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Popular Images versus Self-Images of Science: Visual Representations of Science in Clipart Cartoons and Internet Photographs

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Introduction*

The public image of almost anything is substantially a visual image. Public discourses are visually mediated, and for most people images sustain when words have long been forgotten. Visual images communicate more readily to the public than other media, and even the written or spoken word translate into visual images in the human imagination.

Although it has become the subject of scholarly studies about science only recently, visualization has accompanied science at least since medieval times. Many alchemical texts and Renaissance textbooks of practical knowledge were packed with images, setting the stage for the later tradition of textbook illustrations. Late medieval attempts to classify knowledge were illustrated by woodcuts of the arts, thus establishing emblems of the disciplines. The front page of Renaissance science books typically presented a portrait of its author in his characteristic setting, on which later traditions of portraiture could draw. The satirical literature of the 15th and 16th centuries, which was richly illustrated with woodcuts, did not spare fields like alchemy, pharmacy, and astronomy, nor did the later genre paintings. All these images contributed essentially to the public image of science in their time, and continue to do so today.

Any study of the contemporary public visual image of science is faced with two problems: the sheer mass of existing pictures, and the gap between pictures as the objects of a study and language as the medium of communicating that study. Margaret Mead and Rhoda Métraux in 1957[1] and David Chambers in 1983[2] avoided both problems by letting people, in the first case, describe in words and, in the second case, draw on paper what a typical scientist looks like. Such studies revealed many stereotypes, for example, "a man who wears a white coat and works in a laboratory […] is elderly or middle aged and wears glasses […] wear[s] a beard, may be unshaven and unkempt […] is surrounded by equipment […] and spends his days doing experiments", is a loner with "no social life, no other intellectual interests, no hobbies or relaxations", or associated the scientist with a magician, alchemist, and mad scientist. Another option is to focus on a defined set of images as Marcel LaFollette[3] did for U.S. magazine illustrations and Peter Weingart[4] for film, and then analyze their visual content according to chosen categories.

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[1] M. Mead and R. Métraux: 'Image of the Scientist among High-School Students', *Science*, 126 (1957), 386-387.

[2] D.W. Chambers, 'Stereotypic Images of the Scientist: The Draw-A-Scientist Test', *Science Education* 67 1983, 255-265.

[3] M.C. LaFollette, *Making Science Our Own: Public Images of Science 1910-1955*, Chicago, IL: University of Chicago Press, 1990.

[4] P. Weingart, 'Of Power Maniacs and Unethical Geniuses: Science and Scientists in Fiction Film', *Public Understanding of Science* 12, 2003, 279-287.

In this paper we present a different approach. We take digital images from databases that can be searched by keywords and analyze them both quantitatively and qualitatively to identify the stereotypes, emblematic objects, and typical gestures and elements used to image science. In addition, we examine the differences between the scientific disciplines, their relative visibility, and their characteristic visual representations. Most importantly, however, we distinguish between the *popular image* of science and the *public self-image* of science. The popular image of science depicts how non-scientists see science; in contrast, the public self-image of science communicates how scientists visually represent science to the public.[5] While both images are public images, the public self-image of science is at the interface between science and the public. As with the linguistic interface between science and the public, the way scientists openly depict their field is based on an intricate compromise. They want to describe how it "really" is, but also want to look better than what they perceive as their public image. They want to illustrate the complexity of their work and possibly correct misleading clichés of the public image, but need to draw on simple visual elements and metaphors, because they want to be understood. The public self-image of science thus both responds and adapts to the popular image in subtly differentiated ways. And because there are many scientific disciplines and different institutions that represent science, the responses are necessarily varied.

While discussions of the public image of science have been largely motivated by scientists' complaints about their allegedly bad public repute, our approach is primarily motivated by the need for *understanding* the image of science, whether the popular image or the public self-image. What exactly is the popular visual image composed of and where does it come from? How do scientists intuitively respond to this popular image? Do they, by their public self-images, correct or reinforce the popular image of science? And, if their intent is corrective, does the public self-image have any impact on the popular image of science?

Our approach requires that we first explore the popular image of science, which we elaborate in the next section through the analysis of clipart images. In section 3 we focus more deliberately on chemistry and physics and investigate how and in what ways chemists and physicists respond and adapt to their popular image through their visual self-representations in Internet photographs.

2. The Popular Image of Science in Clipart Cartoons

2.1 Clipart Cartoons and the Methodology of Quantitative Image Analysis

Cartoons are humorous or satirical drawings that present their subject matter in a very reduced, stereotypical manner. They depict and compose only the most essential characteristics, so that the subject matter is easy to recognize and the image memorably humorous. Unlike our conception of what fine artists do, cartoonists visually analyze and reproduce clichés and stereotypes that are part of the cultural heritage of both visual and literary images. Cartoons are an extremely popular visual medium that use an artistically simplistic style to communicate deep seated cultural assumptions and, therefore, cartoons of science are an ideal source for analyzing the popular image of science, its cultural clichés and visual stereotypes.

Cartoons are now commercially available in digital form in huge searchable databases of clipart for illustration of virtually any topic in print and electronic media. The Internet has made clipart cartoons the most popular image source for private and professional use. Because clipart databases are searchable by keywords, they are an ideal source for analyzing visual stereotypes both qualitatively and quantitatively. Qualitative analysis selects a set of

[5] We distinguish between the public self-image of science, which refers to the image scientists wish to project to the public, specifically on the Internet, from the self-image of science, which is private and idiosyncratic, dependant on the scientist or specific scientific discipline; the two, of course, overlap at points.

cartoons by keyword search and analyzes the visual content according to standard procedures from art history or visual studies. Since the results are supposed to be expressed in linguistic form rather than in images, the analysis includes the crucial step of image interpretation that translates visual content into linguistic form. That procedure is faced with the two main problems of any visual study: the subjectivity of image interpretation and the practical limitation regarding the number of images that can be analyzed in reasonable time.

Quantitative analysis avoids both problems by focusing on the keywords alone. If the image content has been professionally analyzed by database managers and encoded by keywords, such that database users can easily find their desired motifs, the analysis can be performed at the linguistic level of keywords on any number of images within seconds. The procedure of image analysis is then similar to co-keyword analysis, as familiar from bibliometrics. A set of images selected by one keyword can be analyzed according to the co-occurrence of other keywords or of combinations of keywords. Once the set of images representing science is identified, the frequency of co-occurring keywords provides a quantitative measure for visual associations with science. Measuring the strength of visual associations is the key to quantitative visual studies. In our study it allows us not only to measure the dominant associations with science but also the relative visibilities of disciplines and their respective emblematic objects.

For our study we have used the searchable online database www.clipart.com by Jupitermedia. As is true of any database, clipart.com does not meet all the ideal requirements for research. In particular, keywords have not been assigned in the same systematic way for all the images, because the database combines images from more than ten primarily US based clipart publishers, each combining images drawn by a variety of cartoonists. Yet, the difference in keyword assignment and possible distortions by selective image input are presumably leveled out in most cases due to the number and diversity of original sources and the large number of images. Indeed, clipart.com had more than 2.1 million clipart images at the time of our analysis (June 2004).

2.2 The Relative Visibility of Science and Its Disciplines

As with all database analysis, analyzing a clipart database requires extensive pre-studies and qualitative checks of the images retrieved by the keywords. Indeed, the unmodified keyword "science" provides mostly (78%) cartoons of animals in anthropomorphic gestures, reminiscent of the pre-scientific medieval tradition in which the "animal kingdom" served to illustrate moral fables which survives in modern comic strips. Since these images are not associated with specific scientific keywords, like "biology", we have excluded them in the following analysis, as we have similar cartoons of flowers and trees. In addition, we have excluded all science images associated with the keyword "technology", although the overlap between science and technology is surprisingly low (10%). Thus refined, the search provides 1360 cartoons about science,[6] which represents 0.6% of the overall clipart database. If this number measures the relative visibility of science in the popular visual culture, it suggests that science plays only a very marginal role, compared for instance to the much more visible field of technology (3%).

Our first analysis of the set of science clipart images compares the relative visibility of the disciplines. About three quarters of the images are keyword-related to at least one discipline, but the distribution reveals a clear disciplinary focus (Figure 1). Indeed, more than 40% are related to the discipline of chemistry, demonstrating that chemistry dominates the popular visual stereotype of science overall. Next comes physics with only 16%. Apart from that, only five other disciplines play a visible role. The combined field of the biomedical sciences is

[6] The actual search phrase has been "+scien* -(animal* flower* tree* herb technol* music* fiction)"; for the syntax of search phrases, see the website of clipart.com.

represented in 12% of the images.[7] The relatively strong presence of "rocket science" (11%) suggests a clear US origin of the cartoons, where space engineering has strongly influenced the popular view of science since the Apollo program – and has generated "rocket science" as an ironic idiom for any "endeavor requiring great intelligence or technical ability"[8], usually, however, in the negative, i.e., "It isn't rocket science". In visual images, anatomy (9%) is distinguished from the biomedical sciences, as is astronomy (7%) from physics. Although strictly speaking not a natural science, mathematics follows with 4%, whereas all the other real sciences are virtually absent in the visual stereotypes of science.

The co-occurrence of disciplinary keywords provides further insight into how the visual image of science is structured. Overall, there is little overlap (about 5%), which suggests that each of the disciplines has a relatively clear visual identity. Apart from some minor overlap between astronomy and rocket science, anatomy and biomedical sciences, physics and mathematics, and physics and chemistry, only the biomedical sciences stand out because 28% of their cartoons are also related to chemistry. This overlap is related to the relative weakness of the emblematic object of the biomedical sciences (see below).

Several approaches explain the relative visibility of the various disciplines and why the weight of each discipline's visibility does not necessarily accord with its impact on the actual modern-day research landscape. There are of course historical reasons, which we explore in Section 2.6, but there are also specific visual reasons that we investigate in the next section, thereby illustrating the potential of our approach for quantitative emblematic studies.

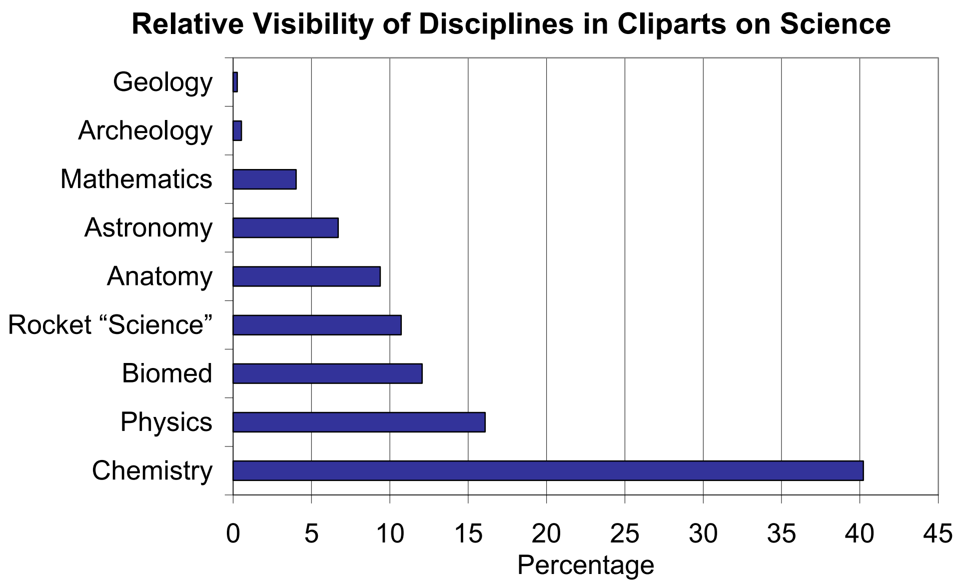

Figure 1. The relative visibility of disciplines in clipart figures on science.

2.3 The Emblematic Objects of Scientific Disciplines

The visual stereotypes of science contain emblems that stand for science or for a scientific discipline and which must be simple enough to be easily recognized. A discipline without an emblem hardly exists in the popular visual image of science. Of the seven visible disciplines in Figure 1, six have strong emblematic objects (Figure 2). Glassware such as beakers, flasks, or test tubes epitomizes chemistry; the microscope, the biomedical sciences; a rocket, the popular idea of "rocket science"; bones stand in for anatomy; the telescope, astronomy; and mathematics finds representations either by means of formulas (algebra) or a pair of com-

[7] Search phrases need to be carefully selected so as to cover adjectives and nouns as well as singular and plural forms. For instance, for the biomedical sciences our search phrase is "+(biolog* medic*)".

[8] *The American Heritage Dictionary of the English Language*, 4th edn., Boston: Houghton Mifflin, 2000.

passes (geometry). Physics is the exception to the rule because it has no such popular emblem, although it shares with chemistry to some degree the atom. Indeed, the cartoons that are keyword-related to physics consist largely of images of rather unspecified experimental settings, which suggest that the keyword "physics" is rather understood in terms of its pre-modern meaning where it was used to denote the natural sciences overall.[9] One of the reasons why physics has no clear visual emblem might be that its more abstract subject matter has resisted the visual imaginability of the popular culture.

Figure 2 illustrates that the emblems can be research instruments, objects, or graphical languages, but each must be easily recognized by anybody. Compared to the other emblems, the main emblems of chemistry (beakers, flasks, and test tubes) stand out because they have the simplest graphical structure and can even be drawn with a single line. This points to a possible visual reason for chemistry's dominance in the visual image of science, since the elegance of the emblems enables them to serve as emblems of science overall.

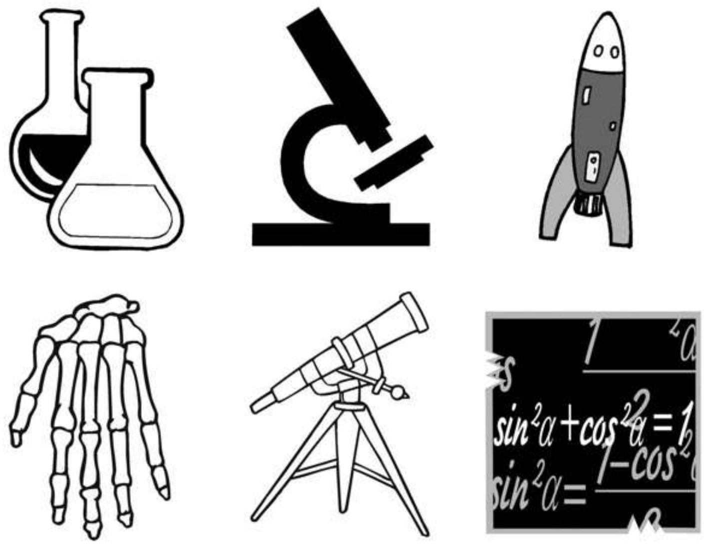

Figure 2: Emblematic objects of the disciplines chemistry, biomedical science, "rocket science", anatomy, astronomy, and mathematics.

The emblematics of the popular visual image of science obviously does not reflect the actual instrumentally based scientific practices of today. For instance, much of the emblematic glassware portrayed in the database was previously used by many scientific disciplines but is currently outdated. And although chemists historically used microscopes and occasionally still do today, that instrument is now much more important in other fields. Yet, the popular visual culture has its own rules for selecting emblems, which seem to draw more on the history of science rather than on modern methodology.

The clipart database is an excellent research tool for quantitative emblematic studies. Based on the assumption that a visual element is an emblem of a field if the element occurs frequently in visual representations of the fields, we can make two key distinctions. First, we can distinguish between *weak* and *strong* emblems, depending on how frequently the element appears in representations of the field compared to those of other fields (i.e. on the percentage of co-occurrences of element and field keywords based on the total number of element key-

[9] In the early 19th century, "physics" was still the generic term for the natural sciences, almost similar to "natural philosophy". Modern physics emerged as its own discipline only in the second half of the 19th century by combining parts of applied mathematics with parts of what was formerly called "experimental philosophy". For more details, see R. Stichweh, *Zur Entstehung des modernen Systems wissenschaftlicher Disziplinen: Physik in Deutschland; 1740-1890*, Frankfurt: Suhrkamp, 1984.

word occurrences). Second, we can distinguish between *important* and *less important* emblems, depending on how many representations of the field contain the emblematic elements (i.e., on the percentage of co-occurrences of element and field keywords based on the total number of field keyword occurrences).

Let us clarify these distinctions: the Bunsen burner, beaker, flask, and test tube are all strong emblems of chemistry because they almost exclusively occur in representations of chemistry (Figure 3). However, the Bunsen burner, which is the strongest emblem, is also the least important one because only 4% of the chemistry images contain it, compared, for instance, to 44% of the chemistry images that are keyword-related to glassware.[10] Surprisingly, the microscope is a slightly stronger emblem of chemistry than of the biomedical sciences (Figure 3). However half of the chemistry images, including the microscope, are also related to the biomedical images, which explains the disciplinary overlap mentioned above; and since 35% of all the biomedical images show a microscope, it is the most important emblem of this field. Overall, the most important visual emblems of science are glassware (beaker, flask and test tube; present in 18% of all science images) and the microscope (10%). Although these percentages based on science overall are not very high due to the visual diversity of the disciplines, they are the strongest emblems of science.

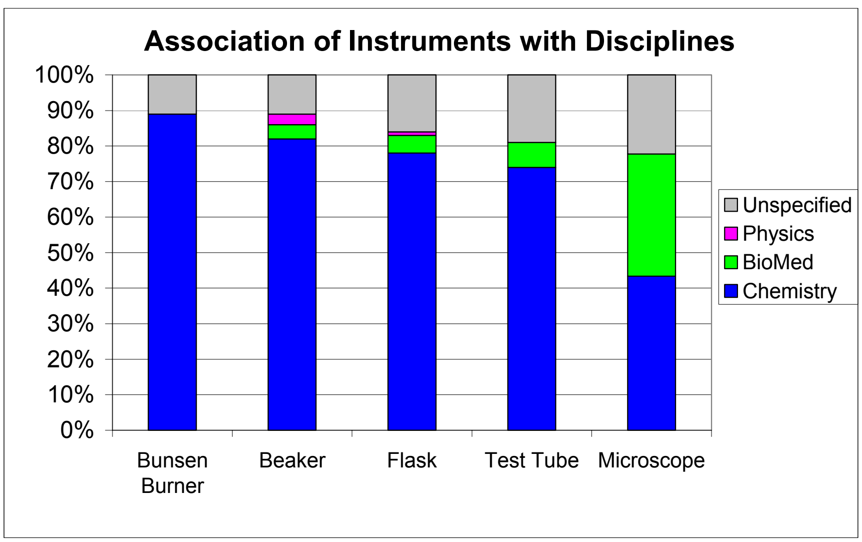

Figure 3: Identification of emblematic laboratory instruments by association with different disciplines

2.4 The Laboratory as the Archetypical Location of Science

The previous two sections supply foundations for a co-keyword analysis of the inner structure of the popular visual image of science, i.e. of which disciplinary elements and of which emblematic objects it is composed of. Co-keyword analysis also allows for the investigation of the outer structure of the popular visual image of science, giving us a perspective on the broader symbolic associations of science. Before doing this, however, we focus on the semantic field of "research" and its relation to the various disciplines.

In the public view, research is not confined to science (Figure 4, first column). Clipart demonstrates that, visually, people associate research equally with scientific and other disci-

10 The percentage of chemistry images that contain glassware is actually much higher, since keywords usually do not note cases in which some glassware appears only in the background or is part of a larger experimental setting (see below).

plines: with test tubes and with reading books and writing texts (39%).[11] They assume, correctly, that scholars in the humanities, lawyers, journalists, bankers, and so forth, all do research. As one might expect, however, if we focus on the keyword "scientific research", reading and writing shrinks dramatically and the dominant research field is again chemistry (Figure 4, second column). In addition to the emblematic objects of chemistry, the microscope is a strong visual emblem of research, both with and without biomedical associations, whereas all the other scientific disciplines and their emblematic objects are virtually absent. The reason for this becomes obvious in the third and forth columns of Figure 4. In the popular image, the characteristic activity of scientists is laboratory research, and the stereotypical laboratory is equipped with glassware – the emblematic objects of chemistry. This stereotype is so strong that 95% of all cartoons depicting laboratory research are keyword-related to chemistry and only to chemistry. A corresponding analysis shows that chemistry is also the archetypical field of experimentation.

This suggests another reason for the dominance of chemistry in the visual image of science. Apart from their elegant graphic structure, depictions of glassware are the simplest visual elements to indicate science: a room equipped with some glassware turns into a laboratory; a person holding a test tube is a scientist. In sum, glassware epitomizes scientific research, which in the visual popular image means conducting chemical experiments in a laboratory. This popular image, while at odds with actual contemporary scientific activity, is historically linked. Before the early 19th century, the laboratory per se was a chemical or alchemical laboratory and experimental research approximated chemical research.[12] The clipart image featured in Figure 5, which presents a typical modern cartoon of laboratory research, is a legacy of this tradition. The object that reveals the cartoon's alchemical legacy most overtly is the flask in the foreground: shaped like the retort used by alchemists, it unconsciously assimilates the historical references included in these images.

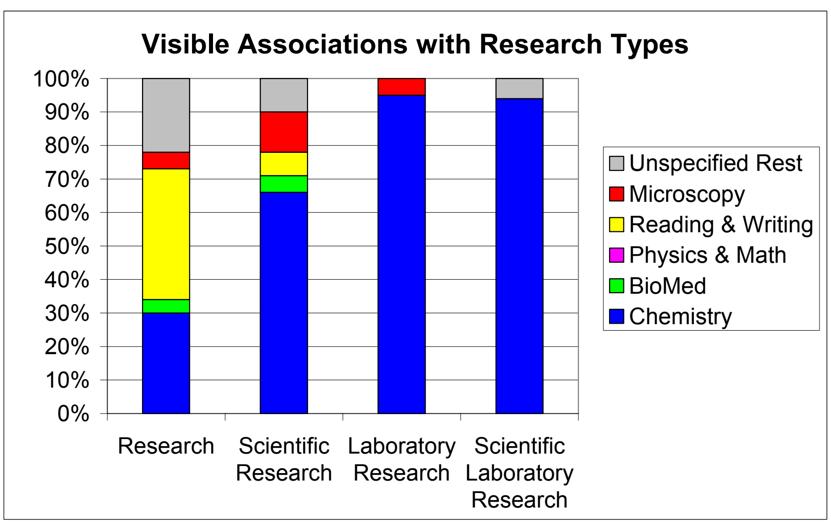

Figure 4: Visible associations with research types. (Note that other disciplines, like physics and mathematics, are hardly associated with any of these research types.)

[11] To illustrate our keyword strategy, after sampling the images of research the best search phrase for capturing the field of reading and writing turned out to be "+(book* library document* text writ* read*)"

[12] See Mary Jo Nye, *Before Big Science: The Pursuit of Modern Chemistry and Physics, 1800-1940*, Cambridge, MA: Harvard University Press, 1996, pp. 9 ff.

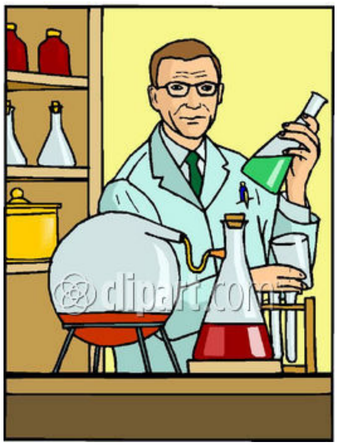

Figure 5: Typical clipart cartoon of laboratory research

2.5 The Mad Scientist and Other Visual Associations

Keyword analysis allows studying the broader visual associations with science simply by counting the frequencies of all the keywords assigned to cartoons of science. However, keyword frequencies are generally lower than the actual occurrences of the corresponding elements in the cartoons, because background elements and details are frequently not considered in the keywords; as a result, the frequencies have only relative significance. Instead of presenting a long list of keyword frequencies, we link the keywords to semantic groups. For instance, the educational context is indicated by the set of keywords "class, school, teacher, pupil, student, learning, education". In addition, since chemistry strongly dominates and appears to embody the popular visual image of science, we have confined the analysis to cartoons that are keyword-related to chemistry in order to capture a clear visual character. In principle, however, the analysis can be performed for each discipline for which enough images are available. In the following portrait of chemistry we highlight not only the strong characteristics but also aspects of chemistry that seem to be underrepresented in the popular visual image compared to the actual practice of modern chemistry.

Chemistry is clearly viewed as a science where people (32.2%) do experiments (36.7%) with various instruments and tools (59.2%) in a laboratory (22.5%). Two thirds of the people dealing with chemistry are male,[13] their experiments include reactions and the visual inspection of liquids rather than measurements, and their instruments are mostly glassware. Chemistry is more associated with the biomedical sciences including pharmacy (7.4%) than with physics (2.7%) or mathematics (0.2%). Despite their potentially symbolic use, models of atoms and molecules rarely appear (2.9%), such that the theoretical side of chemistry is hardly visible. Equally uncharacteristic are books (2.3%), computers (1.2%), and diagrams (1.0%, including the Periodic Table of Elements). Apart from research, people associate chemistry visually primarily with education (19.1%) and rarely with industry (0.8%), technology (0.8%), or business (0.6%), although chemical technicians are not unknown (3.5%). Also, toxicity (2.5%), explosions (1.2%), fire (1.0%), and other hazards are rarely represented in cartoons of chemistry, whereas specific cartoons of chemicals indicate such dangers more frequently (8%).

Cartoons of the "mad scientist" deserve particular attention for two reasons. First, scientists often fear that this aspect would dominate their public image. This fear is unfounded,

[13] The gender ratio by keywords does not depict the actual gender ratio of the image contents, because gender specific keywords are more often used for images representing women than for images representing men. This illustrates a general shortcoming of our keyword analysis: elements or aspect of images that are taken for granted are not always indicated by keywords.

however, because only 2% of all science cartoons depict a "mad scientist". Second, these cartoons illustrate how popular visual culture has incorporated elements from other media.[14] Originally, the figure of the "mad scientist" was developed by early 19th-century writers to portray chemists specifically.[15] And, indeed, half of the "mad scientist" cartoons are clearly recognizable as chemists through their emblematic glassware (Figure 6). Yet, the visual image of the "mad scientist" was shaped by movies, particularly by those that adopted and transformed Mary Shelley's *Frankenstein*,[16] from which it moved to cartoons. Mad scientist cartoons thus illustrate the power of the public domain to hijack historical artefacts and, via media as popular and accessible as clipart, to elide the history from which they have been "clipped", and to preserve them, fossilizing a history while simultaneously sustaining an image in the corporate imagination.

Figure 6: Typical mad scientist cartoon

2.6 Conclusion: The Conservativeness of the Popular Visual Culture

Because they capture visual stereotypes, cartoons are an important source for the study of popular visual culture in general and the popular image of science in particular. Collected in huge searchable databases, cartoons allow quantitative investigations that are otherwise not viable in visual studies. If performed with due care and an understanding of the keyword assignments, co-keyword analysis is a powerful tool for the investigation of the inner and outer visual structure of a field. Combined with the qualitative analysis of pictorial elements, new types of visual arguments can be developed that the relatively new field of visual studies deeply needs.

Because the popular visual culture has incorporated historical elements, such analysis must also be historically informed. This is particularly true of the popular visual image of science, which has conserved age-old stereotypes. In fact, the cartoons contain few elements of actual science from the last two centuries, but refer instead to a period before the 19th-century professionalization of the sciences.

Perhaps most striking is the relative invisibility of science overall, which corresponds to a historical period when only a few amateurs were doing science in private, unlike the publicly funded "Big Science" that has emerged since the 19th century. Furthermore, only the sciences that developed a disciplinary character before the 19th century are specifically visible in the cartoons, while the visually unspecific character of physics reflects the premodern

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14 On the transformation of the "mad scientist" from literature to movies, see C.P. Toumey, 'The Moral Character of Mad Scientists: A Cultural Critique of Science', *Science, Technology, and Human Values* 17, 1992, 411-437.

15 See J. Schummer, 'Historical Roots of the 'Mad Scientist': Chemists in 19th-century Literature', *Ambix* 53, no. 2, 2006, 99-127.

16 On the transformation of the "mad scientist" from literature to movies, see C.P. Toumey, 'The Moral Character of Mad Scientists: A Cultural Critique of Science', *Science, Technology, and Human Values* 17, 1992, 411-437.

meaning of "physics" as the generic term for the natural sciences. The emblematic objects go either back to antiquity (glassware, bones, mathematical formulas and a pair of compasses) or are inventions of the early 17th century (microscope and telescope). Only rockets are new, but "rocket science" is neither a science nor a developed engineering discipline outside the US, which suggests that powerful national publicity can under certain conditions impact the visual culture of science in a country.[17]

The characteristics of the popular image of chemistry as the visually dominant discipline provide further support for the extremely conservative nature of the visual culture. Although chemistry is still by far the biggest scientific discipline,[18] its visual role as epitomizing laboratory research and experimental science goes back to the period before the early 19th century, when chemistry was *the* prototypical experimental science. The absence of measurement instruments and experiments, which have dominated chemistry since the late 18th century, the virtual lack of theoretical aspects of chemistry (except a few images of the atom and the Periodic Table) and the neglect of industrial chemistry, which has otherwise come to the public attention at least through environmental problems, all reveal the pre-19th-century origin of the popular visual image. This is also true of the emblematic glassware which harkens back to early alchemy.[19] The only component of the popular visual image from the 19th-century seems to be the "mad scientist", but that figure also has its origin in medieval and early modern portraits of the "mad alchemist" both in writing and painting.[20] Finally, the archetypical image of a chemist, which is a person gazing at a flask that contains some liquid, goes back via 16th-century iatrochemistry to 13th-century medicine, where it represented uroscopy as the emblematic gesture of medicine for about four centuries (Figure 7).[21] Although this motif was carefully avoided in any of the portraits of famous chemists until the late nineteenth century, it has persisted in the popular visual culture up to the present day.

All these findings suggest that the popular visual culture of science is extremely conservative, and has not readily incorporated new visual elements for centuries. Cartoons are expected to convey older stereotypes, but it may be surprising that their visual components go as far back as the 13th century. Cartoons like those found in clipart are a source for considerable amusement, but they also conserve historical visual traditions that are sometimes no longer part of explicit public knowledge.

In the second half of this paper, we explore a different component of the public image of science, i.e. how scientists visually represent themselves to the public. One of the guiding

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17 More potently for clipart, "rocket science" probably has much less to do with a discipline than with the cold war space race that generated the much-loved term "it's not (ain't) rocket science". The sticking power of rocket science in the popular imagination is its association with a distinctively American ironic attitude toward intellectual labor that is encoded in this humorous phrase.

18 In terms of the number of publications indexed by their respective abstract journals, chemistry is as big as the total of all the other sciences; for some data, see J. Schummer, 'Why do Chemists Perform Experiments?', in D. Sobczynska, P. Zeidler and E. Zielonacka-Lis (eds.), *Chemistry in the Philosophical Melting Pot*, Frankfurt: Peter Lang, 2004, pp. 395-410.

19 The history of the visual representation of glassware and other chemical instruments, which goes back via modern chemistry textbooks and early modern chemical craft textbooks to early alchemy, is well documented; see for instance, D. Knight, ''Exalting Understanding without Depressing Imagination'. Depicting Chemical Process', *Hyle: International Journal for Philosophy of Chemistry* 9, 2003, 171-189; J. Weyer, 'Chemie und Alchemie im 16. Jahrhundert und die chemische Fachliteratur jener Zeit', in Stadt Rastatt (ed.), *Von der Astronomie zur Alchemie*, Raststatt, 1991, pp. 59-117; B. Obrist, 'Visualization in Medieval Alchemy', *Hyle: International Journal for Philosophy of Chemistry* 9, 2003, 131-170.

20 See J. Schummer, 'Historical Roots of the 'Mad Scientist''.

21 The visual history of the archetypical image of a chemist is presented in more detail in J. Schummer and T. Spector, (2007) "The Visual Image of Chemistry: Perspectives from the History of Art and Science", *Hyle: International Journal for Philosophy of Chemistry*, 13 (2007), 3-41, as part of a special issue on the "Public Image of Chemistry". From our 2004 talk in Paris, Philip Ball has composed a brief picture story (P. Ball, 'What is in the flask? The origin of the archetypical image of the chemist', *Nature*, 433, 2005 [6 January], 17.)

questions of our analysis is whether or not they follow the conservative visual tradition of the popular culture.

Figure 7: Left: 14th-century illustration in Avicenna's *Canon medicinae* (trans. Gerard of Cremona, 1283, The Hague, MMW, 10 B 24). It depicts uruscopy that soon became an emblem of medicine. Right: Modern cartoon of a chemist.

3. The Public Self-Image of Science in Internet Photographs

3.1 The Public Self-Image of Science at the Interface of Science and the Public

The preservation of age-old stereotypes in clipart images of science suggests that popular visual culture is not very susceptible to new pictorial input. If such input exists, it most likely comes from the visual self-image of science, i.e. from how scientists and science-related institutions present themselves to the public in pictures. In the visual regime, public self-images of science are at the interface between science and the public. On the one hand, they try to communicate to the public visual aspects of science that scientists think are either important or required to correct or enrich the popular image of science, while on the other hand, they need to adopt symbolic elements from popular visual culture for effective visual communication. For instance, if a self-image is meant to communicate the research strength of an institution, it might employ popular visual emblematics for research, even if that reinforces undesirable stereotypes. Their mediating capacity and multifunctionality make the public self-images of science particularly interesting for a comparative visual study with the popular images of science.

Unfortunately, such comparative studies are faced with several methodological problems, particularly if performed on a quantitative level. In the ideal world, there are two databases of images, one for popular images and one for public self-images of science, with systematic keywords that allow for comparative co-keyword analysis. Yet, in the real world, there is neither a database of public self-images of science nor are there any keywords. Moreover, scientists tend not to represent themselves in cartoons, but in photographs, which are different kinds of images. First, unlike clipart, the primary purpose of photographs is not humor. Photographs are also more authoritative, putting more emphasis on detail, nuance, and authenticity rather than on general impressions and stereotypes; photographs have a variety of creators, including both scientists and professional photographers and are legitimated by a variety of sources – the person being photographed, the person commissioning the photograph (which may be one and the same with the person photographed); and the procedure of selecting and publishing photographs differs considerably from commissioning clipart cartoons for a database. All of this makes it difficult to make a comparison between the two types of images.

The source of public self-images of science that comes closest to the ideal requirements for our study are photographs posted on Internet websites from scientists and science-related institutions such as universities and research institutes. With more than a billion users worldwide,[22] the Internet provides a means by which scientists can put out their self-image more energetically and purposively to the broadest possible public. Compared to images in printed material, these images can easily be retrieved by Internet search engines and quantitatively analyzed in large numbers. In addition, while images in printed material are usually processed by professional designers, Internet photographs are frequently self-made by scientists (or at least self-selected) and thus come closer to their unmediated public self-image. These images may be retrieved by selecting relevant science-related websites and then collecting all their photographs; however, this procedure provides a heterogeneous mixture of images, many of which are difficult to interpret as self-images of science. We found it more effective, though still not satisfactory, to search for science-related photographs using an appropriate Internet search engine and then select the relevant photographs from science-related websites. Even then, using the Google image search tool with science-related search terms tends to provide images that can hardly be defined as self-images of science, since the search engine relates images to search terms only because they both appear somewhere on the same web page. The most effective, though very restrictive, method is to search for images whose file names consist of the keyword in question, e.g. "chemistry.jpg" or "chemist.jpeg". Although science websites use images with different file names to represent themselves, it is almost certain that an image called "chemist.jpeg" on a chemistry website is meant to represent the visual self-image of chemists.[23] The shortcomings of this approach are the limited number of images that meet the formal conditions and the limited number of legitimate keywords.

In the following we explore the feasibility of this approach by combining quantitative with qualitative analysis. We assume that the public visual self-image of science involves a complex response to the popular visual image of science and that different disciplines and different science-related institutions respond differently to, and interact differently with, popular visual culture. Thus, after surveying the relative visibility of disciplines on the Internet compared to those in the clipart database, we analyze the characteristic styles of disciplinary and institutional self-representation and how these intersect with the popular stereotypes represented by clipart images. Because chemistry and physics dominate both the popular image and the self-image of science, and because these disciplines exemplify two opposed styles of representation, we focus on the self-images of these disciplines. And as with the clipart images, our Internet sources are from the English-speaking world and predominantly from the US.

3.2 The Relative Visibility of Disciplines and their Different Styles of Self-representation

To obtain an overall picture of the relative visibility of the various sciences on the Internet, we have used in each case the search terms for the discipline and the corresponding scientist, e.g. "chemistry" and "chemist" (Figure 8). Of course, the results do not show the extreme visual dominance of chemistry, as in clipart images, while smaller, more esoteric disciplines are at least visually present, if only in small proportions. Though less than in clipart, chemists

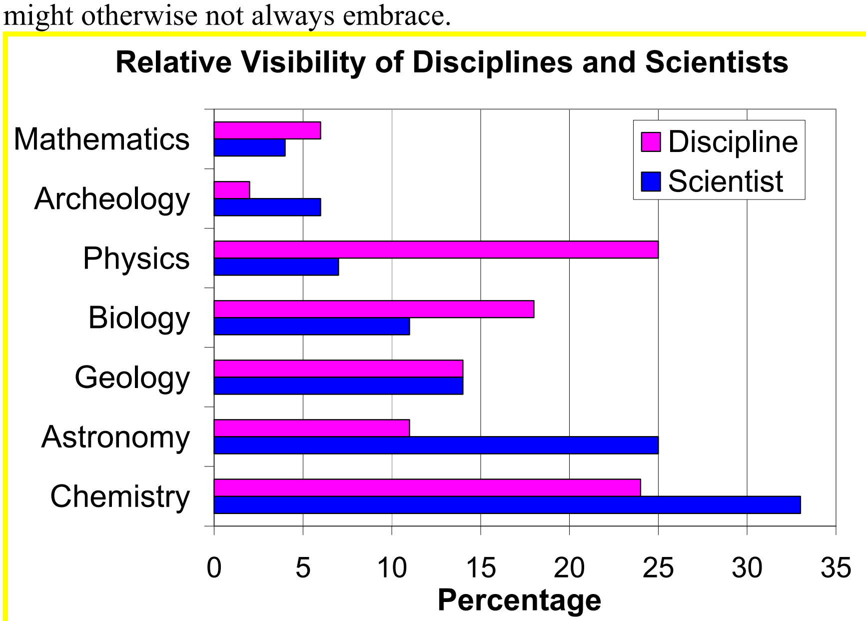
[22] See http://www.internetworldstats.com.

[23] There are some uncertainties about the image naming habits in different institutions due to different stages in the professionalization of website management. Because professional website management, for instance in online magazines, composes web page content out of text and image elements from databases, where image files are typically encoded by numbers, our approach focuses on less professional websites. This is desirable for our study, however, because we want to study the self-image of science rather than the image of science by web designers.

(33%) dominate the portraits of scientists, followed by astronomers, geologists, biologists, and physicists with only 7% of the total scientists' images. On the other hand, images that illustrate the scientific disciplines are dominated by physics (25%), closely followed by chemistry (24%) and then by biology, geology, and astronomy. The almost reverse order between the disciplines and the corresponding scientists and, particularly, the low visual presence of physicists compared to physics calls for explanation.

An examination of the actual images and their websites reveals that the disciplines are primarily linked to educational institutions, including university buildings, teaching labs, and textbook covers. Thus, the order of the visual presence of the disciplines corresponds in some degree to the number of their corresponding institutions, which for chemistry and physics is about the same. In contrast, the images of scientists differ greatly by discipline. Most "astronomers" and many "chemists" are posted on non-scientific or historical websites, which indicates that their visibility reflects only the popular visual image of a generalizable science found in clipart images. If displayed as self-images by science-related websites, the many images of chemists, astronomers, and biologists portray unknown scientists in their research settings surrounded by emblematic objects. Moreover, the prototypical photograph of a chemist shows the historically linked image of a person gazing at a flask of colored liquid. In stark contrast, about half of the relatively few images of physicists depict theoretical physicists, frequently famous people such as Albert Einstein, Richard Feynman, and Enrico Fermi.[24] As self-images of physics, and in direct contrast with chemistry, such photographs of almost mythic physicists translate *the person portrayed* into an emblem of the discipline, rather than their research tools. Apart from chalkboards with equations on them or bookshelves, almost all are devoid of emblematic objects and other scientific or disciplinary indicators.

In their images of scientists, chemists and physicists exemplify two styles of visual self-representation that respond to and interact with the popular visual culture. Physicists draw on famous members of their discipline from the 20th century and actively cultivate their images as popular icons of their discipline. Chemists rely on the strength of their emblematic objects and gestures, which have a deep historical root in popular visual culture. While the conservative strategy of chemists is still successful in terms of public visibility, the price is bland or comic depersonalized images and the adaptation to stereotypes that modern chemists might otherwise not always embrace.



[24] The actual number of images of famous physicists is much higher because these image files are named after the names of the physicists.

Figure 8. Relative number of images of different disciplines from Google image search, each for search terms for the discipline and the scientist, e.g. for "chemistry" and "chemist".

The two different styles of self-representation by chemists and physicists are also seen in the way they represent their own disciplines. For many of the sciences the number of discipline images is much higher than the number of scientist images, and much more so for physics, which suggests that the abstract discipline is, in the self-representation, held more important than the people. In chemistry both image types differ primarily only in whether an anonymous chemist is in the foreground holding some emblematic glassware or in the background behind the glassware (see below). In physics, as mentioned above, many portraits of scientists depict theoretical physicists without emblematic objects. The discipline itself is represented as experimental by some apparatus on which several people may be working or, as a rule, standing behind. This latter image clearly opposes the popular characterization of physics as a brainy, hands-off science as encapsulated in the ubiquitous portraits of a wild-haired Einstein. Unlike the emblematic lexicon of glassware in chemistry, equipment, when foregrounded in physics images, is complex and electronically driven, frequently including oscilloscopes, lasers, mass spectrometers, and other electronic apparatus interconnected with wires and cables that fill whole rooms.[25] And unlike the socially isolated figure in typical portraits of both chemists and chemistry the majority of physics images show people in social interaction in both educational and research contexts.

Although there are exceptions, the visual self-representation of chemistry is very conservative, drawing on long established elements of popular visual culture. Whereas today's actual research includes complex instrumentation and teamwork in chemistry and physics alike, chemists tend to reiterate and reinforce the stereotype of the isolated researcher who employs historically outmoded methods and instruments. In contrast, physicists, who lack the heritage of visual stereotypes, have introduced a new lexicon of imagery that portrays their science as a modern instrument-driven and collaborative enterprise. Because that does not easily translate into simple emblems in the popular visual culture, they are more ready to develop a differentiated and up-to-date self-image of their discipline.

3.3 Different Aspects of Science Highlighted by Different Institutions

Because our Internet search method is focused on image file names, the variation of search terms to explore broader visual associations with science is limited. Yet, at least for chemistry, a set of five search terms from the semantic field of chemistry, allows for the distinctions of five different aspects of the public self-image (Table 1).

The term "chemical" is predominately associated with industrial sites (i.e., chemical plant exteriors and interiors) and the term "chemicals" with commercial chemical products (e.g., bottles of chemicals). The three terms "chemist", "chemists" and "chemistry" provide typical images each with scientists interacting with glassware, but in different manners: the first type of image features a person, the second indicates a social research context, whereas research instruments (glassware, apparatus, a complete laboratory) dominate the third. Since each of these image types focus on a different aspect of chemistry (chemical plant, industrial products, researcher, social context, and research apparatus), an analysis of their frequency and institutional contexts provides a differentiated view of the visual public self-image of chemistry.

[25] It is important to note, however, that these distinctions between the uses of instrumentation in chemistry and physics blur at their intersections in the fields of physical chemistry, chemical physics, material science, etc.

Table 1: Internet image search results from the semantic field of chemistry

Search term	Relative frequency	Predominant image content
chemical	30%	chemical plant
chemicals	21%	industrial products
chemist	10%	researcher
chemists	2%	social context
chemistry	37%	research apparatus

Overall, our Internet image survey shows that both research instruments and chemical plants dominate the visual image of chemistry, and that the social context is almost absent (Table 1). Unlike the stereotypical image of chemistry in cartoons, where associations with chemical industry are extremely rare, half of the digital photographs present industrial plants or products. While this might be seen as an attempt to correct one stereotype, the relative lack of social contexts found in the sum of these photographs reinforces another one, that of the scientist working in isolation.

Based on a sample of 50 images for each image type, a closer look at the institutional context in which these images appear reveals how different institutions present different aspects of chemistry. Indeed, about 90% of the images in our sample have been posted on the websites of institutions that are in various ways engaged in chemistry, i.e., universities, schools, industry, and government (particularly governmental research institutes). As these four institutions represent the breadth of chemistry's institutional reach, their images represent the public self-images of chemistry.

Figure 9 shows the distribution of each of the five chemistry image types over the four chemistry institutions. Not surprisingly, industry focuses on chemical plants and products, whereas universities present chemistry primarily through research instruments and laboratories. What is striking, however, is that governmental institutions, including governmental research institutes, present chemistry in almost the same way as industry: they focus on industrial plants and products and almost ignore actual laboratory research and, particularly, its social contexts. On the other hand, for elementary and secondary schools, the social context (the interaction between students and between students and teachers) is the most important aspect of chemistry, which suggest that schools, and only schools, are strongly engaged in correcting the stereotype of the isolated researcher and thus in "humanizing" chemistry.

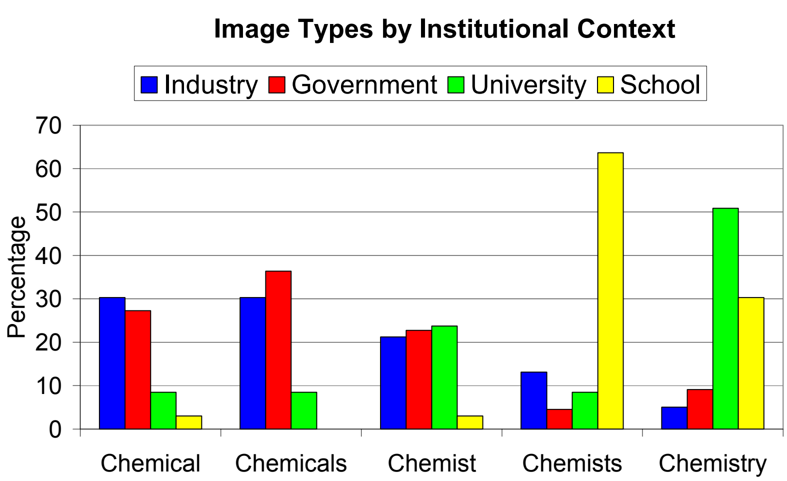


Figure 9. Distribution of chemistry image types over science related institution on their website.

An analogous analysis for physics is faced with both the lack of correspondingly meaningful search terms and the fact that the self-image of physics is strongly dominated by universities. Yet, based on qualitative image analyses, some aspects of the public self-image of physics relative to that of chemistry are worth mentioning. First, images associated with the keyword "physicists" are extremely rare, because the social context is usually displayed in images associated with "physics"; this once more suggests that the social context is considered an integral part of the discipline of physics. Whereas universities highlight instrumentation and laboratories, government institutions clearly favor portraits of (theoretical) physicists over equipment and laboratories. This finding suggests that physicists in governmental research institutes, where cross-disciplinary departments of applied research are much more common than in universities, try to distinguish themselves from experimental and applied work. Furthermore, industrial aspects of physics are extremely scarce, despite its notorious industrial and government associations with weapons development, which physicists would presumably wish to de-emphasize in their public self-image.

3.4 The Question of Gender

The study of gender proportionality in science has had a strong tradition in feminist analyses of the disciplines for several decades, ranging from the dearth of female role models (associated with research primarily in the 1970s and 1980s) to the unequal allocation of male and female laboratory and office space at the most prestigious research institutions.[26] More recently, several studies have also analyzed the differential representation of female and male scientists in popular US media. In 1990 LaFollette looked at the public image of science in popular US magazines from the first half of the twentieth century finding that the illustrations in the articles "depicted women as minority characters in the drama of science" with women shown as technicians and assistants and men as supervisors.[27] In 2003 Flicker analyzed 60 feature films finding that "The role of the professional scientist is reserved for men" and that women were represented less than a fifth of the time as professional scientists.[28] These studies suggest that the popular image of science, both visual and non-visual, is strongly dominated by male scientists, as it actually was, several decades ago. Today, the situation is much different in the US (Table 2).[29] In chemistry, which so strongly dominates the popular image of science, women receive a third of all PhDs, while in biology the number of men and women receiving PhDs is almost equal. While most women work as professional scientists in industry, government, or universities, the number of women gradually drop with professorial rank in universities.

How then do scientists in their public self-image represent gender proportionality? Do they conservatively tender the outdated popular image, do they represent the actual gender ratio, or do they progressively represent themselves as gender balanced to overcome the bias?

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[26] N. Hopkins, 'Report of the School of Science', in: *Reports of the Committees on the Status of Women Faculty*, Massachusetts Institute of Technology, March 2002 (http://web.mit.edu/faculty/reports/).

[27] M.C. LaFollette, 'Eyes on the Stars: Images of Women Scientists in Popular Magazines', *Science, Technology, & Human Values* 13, 1988, 262-275.

[28] E. Flicker, 'Between Brains and Breasts – Women Scientists in Fiction Film: On the Marginalization and Sexualization of Competence', *Public Understanding of Science* 12 (2003), 307-318. See also Melissa Pollak, 'Science and Technology: Public Attitudes and Public Understanding', in *Science & Engineering Indicators - 2002*, (2002), ch. 7, pp. 1-6 (http://www.nsf.gov/statistics/seind02/c7/c7h.htm).

[29] From J. Handelsman et al., 'More Women in Science', *Science*, 309 (5738), 2005, 1190-1191. The data is from 2001-2004 and based on the top 50 research departments of each discipline in US universities according to the NSF ranking .

To answer this question, we have quantitatively examined images in our data set for chemistry and physics for gender ratios.

Table 2: Male/female ratio of Ph.D.'s and faculty positions in US universities

Discipline	Ph. D.	Asst. Prof.	Assoc. Prof.	Full Prof.
Biology	1.2	2.3	3.0	5.8
Chemistry	2.0	3.7	3.9	12.1
Physics	5.8	8.0	9.6	18.1

Source: Handelsman et al. 2005

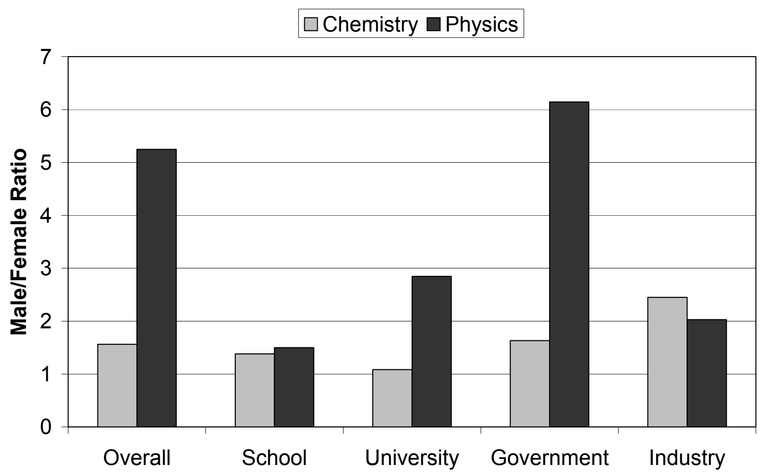

Figure 10. Male/female ratio in people containing images of chemistry and physics by institutions.

Overall, men dominate the public self-image of science, with physics presented as significantly more male dominated than chemistry (Figure 10). However, the male/female ratios are very close to those of the PhDs in both disciplines (Table 2), which suggests that the self-images depict the actual conditions and thus neither adapt to the popular image nor visually encourage a gender balance. A breakdown by institutional context shows that for both chemistry and physics primary and secondary schools present a more gender balanced image, albeit not the actual gender ratio of their pupils which we assume to be balanced. The self-image that most closely displays a gender balance is that of chemistry at universities. This finding is surprising given the otherwise very conservative self-image of chemistry. The largest gender differentials for the institutional context of chemistry is found in industry, while for physics it is in government. If one takes only the images called "physicist", the male/female ratio rises to 19. This suggests that, unlike the chemists' preference for anonymous figures, the physicists' focus on personalities is particularly susceptible to the conservation of gender stereotypes.

A closer look at physics photographs shows that women are equally unassociated with the research aspects of physics, both experimental (indicated by complex apparatus) and theoretical (indicated by boards with equations and diagrams). Instead, when shown at all, they are predominately represented as secondary school students or lower division university students. A typical example might be the depiction of an older man dressed in a suit and tie observing a young woman in a lab coat interpreting X-ray data. Even though such pictures depict an educational context, the absence of images with reversed gender roles indicates the importance in the public self-image of physics of men remaining in charge.

In contrast, in images from chemistry, women appear to be almost equally as professionalized as male chemists. Both genders are shown in the professional scientists' gear (lab coats and goggles) and both interact with glassware and instruments in approximately the same ratio. Only industry, the most male dominated institutional context of chemistry, has highly differentiated images of men and women. In these, men are found in hard-hats in large scale industrial sites, while women are shown in their professional scientist gear in laboratories using the glassware and instruments found in the images associated with the other chemistry-related institutional contexts. This would seem to undermine an emerging progressive public self-image. Nevertheless, it may be interpreted quite differently as a gesture toward gender parity. Thus, these images project a conservative desire to retain gender distinctions while moving to a progressive public self-image of equal capability. They put forward the idea that both men and women are adept "in the field" – men at the industrial site and women in the lab (women are not under the auspices of an older male authority figure or in a teacher-student relationship) but make distinct contributions in industrial chemistry. Ironically, of course the lab (feminized in these images) is the site normally associated with "brains" while the industrial site is associated with "brawn".

Much more so than the quantitative ratios, the different visual gender associations in chemistry and physics show how deeply seated our cultural narratives about the hierarchy of rigor in science remains in the public self-image of science – that physics is the hardest, most abstract science (i.e. masculine) while chemistry is the less mathematical and more life-related life science (i.e. feminine). The result of these narratives is clearly reflected in Table 2.

In sum, unlike the other aspects discussed in previous sections, the gender aspects of Internet photographs reveal the self-image of physics as extremely conservative as it continues to reinforce gender stereotypes of the popular image of science, while chemistry, despite its legacy of visual stereotypes, is socially progressive.

4. Conclusion

The public use of images is, despite its dramatic increase, still the least understood form of public communication, compared to communications in the written or spoken word that have been studies by rhetorics since antiquity. Although there were earlier attempts, like Roland Barthes' visual semiotics from the 1960s, it was not before the 1990s that scholars with such powerful catch-words as "pictorial turn" (William J.T. Mitchel) or "iconic turn" (Gottfried Böhm) tried to break open the limited scholarly focus on art history to establish a field called "visual studies" or "Bildwissenschaft" that broadly investigates the welter of images and their uses.[30] While this field is now flourishing and attracting scholars from various disciplines, its art historical origins still impacts the kind of questions that are posed and the methods used to study them. In this paper we have tried to broaden the focus by transferring questions from the field of public understanding of science to the visual field, by studying new types of images, and by using as far as possible established quantitative methods from empirical sociology, supplemented by qualitative and historical analysis.

Since the early 1990s, studies in the public understanding of science have grown at least as fast as visual studies and, although the public image of science has become an important topic, the public visual image of science has not, not even in terms of gender analysis. We assume that this is due to both methodological and conceptual barriers, and as a result we have put an emphasis in this paper on methods and conceptual clarification. Clearly, there is not one, but many public visual images of science, because there are various publics, each including image producers and consumers, various image types and visual media, and many

[30] R. Barthes, 'Rhétorique de l´image', *Communications,* 4, 1964, 40-51; W.J.T. Mitchel, *Picture Theory: Essays on Verbal and Visual Representation*, Chicago: University of Chicago Press, 1994; G. Boehm, 'Die Wiederkehr der Bilder', in: G. Boehm (ed.), *Was ist ein Bild?*, München: Fink, 1994, pp. 11-38.

different sciences. By focusing on two divergent public images of science, the popular visual image in clipart cartoons and the visual self-image of science in photographs, we have investigated the tensions that exist at the visual interface between science and the public.

Popular visual culture has preserved a visual image of science that, as a whole and in most details, dates back before the 19th century when science in today's sense hardly existed. This implies that there is a deeply seated level of the public understanding of science that has not been affected by the processes of the professionalization, diversification, instrumentalization, industrialization, commercialization, and the growth of science itself (by a factor in the order of 10^5) during the past two centuries. Because the past two centuries were also a period of improved public education and dramatically increased visual image creation and circulation by new media technologies, we may assume that such social and technological advances have had little impact on this level of visual understanding. From that we may conclude that it is unlikely that this popular image of science will easily change in the future.

In their self-images, scientific disciplines and institutions respond in different ways to popular visual culture. We have shown that chemistry and physics have opposing styles of self-representation. While chemistry dominates the popular image of science overall, such that stereotypes from premodern chemistry are the visual emblematics of today's science, modern physics, which emerged much later, has no clearly identifiable character in popular visual culture. In response, in their public self-image, chemists have largely adapted to the popular stereotypes in a conservative manner by featuring characterless and socially isolated chemists in stereotypical gestures with emblematic objects, which, although part of a rich historical tradition, represent premodern rather than modern chemistry. In contrast physicists, lacking such a heritage, have developed a progressive self-image dominated by electronic instrumentation, teamwork, and portraits of famous 20th-century theoretical physicists. This progressive agenda, however, is undermined by gender representation, which reverses the ideology of progress, since self-images of physics tend to cultivate the popular stereotype that science is a male domain. Unexpectedly, chemists, despite conservative self-imaging, present themselves as approximately gender balanced.

With the exception of gender balance, chemists at universities do little to correct the popular clichés of their science. Only schools work hard to depict chemistry in its social context and therefore the more human side of science. The industrial side of science is only highlighted by government and industry and only for chemistry. As we have explored in another paper,[31] these images are indebted to a number of iconological and aesthetic traditions including landscape, still-life, genre, and architectural painting and photography.

Because chemistry dominates the popular image of science, it requires particular attention in studies of the public image of science. In its conservative self-image, chemistry adapts to rather than corrects the popular visual image of science. Given the extremely conservative nature of the popular visual image of science as represented in clipart, one might argue that attempts to correct that by public self-images are ineffectual. However, within popular visual culture clipart represents probably the most conservative type of representation. Other types of popular visual culture like in magazines, movies, and TV would presumably be more amenable to new input from scientific self-images. Yet, if scientists in their public self-images, knowingly or not, reproduce the stereotypes of even the most conservative type, they reinforce clichés about science, which they otherwise complain about, in the entire popular visual culture.

[31] J. Schummer and T. Spector, 'The Visual Image of Chemistry', op. cit.