995	''Digital Image Manipulation: What Constitutes Acceptable Alteration of a Radiologic Image?''	*American Journal of Roentgenology*
1999	''Manipulated Radiographic Material–Capability and Risk for the Forensic Consultant?''	*International Journal of Legal Medicine*
1999	''The Uses of Digital Photography in Dermatology''	*Journal of the American Academy of Dermatology*
2001	''Is It Real?''	*Zoologischer Anzeiger*
2001	''Histopathology and the 'Third Great Lie.' When is an Image Not a Scientifically Authentic Image?''	*Histopathology*
2002	''Figure Manipulation: Assessing What Is Acceptable''	*The Journal of Cell Biology*
2004	''Gel Slicing and Dicing: A Recipe for Disaster''	*Nature Cell Biology*
2004	''What's in a Picture? The Temptation of Image Manipulation''	*The Journal of Cell Biology*
2004	''Fraudulent Management of Digital Endodontic Images''	*International Endodontic Journal*
2004	''When Did Everyone Become So Naughty?''	*Journal of Clinical Investigation*
2005	''Seeing Clearly Is Not Necessarily Believing''	*Nature*
2005	''CSI: Cell Biology''	*Nature*
2006	''Not Picture-Perfect''	*Nature*
2006	''Beautification and Fraud''	*Nature Cell Biology*
2006	''Appreciating Data: Wrinkles, Warts and All''	*Nature Cell Biology*
2006	''Don't Pretty Up That Picture Just Yet''	*Science*
2006	''The Dark Side of Photomicrographs in Pathology Reports''	*Journal of the American Academy of Dermatology*
2006	''A Picture Worth a Thousand Words (of Explanation)''	*Nature Methods*
2006	''How Young Korean Researchers Helped Unearth a Scandal . . .''	*Science*
2006	''. . . And How the Problems Eluded Peer Reviewers and Editors''	*Science*
2006	''Stop Misbehaving!''	*Journal of Clinical Investigation*
2006	''Digital Manipulation of Pathologic Images''	*International Journal of Surgical Pathology*
2007	''Hwang Case Review Committee Misses the Mark''	*The Journal of Cell Biology*
2007	''A Digital Exam For Hematologists''	*Blood*
2007	''Staying True to Our Roots''	*Journal of Experimental Medicine*
2007	''The Proper Conduct of Research''	*Avian Diseases*
2007	''Navigating Through the Gray (and CMYK) Areas of Figure Manipulation: Rules at the JCI''	*Journal of Clinical Investigation*
2007	''Imag*ine* . . . Spot-Checking Figures for Manipulation''	*Nature Cell Biology*
2008	''Digital Forensics and the *American Journal of Neuroradiology*''	*American Journal of Neuroradiology*
2008	''Falsification Charge Highlights Image-Manipulation Standards''	*Science*

(*Continued*)

TABLE 1
Continued

Year	Article Title	Journal
2009	''When a Picture Needs 1,000 Words''	*Chest*
2009	''Impact Of Digital Image Manipulation In Cytology''	*Archives of Pathology & Laboratory Medicine*
2009	''The Darkroom Is Closed. Introducing Digital Image Ethics To A New Generation''	*Microscopy and Microanalysis*
2009	''Fostering Trust—*J Mol Med's* Scientific Integrity Policy''	*Journal of Molecular Medicine*
2009	''Science Journals Crack Down on Image Manipulation''	*Nature*
2010	''Editors as Gatekeepers of Responsible Science''	*Biochemia Medica*
2010	''Fraud: Just Say No!''	*Endocrinology*
2010	''What's in a Number or in a picture?''	*Osteoarthritis and Cartilage*
2010	''Image Rights and Wrongs''	*Nature Nanotechnology*
2010	''Scientific Misconduct: Tip of an Iceberg or the Elephant in the Room?''	*Journal of Dental Research*
2010	''What Were You Thinking?: Do Not Manipulate Those Data''	*Autophagy*
2010	''What Is Truth? Standards of Scientific Integrity in AHA Journals''	*Arteriosclerosis, Thrombosis, and Vascular Biology*
2012	''Manuscript Fabrication, Image Manipulation, and Plagiarism''	*Experimental Eye Research*
2012	''Not Seeing Is Not Believing: Improving the Visibility of Your Fluorescence Images''	*Molecular Biology of the Cell*

Note. Discussions of imaging ethics in science journals increase dramatically in the first decade of the 21st century. Although commentaries have addressed the ethics of adjusting digital images since the 1990s, the issue of digital manipulation became more salient after 2001 and especially after the 2006 Hwang stem cell scandal. Many of the documents in this list could be productive additions to discussions of communication ethics in scientific or medical writing classes.

media; however, it is also a useful tool for comparative analysis. To demonstrate this methodological benefit, this section presents a brief rhetorical history of the Photoshop era (1990–present). I draw on submission guidelines, editorials, feature stories, correction notices, and letters to editors to show the malleable nature of images and objects of agreements in this digital age. Understanding the technological and rhetorical developments of the past two decades can help us understand how scientific images are functioning now.

Adobe Photoshop appeared in 1990 (Story, 2000). By 1993, the popular image-editing program and others like it were influencing policies at scientific journals and associations. In January 1993, the publications board of *Molecular and Cellular Biology* added language on digital adjustments to the journal's submission guidelines; *The Mayo Clinic Proceedings* revised its submission policies in June. These earliest reactions differ in how they describe image manipulation and in how they attempt to preserve the rhetorical status of images as objects of agreement.

Primarily concerned with technical details for submitting reproducible digital images, the *Molecular and Cellular Biology* guidance document provided one sentence about digital enhancement: ''Since the contents of computer-generated images can be manipulated for better clarity, the Publications Board at its May 1992 meeting decreed that a description of the software/hardware used should be put in the figure legend(s)'' (Ryan, Danish, Gottlieb, & Clarke, 1993, p. v). This slim and rather positive statement characterizes digital manipulation as a means to greater clarity and not as a means for fraud; nevertheless, it distinguished digital images from traditional prints. Statements added to captions in *Molecular and Cellular Biology* articles in 1993 were relatively uninformative; for example, ''For panels A and B, Adobe Photoshop and Adobe Illustrator programs were used'' (Ryan et al., 1993, p. 713). But such statements do alert readers to actively consider their presumptions about images. Readers might view digitally processed images with greater skepticism than traditional photographs.

The editorial board of the *Mayo Clinic Proceedings* took a different approach. Authors were to submit unaltered versions of any digitally modified images and describe any alterations in their cover letters (1993, p. 1121). Journal readers would not see this information; however, the new editorial oversight of digital images could maintain existing presumptions about all images in the journal.

Although policies like those at *Molecular and Cellular Biology* and *Mayo Clinic Proceedings* did not proliferate rapidly, they reflect broader conversations about the merits and dangers of image manipulation. In 1994, *Science* contributor Christopher Anderson reported that many journals were slow to change because major problems had not yet surfaced:

> So far scientific journals have received only a trickle of digital photographs (as opposed to computer-generated digital images of molecular structures, which are ubiquitous). As a result, only a few journals have set polices for handling digital photographs. (p. 317)

Some journals and associations raised the possibility of more rigorous auditing of digital images. For example, in 1993 the Council of Biology Editors discussed requiring authors to supply electronic histories of the changes made to an image (Anderson, 1994, p. 317). But by 1998, the Council of Biology Editors policy only requested that authors add ''. . . the name of the application that was used to create the image'' to the figure legend (Rossner, Held, Bozuwa, & Komacki, 1998, p. 189). This suggestion is almost identical to the suggestion in the *Molecular and Cellular Biology* guidelines from 1993. As time passed, it became clear that just identifying software was insufficient. Two developments drew attention to digital manipulation and encouraged changes to imaging standards: the proliferation of digital manuscript submission and the Hwang stem cell scandal.

In December 2001, *The Journal of Cell Biology* began requiring electronic submission for all manuscripts and image files. By September of 2002, the journal's editor, Mike Rossner, had begun what would become a veritable crusade against unethical digital imaging. The journal began forensically analyzing all submitted images (Rossner, 2002). After finding numerous questionable images in submitted manuscripts, Rossner's journal and its publisher, Rockefeller University Press, published four new guidelines on image manipulation:

> No specific feature within an image may be enhanced, obscured, moved, removed, or introduced.
>
> Adjustments of brightness, contrast, or color balance are acceptable if they are applied to the whole image and as long as they do not obscure, eliminate, or misrepresent any information present in the original.
>
> The grouping of images from different parts of the same gel, or from different gels, fields, or exposures must be made explicit by the arrangement of the figure (e.g., dividing lines) and in the text of the figure legend.
>
> If the original data cannot be produced by an author when asked to provide it, the acceptance of the manuscript may be revoked. (Rossner, 2003, p. 837)

A 2003 policy update added requirements regarding the submission of specific information about image acquisition and modification. The required documentation should include such details as microscope models, microscopy settings, temperature measurements, acquisition software, modification software, and all digital adjustments (p. 837).

These polices attempted to preserve the image's ability to function as a fact. Part of this preservation depends on articulating the network of facts that generate images; hence, the requirement for detailed documentation about equipment, settings, and modifications. The forensic analysis allows readers to presume that published images are vetted images.

These policies also articulate what *The Journal of Cell Biology* (and its readers) value in an ideal image: likeness to the captured event and likeness to the original image. Specific loci justify these values. For example, the policies permitting adjustments to the entire image and prohibiting adjustments to select parts draw on a locus of quantity. Changes affecting all pixels are better than changes affecting only some of them. Policies requiring authors to provide ''original'' or ''unaltered'' images draw on loci of quality and order. The unique/original/unaltered image is more real than any derivative form. When a figure is derived from pieces of many images, its composite status must be clearly marked. For composites, the image showing signs of human intervention is preferred over an image without those signs.

The Journal of Cell Biology policies articulated the features and values of scientific digital imaging for its discourse community, but they also influenced policies and behaviors in other fields. The journal's editors publicized their guidelines through editorials, such as Rossner and Yamada's (2004) ''What's in a Picture? The Temptation of Image Manipulation.'' The most influential editorial of the Photoshop Era, this work has been cited more than 100 times in editorials, policy statements, news features, research articles, tutorials, and other documents (*Web of Science* database search, July 26, 2012). As one might expect, editors cited it when articulating their own polices or offering advice in editorials. For example, after providing a link to Rossner and Yamada's article, the editor of *Autophagy* extols the virtues of the policies of *The Journal of Cell Biology*: ''I decided not to attempt to generate an entirely novel set of instructions because those presented on the *Journal of Cell Biology* ''Instructions for Authors'' page have always seemed very clear to me'' (Klionsky, 2010, p. 1007). Rossner and Yamada (2004) also influenced the rhetorical choices of individual scientists. It is interesting that more than half of their citations (53 of 101) appear in scientific research articles; that is, authors cite Rossner and Yamada (2004) to justify digital adjustments to their image data. For example, ''Image manipulation was fully compliant with guidelines for proper digital image handling outlined in Rossner and Yamada (2004).'' Such citations appeared in publications ranging from material science journals (e.g., *Polymer*) to medical journals (e.g., *The Medical Journal of Australia*) and from specialist publications (e.g., *Headache*) to prestigious interdisciplinary journals (e.g., *The Proceedings of the National Academy of Sciences*). By citing Rossner and Yamada (2004), researchers could signal to their readers that their images are reliable objects of agreement. Such rhetorical support became especially important after the Hwang stem cell scandal raised awareness of image manipulation.

In January 2006, after months of rumor, accusation, and investigation, the editors of *Science* retracted two papers on embryonic stem cell research conducted by celebrity scientist Hwang Woo Suk. The research promised to revolutionize stem-cell research by removing the need to destroy embryos to develop stem cells and by allowing stem cells to be cultivated from a patient's own cells. Unfortunately, Hwang's claims were based on fraudulent data presented in fabricated images. Before the fraud surfaced, Hwang was a national hero in South Korea, and his work had convinced other researchers to abandoned stem cell projects because Hwang seemed to control the field (Wade & Sang-Hun, 2006, para. 13). The high-profile scandal drew attention to the issue of unethical image manipulation; it also prompted editors to shore up their editorial procedures. The prestige journals *Science* and *Nature* revised their image submission guidelines in 2006, and imaging ethics became a popular subject for editorials and commentary articles in both field-specific and interdisciplinary journals (see Table 1).

Anecdotal evidence suggests that the increased attention to visual-rhetorical practices changed how some scientists interact with images. Some modified their production practices. For example, a scientist interviewed about image manipulation in 2006 described changes in his rhetorical behavior:

> ''We've all seen gels that look like a complete disaster,'' with ''splotches'' everywhere from artifacts related to processing. ''In the past, I would take those out,'' says Hayden. ''I wouldn't do that now.'' (Couzin, 2006, p. 1866)

Hayden's aversion to removing artifacts reflects the shift in values and presumptions that occurred during this period. All clear images are not the same; the artificially clear image can no longer function as an object of agreement.

Other documents demonstrate more acute reading practices. For example, the following passage from a 2007 correction of a 2002 *Science* article explains that comments from an image-savvy reader prompted the authors to update a figure: ''It has come to our attention that Fig. 3B gives the appearance that lanes might have been spliced or possibly duplicated''

(Hoffmann, Levchenko, Scott, & Baltimore, 2007, p. 1550). The rest of the correction verbally and visually defends the challenged image and the facts it represents:

> The experiments that yielded this figure were carried out in 1997 using autoradiography when the authors were at the Massachusetts Institute of Technology. Similar experiments were rerun after the authors had moved to the California Institute of Technology. Because more stringent standards for handling electronic images have arisen more recently [see, e.g., M. Rossner, K. M. Yamada, J. Cell Biol. 166, 11 (2004)], we provide a recently created figure based on data from a similar experiment (right), as well as an image of the full gel (below) captured with a Molecular Dynamics Phosphoimager. (p. 1550, their parenthetical metadiscourse)

In this case, no misconduct occurred, and the correction does not change the results described in the report. Nevertheless, the authors felt compelled (a) to correct the image, (b) to provide details about their methods, and (c) to insert additional credibility markers in the correction by identifying their institutions—two premiere research universities. Moreover, they attempt to restrain the act-person association of ''a sloppy image equals a sloppy scientist'' by emphasizing three facts: (a) the age of the original image (1997), (b) the experiment had been reproduced, and (c) imaging standards had changed since the article's publication. The authors also produced a new version of the figure and included an image of the entire gel; thus, they provided more visual evidence than initially published to reinforce the credibility of the figure. In short, the correction expressed explicitly what should be tacit presumptions about images, ethos, and scientific skill. The reader would not have questioned those presumptions if not attuned to common signs of image manipulation.

The ethical and rhetorical issues of the Photoshop Era are far from settled. The rates of image-based misconduct remain high, and editors continue to update policies and alert their readers to the ethical hazards of image manipulation. These developments are fortunate for technical communicators because we can continue to learn from these responses and use them to inform discussions of visuals, ethics, and argumentation in our classes.

IMPLICATIONS FOR TEACHING

Understanding the rhetorical dynamics of digital images is especially important for technical-writing students planning scientific careers because they are often blamed for the increase in unethical image manipulation. Various commentators have pointed to the inexperience, job duties, technological savvy, lack of technological savvy, ignorance, or eagerness of early career scientists as causing the proliferation of image-based misconduct (see Table 2). Of course, these (sometimes contradictory) claims are debatable; for example, in a letter to *Nature*, Daniel Peterson, a neuroscience researcher and microscopy trainer, responded to a news story faulting eager students: ''[I]n my courses, many trainees report that they are instructed—often pressured—by the principal investigator to produce images consistent with expectations'' (Peterson, 2005, p. 881). Peterson's alternative explanation suggests how social factors—such as acculturation to a discipline, interpersonal relationships, and expectations within a laboratory—influence imaging practices for better and for worse.

Peterson's account and the other comments about early career researchers (Table 2) demonstrate further why our science writing students must understand the ethical rhetoric

TABLE 2
Comments Suggesting That Early-Career Researchers Are More Likely to Manipulate Images Improperly

Year	*Article Title*	*Journal*	*Comment*
2002	‘‘Figure Manipulation: Assessing What Is Acceptable’’	*The Journal of Cell Biology*	. . . it is possible that some young investigators are not aware of what constitutes ‘‘improper manipulation.’’
2005	‘‘CSI: Cell Biology’’	*Nature*	Scientists and journal editors say that most questionable image manipulation can be traced to inexperienced students or lab staff who are unclear about what is allowable.
2005	‘‘Plagiarism: A Spreading Infection’’	*Current Science*	. . . presentations of data are invariably prepared by students and postdoctoral fellows, who are usually more familiar with the latest software for image manipulation than senior professors . . . .
2006	‘‘Appreciating Data: Warts, Wrinkles and All’’	*Nature Cell Biology*	A whole new generation of scientists has known nothing but the magical world of Photoshop and regularly use tools with fashionable names such as ‘‘clone’’ and ‘‘healing.’’
2007	‘‘Spot Checks’’	*Nature Immunology*	[There is] . . . a ‘generation gap’ between older scientists, who do not necessarily understand the possibilities of imaging software, and younger scientists, who acquire the original data and prepare the images for publication.
2008	‘‘Journals Find Many Images in Research Are Faked’’	*The Chronicle of Higher Education*	Experts say that many young researchers may not even realize that tampering with their images is inappropriate.
2009	‘‘The Darkroom Is Closed: Introducing Digital Image Ethics to a New Generation’’	*Microscopy and Microanalysis*	Most of today’s students have never used an enlarger. Their darkroom is found in programs like Adobe Photoshop. Unfortunately, it seems rare that these students know much about the proper way to work with digital images.

Note. Young researchers are often blamed for the proliferation of image-based misconduct. Technical writing instructors can help their students avoid living up to these presumptions by discussing rhetorical strategies for understanding the explicit and implicit expectations of their fields.

of imaging practices. In addition to being blamed for ethical lapses, students may be assigned to prepare images for publications or pressured by senior colleagues to make unethical images. Although writing teachers might not be able to address all the technical issues of image acquisition and editing, we can provide students with rhetorical concepts and approaches to help them navigate the explicit and tacit standards of their fields. As the preceding analysis demonstrated, *The New Rhetoric* offers one productive vocabulary for understanding ethical multimodal argumentation. This rhetorical vocabulary can be shared through activities in several contexts.

First, in scientific writing courses, we can incorporate rhetorical approaches to digital-imaging ethics into existing activities about disciplinary conventions and ethical communication practices. For example, instructors can modify two activities from the popular textbook *Writing in the Sciences* (Penrose & Katz, 2010) to develop what Dragga (1997) identified as a narrative approach to teaching ethics; that is, teaching moral character through case studies and scenarios rather than prescriptive analytical systems (pp. 174–175). The first of these activities asks students to interview scientists in the disciplines they wish to join; they then write profiles of communication practices in those fields based on the interview and other research (Penrose & Katz, 2010, p. 23). Students could easily include focused questions about field-specific values related to images or about field-specific norms of image making and figure preparation to their lists of interview questions. For example, students might ask questions about image-preparation training or about situations in which scientists faced ethical dilemmas regarding images. Students could then compare comments from their interviews with published comments about digital imaging from journals in their fields. Such research might help students to understand the complex web of presumptions and values that are activated when scientists read and create digital images.

Another activity from Penrose and Katz's (2010) *Writing in the Sciences* asks students to discuss misconduct cases posted on the website of the Office of Research Integrity (p. 87). When I taught this activity from 2004 to 2007, I was struck by the high number of image-based misconduct cases, which ultimately inspired the research for this article. As mentioned previously, many Office of Research Integrity investigations focus on unethical digital images, and the plain-text case summaries of these investigations offer good fodder for discussions about ethics. Students and instructors can enhance discussions of these summaries by examining (a) the offending articles and their images, (b) correction and retraction notices, and (c) relevant commentaries on the ethics of digital imaging.

Writing-across-the-curriculum and writing-in-the-disciplines programs offer other opportunities for technical communication scholars to help students and instructors consider the rhetoric and ethics of preparing figures digitally. Poe, Lerner, and Craig (2010) demonstrated the importance of teaching science students to approach the visual presentation of data rhetorically. Although their case studies focus on the presentation of quantitative data through graphs, digital images are also important data for some fields. Moreover, as Watson and Lom (2008) reported, incorporating image training into science classes can improve undergraduates' overall rhetorical sensibilities:

> A pleasant and unanticipated side effect of our investment in image training occurred during the last few class periods when students discussed recent research articles on stem cells. Many of our students expressed surprise and dismay at the quality of some of the images in the articles our class

> discussed. Students confidently critiqued the scientific results of other researchers; they actively and skeptically compared the visual results presented in the figures with the authors' written claims. In fact, our students were eager to point out how the authors could improve their figures and how their written claims were not always well supported by their figures. (p. 35)

This account suggests that teaching effective and ethical imaging practices can develop critical visual literacy and robust rhetorical skills. Such training could include exposure to rhetorical vocabularies—such as the taxonomy of *The New Rhetoric*—that can account for the explicit and tacit dimensions of multimodal arguments.

Last, we can provide students with questions for assessing the efficacy and ethics of their own images. Toward the end of ''Ethics and Visual Rhetorics,'' Allen (1996) offered a set of questions designed to help technical writing students consider the ethical implications of their visual choices. This productive list includes questions about content, aesthetics, design, and the values of the producer and the audience. Reactions by scientists to the Photoshop era invite additional questions regarding audience, artifacts, arguments, and authorship. Such questions are particularly important for scientific communicators using and modifying digital images:

Audience: What are the standards of my audience for images of this type?
What expectations are my readers bringing to images like this one?
What do my readers value in an image of this type?
Will my readers understand my modifications of this image?

Artifact: Does this image depict real data?
What have I changed in this image?
Were changes applied to the entire image or only part of it?
Have I documented changes sufficiently?

Author: Does this image suggest that I am a credible and ethical communicator?
Have I modified the image to create the impression of credibility?
Will my credibility be reduced if people think I modified this image but did not tell them?

Argument: Does this image represent what I say it represents?
Will adjusting this image improve my argument?
Am I removing traces of visual data that my readers should see?

These questions will need to evolve as the scientific image evolves. As long as they prompt students to consider the various agreements attached to and created with images, such questions will help them use digital technologies ethically and effectively.

NOTE

1. Although scientific images serve as this article's primary examples, the current study also extends the general conversation on ethics and visuals in technical communication—a conversation that has focused largely on data graphics (e.g., Allen, 1996; Dragga & Voss, 2001; Tufte, 1983), document design (e.g., Dragga, 1996; Herrington, 1995), the ethics of abstraction in visual representation (Dragga & Voss, 2003), and selecting appropriate technical visuals to meet rhetorical goals (Manning & Amare, 2006).

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