Scenario

The Study of Technoscientific Imaging in STS

Manuela Perrotta

Abstract In the last few years a flourishing debate has developed on visualization processes and practices of representation in technoscience, fostering an interdisciplinary approach to the study of the production and dissemination of images. This *Scenario* outlines some of the current examples of research in this area, introducing the turn from the study of scientific representation to that of (techno)scientific imaging and visualization. Three main areas of research are discussed: technoscientific imaging in practice; images as evidence; images, imaginations and imaginaries. Finally, some further questions and challanges concerning the future study of technoscientific imaging are raised.

Keywords scientific representation; technoscientific imaging; visualization practices; visual knowledge production; visual logic; imaginaries.

Introduction

Forms of representation as diagrams, graphs and images have always been central in scientific practices. In the last decades, moreover, the development of increasingly sophisticated visualization tools has made the use of images more and more relevant in illustrating scientific results. Images, in fact, seem to have a particular potency for communicating scientific ideas that make them more understandable to a broader professional and non-professional community. For this reason, pictures are used not only in their production sites (usually specific labs) but they travel within the scientific community and beyond. Therefore, appealing scientific images have been spread in the popular culture through magazines, artistic performances and even television series.

In Studies of Science and Technology (STS) a flourishing debate has developed on visualization processes and practices of representation in technoscience. This debate has its origins in the so-called *Laboratory Studies* that have investigated the use of images in the making of science (Latour and Woolgar 1979; Knorr-Cetina 1981; Lynch, 1985a, 1985b; Latour 1986, 1987). A real milestone in this strand of literature is *Representation in Scientific Practice*, a book

TECNOSCIENZA
Italian Journal of Science & Technology Studies
Volume 3(2) pp. 163-175- ISSN 2038-3460
http://www.tecnoscienza.net

T/S TECNOSCIENZA Italian Journal of Science & Technology Studies

edited by Michael Lynch and Steve Woolgar in 1990. This collection has been a classic in the STS literature on visualization and a "starting point for studying the cultural embeddedness of the practices of the making and handling of visual representations and of the shaping, distributing, applying, and embodying of scientific visual knowledge" (Burri and Dumit 2008, p. 300).

Thereafter the debate on visualization in science and technology has exploded in the last twenty years (quoting only a few examples Traweek 1997; Lynch 1998; Beaulieu 2001; Dumit 2004; Joyce 2005, 2006; Prasad 2005a, 2005b; Burri 2008; for a review see Burri and Dumit 2008). A new version of the latter collection, which will brings together recent work on representational technologies in contemporary scientific work, will be co-edited by Catelijne Coopmans, Janet Vertesi, Michael Lynch and Steve Woolgar (forthcoming) and published as *New Representation in Scientific Practice*.

The main aim of this debate has been to overcome the widespread understanding of scientific images as static and "neutral" elements; natural objects independent from cultural and social processes. In the hard science discourse, in fact, often imaging tools are considered as photo cameras able to catch the reality rather than measurement devices. According to an STS perspective, instead, images – as well as scientific representations in general – have a little definite meaning or logical force aside from the complex activities in which they are situated. Representational practices in science, therefore, need to be studied as situated processes of knowledge production. The STS literature developed on the basis of these assumptions illustrated how images assume meaning and fixed interpretation in the complex activities in which they are situated, and in relation with other forms of representation (other data, numbers, graphs, observations, and so on), according to the socio-material practices and processes of knowledge production in which they are embodied.

Nowadays, this field of study is increasingly flourishing, fostering an interdisciplinary approach (Fyfe and Law 1988; Nowotny and Weiss 2000) to the study of the production and dissemination of images. Interdisciplinary conferences have been dedicated to this topic (such as *Visualization in the Age of Computerisation*, held in Oxford in 2011 and *Images and Visualization: Imaging Technology, Truth and Trust*, held in Norrköping in 2012) and a special issue on "Visual Representation and Science" (Gross and Louson 2012) has been recently published in *Spontaneous Generations: A Journal for the History and Philosophy of Science*.

This body of work is thus extremely diverse, and its boundaries are difficult to demarcate. Therefore, any attempt to synthesize the various strands would necessarily be reductive and selective. Instead this *Scenario* will try to outline some of the current examples of research findings in this area in recent years. In the next sections I will introduce the turn from the study of scientific representation to the so-called (techno)scientific imaging and visualization. Following the distinction proposed by Burri and Dumit (2008) I will discuss then three main areas of research: technoscientific imaging in practice; images as evidence; images, imaginations and imaginaries. Finally, I will raise future questions and directions concerning the study of technoscientific imaging.

1. From representation to scientific imaging and visualization

Scientific visual representations have been studied from a variety of different theoretical and disciplinary perspectives. They vary across multiple important dimensions, such as production, use, and type of content (for a detailed account, see Pauwels 2006).

According to Daston and Galison's reconstruction (2007), early modern science has built on an idea of "good" representation which takes for granted the absence of human agency. They described this phenomenon as "mechanical objectivity", the search for a representation that is as automatic and unhampered by personal vision as possible. This alleged purity of scientific representations and the ways in which it is constructed have been unmasked by contemporary science scholars (Daston and Galison 2007; Hacking 1983), as well as those examining everyday practices of scientists (Latour and Woolgar 1979; Latour 1986; Amann and Knorr-Cetina 1990) have underscored that instruments do not produce representations alone.

Accordingly, Burri and Dumit call for a turn to the study of scientific imaging and visualization, which focuses "on the social dimensions and implications of scientific images and visual knowledge rather than inquiring into their nature" (2008, p. 298). The study of scientific imaging and visualization aims to investigate the specificity of the visual as a form of scientific knowledge and therefore it follows the practice turn in science studies (Pickering 1992) and social theory (Schatzki *et al.* 2001). Turning toward the study of scientific imaging and visualizations means to focus on the epistemic practices of the production, interpretation, and use of scientific images.

In their review essay Burri and Dumit organized their discussion around what they defined "three artificially separated topics: the production, engagement, and deployment of visualizations" (2008, p. 300). They claim that this distinction is more relevant in terms of what STS scholars focus on than on the scientific practices involved. Their three categories grasp a core aspect of the *study* of scientific imaging and visualization, i.e. its focus on the visual practices of science.

According to the authors, the study of image *production* deals with "how and by whom an image is made" (p. 302), while studying *engagement* means to focus on "how images are used in the course of scientific work and are made instrumental in the production of scientific knowledge"(p. 302). Finally, the study of *deployment* refers to the analysis of how images leave their production sites and travel to nonacademic environments, i.e. the social world.

In this *scenario* I will use "updated" versions of these three categories and I will take into account the domain of technoscience. Scientific imaging and visualization, in fact, are clear examples (as many others) of technoscience. There is no strict division between the scientific and technological aspects of scientific and research practices, as they rely upon technological intervention as an irreducible element. Therefore, I will explore the current development of the literature concerning the study of technoscientific imaging in STS.

For reasons of space, I will focus attention on recent studies, which will allow me to discuss theoretical developments in the analysis of the production, engagement, and deployment of visualizations. Similarly to Burri and Dumit (2008), I will discuss in the next sections: the technoscientific imaging in practice, focusing the attention on visual logics and styles of representation; the use of images as evidence in the production of scientific knowledge; the relation among images, imaginations and imaginaries. In order to take into account the more recent research findings I will use research examples from the last few years. My aim is not to produce an exhaustive overview of recent literature, rather to explore what best illustrates the challenges within studies of technoscientific imaging in STS.

2. Technoscientific imaging in practice

The study of image *production*, i.e. how images are actually "made" in their production sites, is one of the cornerstones of the study of scientific imaging and visualization in STS. Recent approaches have highlighted the "technoscientific" (rather than scientific) processes of imaging. Even though the attention to actual (and often invisible) work made inside laboratories to explore science in action is rooted in the tradition of Laboratory Studies, the increasing focus on the technical and instrumental aspects of scientific imaging makes me lean towards the term *technoscientific imaging*. For instance, Mody introduces the idea of *instrumental communities*, "a network of individuals who view their involvement with a particular type of instrument and/or instrumentality as ratifying their connection to other nodes in the network" (2011, p. 10).

Similarly, I take for granted that technoscientific imaging is going to be studied from a practice perspective, i.e. studying the practice of imaging and visualization and observing image practices ethnographically. This assumption has recently been criticized (Garforth 2012) arguing that the observational methods rooted in *Laboratory Studies* might devalue "invisible work", i.e. the aspects of knowledge work that are more private and solitary, such as office work.

Even though taking new angles to the study of technoscientific imaging is a core issue in the advancement of this debate, I want to underline what such a perspective can illustrate about the production of images.

For doing so, I will start from a first example coming from the recent sociological debate on "visual rationalities". Through an ethnographic study of medical images, Burri (2012) explores how imaging practices are shaped by what she defines a "visual logic". She claims that social practice is intertwined with a visual logic: the latter shapes medical practices, but at the same time it is (re)produced by social practices. The concept of visual logic has been elaborated from ethnographic research in medical imaging sites. On the methodological level, a multitude of visual logics can be observed. In their empirical form the author defines them as visual rationalities. Reconstructing and analyzing these visual rationalities by investigating how they work in practice is the task of a sociology of images.

Burri (2012, p. 53) argues that there are three different visual dimensions of images that play a role in social practice and are crucial for a sociology of images. These three visual dimensions "emerge from and shape social practice just like any other epistemic category".

The first dimension concerns the *visual value*, which allows a simultaneous perception of visual information. Burri (2012, p. 50) defines it as "the surplus value of images; it makes images different from auditory, olfactory, flavourful, or tactile signs. The visual value is constructed in social practice; it serves as a phenomenological criterion to distinguish images (as visual signs) from other signs, such as numerical or textual signs. It also underlines that images cannot entirely be transformed into textual or numerical signs without losing some of their advantages".

The second dimension deals with the *visual performance*, i.e. what is depicted in the image, and it emphasizes that the way images are represented is a result of social practices of image production and interpretation. The aesthetic appeal of images is an important issue in medical practice, but it is not purely objective, rather contingent and situational, and it is shaped by local sociotechnical arrangements and institutional contexts. In other words, it is always a social and cultural achievement.

The third dimension refers to the *visual persuasiveness*, which regards the power of images in being perceived as objective and true depictions of reality and as able to prove something. I will explore more in depth the topic of images as evidence. Interestingly, Burri (2012, p. 53) notices that "scientific images are especially persuasive because they are both authoritative and seductive": authoritative because of their evidential power; seductive because they build on appealing aesthetics, evoke emotions, and impact actors' perceptions. This persuasive power is even more relevant considering that images are widely used in daily medical practice: "in talks with patients or colleagues to underline an argument and convince others of a diagnosis or research finding" (p. 52).

The last dimension of visual logic is directly related to the second example of research that I want to present in this section, namely *styles of representation*. In his ethnographic study of Italian clinical cytogenetic laboratories, Mauro Turrini (2011, 2012) investigates some examples of divergences in representational practices through which chromosomes are displayed in cytogenetics. According to the author, this field is still considered to be one of the most artisanal among the biological disciplines. Notwithstanding, since the study of chromosomes is involved in several medical areas, cytogenetics is not only well established, but also widely diffused. Turrini explores the "differences in style that coexist in the same period and are recognized within a scientific community as traditions, genre conventions, and the specific circumstances of the production process, skills, and preferences of the scientist. These stylistic diversities – even though they can be defined *scientific*, since they are based principally on scientific procedures perfected by the empirical method of trial and error – are not unique to the lab, but respond to varied aesthetic ways to visualize and view the same scientific object" (2012, p. 3). A crucial feature of representative styles is related to the role of aesthetics and aesthetic judgment, which is not amenable to a mere personal taste, but rather refer to local and situated practices of visual construction of scientific data (Goodwin 1994, 1995). Therefore, diverse styles of representation "at the same time entails *what* to visualize and *how* to view it. The distinct strategies of visualizing and viewing specific objects are the final outcomes of an articulated and stratified process of negotiation among biologists, aesthetics, procedures, reagents, laboratory devices and so forth" (Turrini 2012, p. 15).

To sum up, it can be said that styles of representation illustrate that, even in the same scientific discipline, there can be many different ways to visualize the same objects. However, this does not diminish the scientific representativeness of the images produced, but leads to the topic of the next section: how images are constructed and used as evidence in the process of scientific research.

3. Images as evidence

In a recent article, Emma Frow claims that nowadays images and illustrations are treated "as essential for the communication of knowledge claims in scientific publications, providing 'external' references that complement the written text and help to focus the reader's attention on those aspects of the natural world that the author is trying to make visible" (Frow 2012, p. 370). If the idea that scientific images allow readers to 'witness' natural phenomena at a distance is not new (Shapin 1984), the development of instruments for digital imaging (and the possibility of manipulations that they offer) makes the role of images even more critical. On the one hand, this produces a frantic search for aesthetically pleasing images; on the other hand, a growing concern regarding the use of digital image-processing software and instruments in preparing illustrations challenges the credibility of images in scientific research.

Examining image-processing guidelines and journal commentaries on this topic Frow (2012) analyses how journal editors are drawing lines for the scientific community regarding acceptable and unacceptable practices in image production. The high-profile science journals under examination are not so much concerned with intentional fraud, but rather with routinely alteration of digital images. However, the production of best-practice guidelines raises a number of longstanding ambiguities inherent to the production, circulation and interpretation of digital images in scientific publications, but do not resolve them.

Furthermore, recent ethnographic studies (Carusi 2008, 2012; Monteiro 2010; Spencer 2012; for a review see Perini 2012) show how scientists themselves have doubts about the scientific value of images and how they often express negative assessments of the part that images should play in the accomplishment of good research. As an example of this distrust, I will report an excerpt from Spencer's ethnographic fieldwork with a group of computational physicists:

> "Images lie," says one scientist. "It is much better to work with numbers." A colleague of hers commented that "there is a substantial percentage of scientists, maybe even 10 percent, who will see a pretty picture and just want to use it, without even knowing how it is validated. I think that is just disturbing." More strong language from a third source: "I think pretty pictures are an utter waste of time" and a fourth: "Images tell you nothing" (Spencer 2012, p. 34).

According to Carusi (2012), the distrust of images and "the visual" is still commonplace because it is seen as subjective, and therefore in opposition to objective. The gold standard in science is still the numerical investigation precisely because it replaces subjectivity by objectivity and promises a neutral view. This is due to the traditional distinction (rooted in hard sciences, but widespread also in the social sciences) between qualitative and quantitative data. Interestingly, Carusi notes that huge quantities of data are made tractable through qualitative visual renderings. Moreover, qualitative/quantitative reversals are the characteristic feature of digital visualizations of all kinds, since there is a "continuous interplay between data in quantitative form, the algorithms for processing the data and producing the visualization, and the qualitative visual evaluation of the progress of the algorithm formation" (2012, p. 109). This interplay, moreover, is not only related to the instruments but refers to the actual use of visualizations in scientific practices. The typical screen display, for instance, is not only of a visual still or movie, but will also contain interfaces with quantitative settings and parameter displays.

Despite negative assessments, it is undeniable that images play a key role in conducting contemporary scientific research and that visualization is an indispensable technique, especially within the intermediate stages of the investigative process. For instance, on the basis of his ethnographic observations of a multidisciplinary team's weekly work meetings, Marko Monteiro (2010) analyzes how scientists produce scientific evidence through constructing and manipulating scientific visualizations. Monteiro focuses on how scientists build on "digital objects", which are constructed through embodied practices of interpreting and visualizing numerical evidence. As Montero claims "these digital objects as reliable renderings (and sometimes replacements) of natural objects or phenomena. The idea of "digital objects" seeks to conceptually locate their "materiality" in the relationship established by scientists between the phenomena they seek to explain/represent/model and the digital objects they work with during their research practices" (2010, p. 336). Therefore, these digital objects are also compelling images not only because they fascinate the viewer, but also for their perceived mechanical objectivity. The core potential of digital objects, however, is their possibility of manipulation as a way to directly handle data once available only through numbers. Scientists manipulate these digital objects in order to produce meaning or check for data reliability. Therefore, these manipulations become part of the scientific process of producing evidence.

As we have seen in the previous section, in the scientific communities' rhetoric it is often underlined that – in order to make these data scientific (i.e. objective, and therefore trustable) – instruments have to be used professionally by experts who are able to interpret the data. This process of visual enskillment produces "skilled visions" situated in diverse communities of practice (Grasseni 2004, 2007). However, developments in visualization digital tools have fostered the use of scientific imaging in the communication of science, both inside and outside the scientific community. The use of digital images as evidence in the research practices and communication can bring the non-scientific audience to embrace the idea that these instruments are able to pick up the "reality". In the next section, I will deal with the relation among images, imaginations and imaginaries.

4. Images, imaginations and imaginaries

The spread of visual displays and representations in science communication crosses the boundaries of the scientific community and reaches, often through the media, the audience of non-experts. However, the lay public tends to consider the images presented by the media (including artistic and fantastic) as the actual evidence of existing objects, even though they are invisible and inaccessible to direct observation (Maestrutti 2008).

This phenomenon is particularly relevant in the increasing interest on nanotechnologies and the diffusion of images from this field. As it has been argued by the research examples I have presented in the previous sections, technoscientific images are epistemologically problematic. In the case of nano images this problematic is even more evident, since pictures of an atom or a molecule cannot possibly "look like" an atom or a molecule (Moriarty 2010). Among the nano images, moreover, images of atoms and molecules are accompanied by pictures of imaginary nanoscale machines that might or might not become real in the future, such as nanobots (i.e. nano-robots) that navigate within blood vessels, acting as mechanical shovels to remove plaque, or nanobots that grasp blood cells. As Nerlich (2008) has argued, artistic depictions of nanobots are meant to make the unfamiliar features of nanotechnology seem familiar to broad audiences and to make things that do not exist seem as if they might soon exist. According to the author, this is because nanotechnology will seem normal if people accept pictures of nanobots. However, Nerlich claims, nanobots have captured public *imagination*.

Exploring different types of images from Nanotechnology Image Galleries, de Ridder-Vignone and Lynch (2012) have analysed the relation between *images* and *imaginations*. They argue that all the types of nano images they have investigated distinctively challenge the viewer's imagination, while drawing upon what is familiar: they are at the same time "realistic" in their appearance (as unadorned, monochromatic or black-and white, micrographic images can be) as well as they involve distinctive modes of imagination. The authors even argue that "the most ostentatiously imaginative images often deploy the most conventional means to depict nanoscale reality" (2012, p. 447).

As Toumey and Cobb (2012) argue, the two interweaving families of nanoscale images (i.e. pictures of atoms and molecules and pictures of imaginary nanobots) raise a number of questions about our knowledge of reality at the nanoscale. On the basis of a survey in the U.S. the authors illustrate how epistemology meets public interpretation in the case on nano images: "We see how a depiction of an object that is not real now and may never become real nevertheless affects public attitudes about the health and medical implications of nanotechnology" (Toumey and Cobb 2012, p. 464).

The imaginaries of nanotechnology, moreover, are strictly related to the imaginaries of body transformations (Maestrutti 2011a). Accordingly, I will move my attention to the technoscientific imaging of the human body, which seems to be an extraordinary example of the relation among images, imaginations and imaginaries. As argued by Maestrutti (2011b) one of the main characteristics of technoscience is the creation of what she defines as "techno-imagination", which develops around the body. The body seems to be one of the more fruitful *loci* for the development of techno-imagination for two main reasons: on the one hand, it is a site of experiment and transformation of life and organic materials; on the other, it is a *locus* of construction of new forms of identity.

In order to explore the relationship between the production and diffusion of appealing scientific images and new imaginations and imaginaries of human bodies, I will present a last example of research on the technoscientific imaging and visualization of human reproductive cells (Lie 2012). Through the example of the website of a Norwegian governmental organization for information on biotechnology and bioethics, the author investigates how new images of the human body (in this case mainly egg and sperm cells at the moment of conception) may affect the understanding of human bodies (and human reproduction), contributing to change imaginations and imaginaries of the body itself. The website under scrutiny, as many others intended for the lay public, displays images of egg and sperm cells related to techniques of assisted reproduction.

Technoscientific imaging can transform human cells into astonishing and aesthetically appealing images. Cells, and even their interior, are depicted via medical visualization technologies and become concrete bodies. Cells are cleaned (i.e. organic matter is removed) and colours are added to distinguish various aspects: the result appears as images of real human cells. Through this "manipulation" a cultural transformation is also achieved and cells reappear as individual and autonomous entities. As Lie (2012, p. 19) argues, once cells "are detached from the self, they can be studied, discussed and referred to at a distance, and once they have a shape or description they are identifiable and manageable". When gametes are de-contextualized from human bodies they become detachable, usable properties. This cultural transformation fosters the re-imagination of the "facts of life". The new imaginations and imaginaries of the human bodies, directly affect our sense of self, body and humanness. When cells are understood as autonomous entities, rather than fragment of a whole body, the same biological material can assume a different ontological status according to the sense-making process in which it is embedded (for a detailed discussion, see Perrotta 2013).

5. Conclusions: future studies of technoscientific imaging in STS

The array of studies presented in the previous pages is not an exhaustive review, although it represents some of the most interesting studies in the recent STS literature on technoscientific imaging. I decided to focus on the three strands of analysis which best represent the state of the art: technoscientific imaging in practice; images as evidence; images, imaginations and imaginaries.

Through the literature presented, I have pointed out the role of visual logic and styles of representation, the relevance of aesthetics in the sharing and production of scientific knowledge, and the importance of images in the transformation of imaginations and imageries. Not by chance, some recent experiences of hybridization have shown a great potential for new future studies of technoscientific imaging. The call for a broader development of an STS approach to the arts (Benschop 2009), the study of the emerging area of BioArt (Yang 2011), and the increasing number of joint projects between STS scholars and (mainly bio)artists (Anker and Franklin 2011) can bring a new breeze to the future studies of technoscientific imaging.

Although the collaboration among artists and natural and social scientists has already provided interesting examples of research successes, the increasing hybridization between STS and art represents a challenge for future studIES of technoscientific imaging. The field of STS, as an interdisciplinary research environment, could afford new opportunities of collaboration between artists and scientists, as well as support further research efforts to explore technoscientific imaging.

References

Amann, K. and Knorr-Cetina, K. (1990) *The Fixation of (Visual) Evidence*, in M. Lynch and S. Woolgar (eds.) *Representation in Scientific Practice*, Cambridge, MIT Press, pp. 85-121.

Anker, S. and Franklin, S. (2011) *Specimens as Spectacles. Reframing Fetal Remains*, in "Social Text", 29 (1), pp. 103-125.

Beaulieu, A. (2001) *Voxels in the Brain: Neuroscience, Informatics and Changing Notions of Objectivity*, in "Social Studies of Science", 31 (5), pp. 635-680.

Benschop, R. (ed.) (2009) *STS on Art and the Art of STS*, Special Issue of "Krisis. Journal for contemporary philosophy", 1.

Burri, R.V. (2008) *Doing Distinctions: Boundary Work and Symbolic Capital in Radiology*, in "Social Studies of Science", 38 (1), pp. 37-64.
Burri, R. V. (2012) *Visual rationalities: Towards a sociology of images*, in "Current Sociology", 60 (1), pp. 45–60.
Burri, R. V. and Dumit J. (2008) *Social Studies of Scientific Imaging and Visualization*, in E.J. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman (eds.), *The Handbook of Science and Technology Studies*, Third Edition, Cambridge, MA, MIT Press, pp. 297-317.
Carusi, A. (2008) *Scientific visualizations and aesthetic grounds for trust*, in "Ethics and Information Technology", 10 (4), pp. 243-254.
Carusi, A. (2012) *Making the Visual Visible in Philosophy of Science*, in "Spontaneous Generations: A Journal for the History and Philosophy of Science", 6 (1), pp. 106-114.
Coopmans, C., Vertesi, J., Lynch, M. and Woolgar, S. (eds.) (forthcoming) *New Representation in Scientific Practice*, Cambridge, MIT Press.
Daston, L. and Galison, P. (2007) *Objectivity*, New York, Zone Books.
de Ridder-Vignone, K. D. and Lynch, M. (2012) *Images and Imaginations: An Exploration of Nanotechnology Image Galleries*, in "Leonardo", 45 (5), pp. 447-454.
Dumit, J. (2004) *Picturing Personhood: Brain Scans and Biomedical Identity,* Princeton, Princeton University Press.
Fyfe, G. and Law, J. (eds.) (1988) *Picturing Power: Visual Depiction and Social Relations*, London and New York, Routledge.
Frow, E. K. (2012) *Drawing a line: Setting guidelines for digital image processing in scientific journal articles*, in "Social Studies of Science", 42 (3), pp. 369-392.
Garforth, L. (2012) *In/Visibilities of Research: Seeing and Knowing in STS*, in "Science, Technology, & Human Values", 37 (2), pp. 264-285.
Goodwin, C. (1994) *Professional vision*, in "American Anthropologist", 96 (3), pp. 606-633.
Goodwin, C. (1995) *Seeing in depth*, in "Social Studies of Science", 25, pp. 237–274.
Grasseni, C. (2004) *Skilled vision. An apprenticeship in breeding aesthetics*, "Social Anthropology", 12 (1), pp. 41-55.
Grasseni, C. (ed.) (2007) *Skilled Visions. Between Apprenticeship and Standards*, New York and Oxford, Berghahn Books.
Gross, A. and Louson, E. (2012) *Visual Representation and Science: Editors' Introduction,* in "Spontaneous Generations: A Journal for the History and Philosophy of Science", 6 (1), pp. 1-7.
Hacking, I. (1983) *Representing and Intervening*, Cambridge, Cambridge University Press.
Joyce, K. (2005) *Appealing Images: Magnetic Resonance Imaging and the Production of Authoritative Knowledge*, in "Social Studies of Science", 35 (3), pp. 437-462.

Joyce, K.A. (2006) *From Numbers to Pictures: The Development of Magnetic Resonance Imaging and the Visual Turn in Medicine*, in "Science as Culture", 15(1), pp. 1-22.

Knorr Cetina, K. (1981) *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science*, Oxford, Pergamon Press.

Latour, B. (1986) *Visualization and Cognition. Thinking With Eyes and Hands*, in H. Kuklick and E. Long (eds.), *Knowledge and Society: Studies in the Sociology of Culture Past and Present*, Greenwich, Connecticut and London, JAI Press, pp. 1-40.

Latour, B. (1987) *Science in Action. How to Follow Scientists and Engineers Through Society*, Cambridge, Harvard University Press.

Latour, B. and Woolgar, S. (1979) *Laboratory Life: The Construction of Scientific Facts*, Princeton, Princeton University Press.

Lie, M. (2012) *Reproductive Images: The Autonomous Cell*, in "Science as Culture", 21 (4), pp. 1-22.

Lynch, M. (1985a) *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory*, London and New York, Routledge & Kegan Paul.

Lynch, M. (1985b) *Discipline and the Material Form of Images: An Analysis of Scientific Visibility*, in "Social Studies of Science", 15 (1), pp. 37-66.

Lynch, M. (1998), *The Production of Scientific Images: Vision and Re-vision in the History, Philosophy, and Sociology of Science*, in "Communication & Cognition", 31, pp. 213–228.

Lynch, M. and Woolgar, S. (eds.) (1990) *Representation in Scientific Practice*, Cambridge, MIT Press.

Maestrutti, M. (2008) *Rendere visibile l'invisibile. Il ruolo della visione e dell'immagine nella costruzione di una storia delle nanotecnologie*, in "Rassegna Italiana di Sociologia", XLIX (3), pp. 427-50.

Maestrutti, M. (2011a) *Imaginaires des nanotechnologies : mythes et fictions de l'infiniment petit*, Paris, VUIBERT.

Maestrutti, M. (2011b) *Techno-imaginaires du corps à l'ère des technosciences. Art contemporain et utopie de la transformation*, in "Cahiers de recherche sociologique", 50, pp. 77-95.

Mody, C.C.M. (2011) *Instrumental Community. Probe Microscopy and the Path to Nanotechnology*, Cambridge, MIT Press.

Monteiro, M. (2010) *Reconfiguring evidence: Interacting with digital objects in scientific practice*, in "Computer Supported Cooperative Work", 9 (3-4), pp. 335-354.

Moriarty, P. (2010) *Resolution Frontiers*, in "Physics World", 23 (11), pp. 29-34.

Nerlich, B. (2008) *Powered by imagination: Nanobots at the Science Photo Library*, in "Science as Culture", 17 (3), pp. 269–292.

Nowotny, H. and Weiss, M. (eds.) (2000) *Shifting Boundaries of the Real: Making the Invisible Visible*, Zürich, Vdf.

Pauwels, L. (2006) *A theoretical framework for assessing visual representational practices in knowledge building and science communication*, in L. Pauwels (ed.) *Visual cultures of science: Rethinking representational practices in knowledge building and science communication*, Lebanon, New England University Press, pp. 1-25.

Perini, L. (2012) *Image Interpretation: Bridging the Gap from Mechanically Produced Image to Representation*, in "International Studies in the Philosophy of Science", 26 (2), pp. 153-70.

Perrotta, M. (ed.) (2013) *Re-conceiving Life in the Labs: The Emerging Meanings of Cells in the Italian Reproductive Biomedicine and Beyond*, Special Issue of "Tecnoscienza: Italian Journal of Science & Technology Studies", 4 (1) (forthcoming).

Pickering, A. (1992) *Science as Practice and Culture*, Chicago, University of Chicago Press.

Prasad, A. (2005a) *Making Images/Making Bodies: Visibilizing and Disciplining Through Magnetic Resonance Imaging (MRI)*, in "Science, Technology & Human Values", 30 (2), pp. 291-316.

Prasad, A. (2005b) *Scientific Culture in the 'Other' Theater of 'Modern Science': An Analysis of the Culture of Magnetic Resonance Imaging Research in India*, in "Social Studies of Science", 35 (3), pp. 463-89.

Schatzki, T., Knorr Cetina, K. and von Savigny, E. (eds.) (2001) *The Practice Turn in Contemporary Theory*, London and New York, Routledge.

Shapin, S. (1984) *Pump and circumstance: Robert Boyle's literary technology*, in "Social Studies of Science", 14 (4), pp. 481-520.

Spencer, M. (2012) *Trouble with Images in Computational Physics*, in "Spontaneous Generations: A Journal for the History and Philosophy of Science", 6 (1), pp. 34-42.

Traweek, S. (1997) *Iconic Devices: Toward an Ethnography of Physics Images*, in G.L. Downey and J. Dumit (eds.), *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, Santa Fe, School of American Research Press, pp. 103-115.

Toumey, C. and Cobb, M. (2012) *Nano in Sight: Epistemology, Aesthetics, Comparisons, and Public Perceptions of Images of Nanoscale Objects*, in "Leonardo", 45 (5), pp. 461-465.

Turrini, M. (2011) *"Se vedo solo il bianco e il nero non vedo le sfumature". Stili visuali e incertezza nei laboratori clinici di citogenetica*, in "Etnografia e Ricerca Qualitativa", 4 (1), pp. 39-60.

Turrini, M. (2012) *Continuous Grey Scales Versus Sharp Contrasts: Styles of Representation in Italian Clinical Cytogenetics Laboratories*, in "Human Studies", 35 (1), pp. 1-25.

Yang, A.S. (2011) *Interdisciplinarity and Critical Inquiry: Visualizing at the Art/Bioscience Interface*, in "Interdisciplinary Science Reviews", 36 (1), pp. 43-55.

Manuela Perrotta Norwegian University of Science and Technology
Department of Interdisciplinary Studies of Culture
Dragvoll, Edvard Bulls veg 1, 7491, Trondheim, Norway
Email: manuela.perrotta@aruba.it