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Scientific Images as Circulating Ideas –

An Application of Ludwik Fleck's Theory of Thought Styles

Nicola Mößner

Abstract

Without doubt, there is a great diversity of scientific images both with regard to their appearances and their functions. Diagrams, photographs, drawings, etc. serve as evidence in publications, as eye-catchers in presentations, as surrogates for the research object in scientific reasoning. This fact has been highlighted by Stephen M. Downes who takes this diversity as a reason to argue against a unifying representation-based account of how visualisations play their epistemic role in science.

In the following paper, I will suggest an alternative explanation of the diversity of scientific images. This account refers to processes which are caused by the social setting of science. What exactly is meant by this, I will spell out with the aid of Ludwik Fleck's theory of the social mechanisms of scientific communication.

Keywords: Ludwik Fleck, scientific communication, scientific images, social mechanism, thought collective, visual representations

1 Introduction

Stephen M. Downes (2012) draws our attention to the fact that not only a variety of phenomena are subsumed under the label of *scientific images*, but that they fulfil many different functions in epistemic practices in science, too. Downes connects this more general observation with considerations about how people theorise about this phenomenon in philosophy of science. He writes “[...] at one end of the spectrum there are those who believe that images do no real epistemic work and, at the other end, there are those who believe that if images do any epistemic work, there must be one unifying account of how they do so” (Downes 2012, 117). Downes then argues against such a *unifying account of scientific visualisations*[i], i.e. a theory that explains the contributions of visual representations to the diverse epistemic processes exclusively by highlighting the same representational property (e.g. resemblance relation or causal connection[ii]). Proponents of such an account thereby attribute the same functional role and the same epistemic significance to those visual representations in all instances.

Contrary to this, Downes emphasises the relevance of the different contexts of usage to understand and explain the functions of the visual correctly. “I hold that scientific images function in a number of ways, doing different kinds of epistemic work and, sometimes, none at all” (ibid., 117f.). Accordingly, some visual representations may be used to play an evidential role in scientific publications (see e.g. Wilder 2009; Perini 2005, 2010) or even may be regarded as a kind of proof (see e.g. Brown 1997; Vögtli and Ernst 2007). Some may be used as a surrogate for the object under investigation to find out more about the latter (see e.g. Cartwright 1997, Weiss 2012). Others may be regarded as heuristic means in educational contexts (see e.g. Müller et al. 2012) or may be used as mere eye-catchers, i.e. to attract the attention of the intended audience of a presentation or publication (see e.g. Carter 2013, 137ff.).

Laura Perini (2010) urges us to take this functional diversity seriously when considering scientific cognitive processes. “If the goal is to understand scientific reasoning, we need to understand the representations scientists use when they communicate” (Perini 2010, 152). Following her advice, we will stick to the idea of diversity in this article and suggest a way to cope with it without referring to a unifying representation-based account.[iii] In doing so we will

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take advantage of Ludwik Fleck's theory about the social determination of scientific cognition (see Fleck 1979).[iv] His explanation of *scientific communicative practices* will be especially helpful for our purpose. It will turn out that regarding visual representations as parts of communicative processes, performed with different aims and for different target audiences, will allow us to account for the stated diversity. The clue to our explanation will be Fleck's detailed analysis of the social setting of science and its influence on scientific reasoning.

After introducing some essential terminology (sec. 2), we will discuss Fleck's account of scientific communication (sec. 3). After that, we will analyze the applicability of Fleck's theses about the written word to scientific visualisations. On the one hand, we will analyze what Fleck claims about visual representations in science (sec. 4.1). And, on the other hand, we will make use of his theory to suggest a twofold explanation with regard to the changes of appearances and functions of visual representations in different scientific contexts (sec. 4.2).

2 Circulating Ideas

To understand Fleck's conception of scientific communication correctly it is necessary to introduce some terminology.[v] "Thought collective" is then the first relevant concept to talk about (see Fleck 1979, 102ff.).[vi] Such a collective comprises people being involved in a joint conversation (see ibid., 39, 44, 102). Because of this broad definition such collectives appear in scientific as well as in everyday contexts (see Mößner 2011, 367). Anyway, as we are interested in *scientific* images here, I will focus my considerations on the former and take it, that Fleck's term "thought collective" can, amongst others, be understood as denoting a *scientific community*, referring to a *group of people* (see Fleck 1979, 39, 102f.).[vii] Such a community is structured, i.e. it comprises different parts. There are the experts who belong to the "esoteric circle" – forming a group around the specialists of a certain topic. Additionally, there are the more or less informed and interested laymen as members of the "exoteric circle" (see ibid., 111). These realms are not strictly separated; expertise is rather gradually reduced.

Moreover, there is more than one such collective in science. Actually, there are innumerable ones due to their origin in joint conversations (see ibid., 102). Accordingly, we find a wide variety of different collectives in science, as they are not congruent with the formal disciplinary boundaries, e.g. between biology and physics. In this sense, there may be a thought collective of researchers exploring the formation of galaxies, one who is interested in comets, one who is concerned with the developments of stars, etc. – and all of them belong to the realm of astrophysics. Furthermore, a single individual can be a member of diverse thought collectives on different levels at the same time (see ibid., 105).

This idea of thought collectives as groups of people clustered around a common topic of interest – or a set of beliefs – can be regarded as a first approximation to what Fleck holds to be the collective's unifying element. He calls this element which also demarcates a particular community from others "thought style" (ibid., 99). This central concept in Fleck's theory is not easily understandable as it consists of different components varying with different contexts.[viii] Focusing on the scientific realm again, we can say that some of these elements are epistemological in nature – such as background knowledge, theories, etc. – and some of them are of a more psychological nature – such as a certain mood.[ix] Furthermore, the usage of certain instruments is also part of the thought style as is the particular way to represent and to publish research results (see ibid., 99). In a nutshell then, Fleck states that "[w]e can therefore *define thought style as* [the readiness for] *directed perception, with corresponding mental and objective assimilation of what has been so perceived.* It is characterized by common features in the problems of interest to a thought collective, by the judgements which the thought collective considers evident, and by the methods which it applies as means of cognition. The thought style may also be accompanied by a technical and literary style characteristic of the given system of knowledge" (ibid., his italics).

Finally, a collective's thought style gives rise to certain consequences with respect to the work of the particular researcher. The individual's perceptions and actions are influenced and directed by her collective. Here[x] I only want to mention one aspect of this social determination which is also relevant for scientific visualisations, namely its impact on scientific observations.[xi] In this context, the individual shows a specific liability to observe only what is of interest to her collective. Fleck claims that "[w]e look with our own eyes, but we see with the eyes of the collective body [...]" (Fleck 1947, 137). This way of perceiving things is constituted by the background knowledge provided by the collective the particular scientist is a member of. What is relevant to observe and how to perceive correctly, i.e. in accordance with the prevalent thought style, the particular researcher will learn during a period of practical training.[xii] By becoming familiar with what is of importance to the thought collective, the individual's mind becomes equipped with certain perceptual patterns, so to speak, which will guide her in finding a starting point for new observations later on.

Referring to this process of learning the basic forms of stylised perception, Wojciech Sady compares these patterns with Kant's conception of *forms of pure reason* (*Formen reiner Anschauung*) and writes: "Fleck adopted Kant's thesis on the active role of cognition a priori: an empty mind would neither perceive nor think. So, before a mind starts to experience, and on the basis of experience starts to think, it has to be filled with some initial knowledge" (Sady 2012, ch. 3).[xiii] In the same way as Kant suggests that perception and understanding of what is perceived is impossible without the aid of such forms, Fleck argues that the particular researcher will look for certain starting points in the chaotic beginning of scientific observation which are provided by these very patterns (see Fleck 1947, 139ff.; 1979, 92). Ilana Löwy explains this as follows: "Isolated researchers may at first be bewildered by the chaos and disorder of their observations and may have great difficulty in separating fact and artefact. The shared conceptual framework of their scientific communities and the techniques and methods elaborated by these communities provide them with cognitive and material tools that enable them to distinguish signal from noise [...]" (Löwy 2008, 375f.). Such a concept of scientific observation also implies that the scientist will be somehow blind to deviations from the prevalent style-determinate content of her perception. She will be prone to omit some details and to add others (see Fleck 1947, 137).

With this theoretical background in mind let us now come back to the question about the diversity of scientific images. The relevant starting point for this purpose is Fleck's account of scientific communication.

3 Scientific Communication

To make use of Fleck's theory to describe and, maybe also, to account for the diversity of scientific images, we have to consider the two parts of his explanation of scientific communication. The first one is about *communicative purposes*. The second aspect is about the *different modes of publication*, i.e. ways of communicating results and hypotheses to the scientific community. Both issues are involved in the circulation of ideas that enables progress and failure in scientific reasoning.[xiv] Claus Zittel describes this wandering of ideas as follows: "Thoughts may wander within a thinking-collective from the esoteric to the exoteric circle of the lay person, where they become factual knowledge and return to the collective as such" (Zittel 2012, 64). The mechanisms involved in this wandering and changing of ideas in science will now be described in more detail below.

3.1 The Purposes of Conversation

Starting with the aims of communication, we have to make a distinction between communication *within the boundaries* of one's own thought collective – the "intra-collective thought exchange" – and communication *across the borders*, called "inter-collective thought exchange". Both kinds result in certain modifications of the original thought (see Sady 2012, ch. 5).

In the case of *intra-collective* communication, the original thought traverses different stages of modification, depending on the target audience and the envisaged purpose. Accordingly, Fleck distinguishes three aims that can be correlated with the communication of an idea within one's own collective, namely *to legitimise* it or *to popularise* it or *to inform* the group's members (see Fleck 1936, 86f.). These three communicative aims correspond to the collective's structure. If, on the one hand, a specialist from the esoteric circle speaks to the laymen of the exoteric circle an act of popularisation takes place. On the other hand, the communication between members of the esoteric circle can be aimed at information or legitimisation. It is not surprising then that the same idea is expressed differently, if it is communicated to different target audiences. Fleck, however, does not only emphasise a harmless variation in expressions, but also points out that the *idea itself* is changed. This is what happens in the contexts of popularisation and legitimisation, whereas the act of information leaves the idea more or less untouched (see ibid., 86).

Let us take a look at what happens in those instances and start with the case of *popularisation*. If a specialist communicates her thoughts to a layman within her own community, she will have to take into account that her recipient will not be able to understand all the details and the technical terms of her research. Consequently, the act of popularisation leads to simplifications. The specialist does not communicate the subtleties of the discussion, leaves out divergent opinions "[...] and stresses some aspects of the problem by way of pictures and comparisons" (ibid.). Modern science journalism illustrates Fleck's thesis neatly.

Information and legitimisation are purposes of communicative acts between more or less specialised experts. In the first case, a particular scientist wants to transmit her research results to her peers, i.e. scientists working on the same theory or problem. And as they all share pretty much the same background knowledge, the informing scientist does not have to tailor her transmission in a particular way. Thus, the transmitted thought stays more or less unchanged (see ibid., 87).

Although in the case of legitimisation the participants of the communicative act remain more or less the same[xv], the transmitted piece of information is affected radically differently.[xvi] The scientist who transmits her idea asks the collective to legitimise it, i.e. to declare its conformity to the prevalent thought style (see ibid., 86). In this sense, the particular scientist plays the role of someone asking for the collective's approval. Moreover, this role also affects the way in which she presents her ideas, namely by using carefully formulated hypotheses and not bold claims. When the process is finished we will find the stylised, i.e. transformed idea being integrated in the correlated collective's handbooks (and textbooks). Thus, two different media are involved here: *Journals* to present the initial idea and to raise the discussion, and *handbooks* to present the legitimised thought when the debate is closed.

Let us now turn to the last purpose of communication in science, which Fleck mentions, namely the case of *propaganda*. Here we are confronted with the inter-collective instance of communication, i.e. the attempt to communicate an idea to a different thought collective[xvii] (see Fleck 1936, 85).[xviii] Again we notice a change in meaning of the idea transmitted. Taken in its simplest form this variation may be comparable to what happens in the case of popularisation. Propaganda, however, can, also imply complete misunderstandings and, thereby, the destruction of the meaning of what should have been transmitted (see ibid.; also Fleck 1979, 109f.).[xix] The reason for these difficulties consists in the necessity of translating the idea into the language of the foreign group. The aim is comprehensibility; the researcher has to simplify her original statement and to retreat from her technical terms, etc. However, at some point it might be impossible to find a common language which both communities can understand correctly.

Now that we have an idea of Fleck's conception of the *purposes of (scientific) communication* and their effects on the transmitted ideas, we can take a look at his considerations about the *modes of scientific communication*. Both aspects will help us to explain the diversity of scientific images as a consequence of the social setting of science.

3.2 The Modes of Communication

Without doubt, a crucial aspect of Fleck's theory consists in his elaborate description of scientific publishing practices and their influence on transmitted ideas (see Fleck 1979, ch. 4.4). In this context, Fleck distinguishes *four different categories of science* according to their different media of publication.

Firstly, there is what he calls *popular science* as "science for nonexperts" (ibid., 112). This can be related to the aim of popularisation with the above-mentioned consequences of simplification and apodictic valuation. Schoolbooks and science journalism (such as *Scientific American*) offer examples here. They are designed for laymen. Furthermore, an interesting feature of popular science is its tendency to include pictorial elements (see ibid., 114). We will come back to this point in due course.

Additionally, Fleck mentions three further kinds of science: *textbook science*, *vademecum science*[xx] and *journal science* (see ibid.). All of them belong to the esoteric circle of a collective and are related to the aims of information and legitimisation. Fleck does not explicitly deal with the case of textbooks[xxi] needed for education; his concern is more with the vademecum and journal science and the wandering of ideas from one to the other. In short, an idea starts its journey in the journal science, is discussed by the collective, will eventually be added to a handbook in a somewhat modified version and from there it will influence new research in the same field. Fleck describes a circle of knowledge here that, on the one hand, shows the interaction of the different parts of a certain thought collective and, on the other hand, points out how the act of legitimising an idea proceeds within the community.

The first step is to publish particular results in a certain scientific journal, e.g. *Physical Letters A*. Here the individual researcher (or a certain group of people) is the author of the idea. However, the aim of this publication is not only to inform others about results, but also to ask for a legitimisation of those results. Therefore, the published idea is presented in accordance with a certain formal style corresponding to these aims. Fleck describes the way to present an idea in a journal article as containing especially cautious formulations, no bold claims. And, as individual results are presented, so are particular methods, instruments, theories, etc. mentioned. Thus, Fleck describes the style of journal articles as bearing "[...] the imprint of the provisional and the personal" (ibid., 118).

If we now consider a handbook, it becomes clear that the way to create such a condensed work of science cannot consist in just combining all those different journal articles on a certain topic. Consequently, Fleck states that "[t]he vademecum is [...] not simply the result of either a compilation or a collection of various journal contributions. The former is impossible because such papers often contradict each other. The latter does not yield a closed system, which is the goal of vademecum science. A vademecum is built up from individual contributions *through selection and orderly arrangement* like a mosaic from many colored stones. The plan according to which selection and arrangement are made will then provide the guidelines for future research" (ibid., 119f., my italics). Fleck's description of the handbook's origin seems to be plausible. Surprisingly, however, Fleck claims that the author of the altered idea is not a particular individual anymore but the collective as a whole (see ibid., 120). Why does this happen?

Fleck's explanation is based on the process of the idea's alteration: It is adjusted to the community's thought style and, thereby, deprived of the individual's influence. He explains this by showing that there are always different hypotheses available concerning a particular topic. They are presented in the diverse journal articles which all claim to be the next developmental step of the theory at hand. Vademecum science takes them all into account, assesses their values, combines them with the research tradition of the field and, in the end, follows maybe none of them (see ibid., 124). One might object that nonetheless the handbook has an identifiable author, the one who wrote the book, but this is not Fleck's point of concern. He does not deny that there is an author in this sense, what he denies is that the presented idea is made up solely in the mind of a particular researcher without taking into account the set of background knowledge provided by the collective.

Fleck's account is easier to understand when we take into consideration that the described adjustment of the idea can also take place within one and the same scientist (see ibid., 120). Although the normal case seems to be the discussion and alteration of the idea by a group of people, it is by no means precluded that the particular researcher carries out the described evaluation of the idea alone. In this context, Zittel states that "[a]n individual person can also form a collective when he or she discusses with him/herself" (Zittel 2012, 63). And, as Fleck claims, in the end it won't be her idea that she will put forward in the handbook, but an idea adequate to the thought style of her collective, taking into account its traditions, its style of writing, its interests and biases, etc. The social mechanisms involved here are explained by Sady: "Each member of the group reads different texts (both popular and professional), participates in different experiments, and belongs to more or less different thought collectives (both scientific and non-scientific). So, when they start speaking to each other and reading each other's papers, a series of misunderstandings arises. Ideas circulate within a collective and are enriched by new associations, and therefore the words that are used change their meanings. [...] Having conducted countless studies and conversations and embarked upon a long journey, the scholars finally create a thought style which nobody intended. And after this has happened, nobody post factum knows when and how that style started to operate and who, specifically, created it" (Sady 2012, ch. 5).[xxii]

Furthermore, Fleck points out that, as the idea is no longer the product of a particular individual but the product of the community, it seems to be approved by the collective. This is also supported by the way of presenting the information, the formal style which declares the published idea to be a common fact. He claims that "[a] statement appears ipso facto more certain and more soundly established in the organized system of a discipline as presented in a vademecum than it does in any fragmentary description found in a journal. It becomes a definite thought constraint" (Fleck 1979, 121).

4 The Diversity of Scientific Images

After having introduced Fleck's account of scientific communication, let us come back to our initial concern about scientific images. The thesis, which shall be defended in the following, is that his theory is as well applicable to the linguistic as to the pictorial domain of science and, thereby, can account for the diversity of scientific images as stated in the beginning of this article. The former part goes without question as it is the intended scope of Fleck's theory. The latter, however, has still to be shown. Let us start with what Fleck himself says about scientific images.

4.1 Fleck on Visual Representations in Science

There are several hints in his work that he wants his theses being applied to visual representations as well. These remarks might have contributed to the fact that Fleck's theory has become somehow fashionable amongst philosophers, art historians (see e.g. Bredekamp et al. 2008, Zimmermann 2009), historians and sociologists of science theorising about scientific visualisations (see Egloff and Fehr 2011, 8; Zittel 2012, 55).[xxiii] However, whereas his theory about (linguistic) scientific publication processes and their embedding in social practices is quite elaborated, his ideas about scientific images are rather scattered over his work. In the following, we will collect some of the most important theses in this context.[xxiv]

To start with, there are his remarks about scientific illustrations in medical textbooks which Fleck takes to show both the particularities of perception in divergent thought styles and of representations as manifestations of what is so perceived (see Fleck 1979, 136ff.). In the previous section we already learnt about his thesis that thought styles determine not only the way scientists conduct experiments and observations, i.e. what instruments they use, etc., but also what is perceived by them – both in the sense of *what scientific puzzles* (entities, processes, etc.) they draw their attention to and *what they will actually see* during their investigation. According to Fleck, such particularities of stylised scientific observations can be detected by outsiders when they analyze illustrations in textbooks.[xxv] Consequently, he describes these images as representations of certain perceptional liabilities in a particular scientific community. He writes, "[w]e are thus confronted with ideograms [Ideogramme], or graphic representations of certain ideas and certain meanings" (ibid., 137).

Fleck points out that the inclination to stick to the prevalent thought style in a given community may result in its members' disposition to modify visual representations. While explaining what provoked the modifications in his exemplary illustration (which is about certain anatomical features, see ibid., 34), Fleck complains about not having been able to find a *neutral* illustration as a point of comparison here, not even a *neutral photograph*, since each one highlighted the corresponding thought collective's special viewpoint (see ibid., 33ff.). The obvious question then is: why is he of the opinion that even photographic pictures cannot provide information in a neutral way? One might object that photographs[xxvi] are the outcome of a merely causal process so that you can only depict what has been in front of the camera.

How is it possible then to argue that photographs do not neutrally show what was in front of the camera at the time of exposure?

Two aspects are of importance here. On the one hand, these pictures are part of the process just described. The scientist who took the photograph is a member of a certain thought collective. Therefore, she will make her observations *through the eyes of her community*, as Fleck puts it. She will only see what is of interest to them. Accordingly, she may take her photograph from a certain angle or use a particular kind of exposure. Maybe she will use filters to enhance the picture in the way she thinks it would be important. In this way, the photograph, even if it is the outcome of a causal process of depiction, will become a product of the thought collective. The "thought constraint" (ibid., 99) which triggers the photographer's decisions is thereby an inherent part of her own judgements; it is not forced on her from the outside. Sometimes she does not even notice that she acts in accordance with a certain thought style.

On the other hand, Fleck calls attention to the *educational* context of the photograph's usage. He points out that it was part of a medical textbook (see ibid., 33). Accordingly, the picture is meant to train the students' eyes to recognise particular visual patterns, in this case certain anatomical features. Sady highlights the consequences of such an educational practice in Fleck's theory by stating: "An expert sees differently than a layperson because she went through a special training during which she was familiarized with many examples [...]" (Sady 2012, ch. 5). Hence, it appears natural to argue that the picture in Fleck's example was prepared for the sake of this educational purpose.

Both aspects may serve as an explanation for the fact that even photographs – as the output of a (at first glance) merely causal process – are cultural products in Fleck's sense. This insight also forces him to say: "It is only theories, not illustrations, that can be compared" (see Fleck 1979, 35). Illustrations will only reveal the theoretical assumptions in their background, but will not provide a neutral point of comparison. He thinks that this holds true for illustrations, photographs, etc. used in contemporary books as well. Although we might regard them as objective[xxvii] depictions, they are soaked with the thought style of our own community.[xxviii] We may just not be able to detect this anymore, because we got used to this way of depiction as the 'norm' during our studies (see Löwy 2008, 376). In this sense, Fleck claims that there are no neutral visualisations whatsoever.

I do not agree with him about this very strong thesis with regard to scientific observations, as I think that at least in certain respects we are not completely free to see and visualise what a prevalent thought style might recommend to see. However, I acknowledge the fact that *background beliefs can guide our attention* in certain ways which might also explain some of the distorting influences mentioned above.[xxix]

Fleck's assumptions about the process of perception and the influence of thought styles have been broadly discussed[xxx] so that dwelling on this point here would go well beyond the scope of this article. Nonetheless, I agree with Fleck that *social mechanisms* in science are responsible for certain ways of presenting and also for modifying scientific ideas. Considering his study on communicative acts in science makes this clear. This aspect has not been analyzed as deeply as his theory of perception. Thus, in favour of elaborating on this more underdeveloped part of the philosophical debate, I will slightly neglect the philosophical discussion of Fleck's theory of perception.

From Fleck's point of view, images can be parts of the same communicative processes as verbal descriptions. Visual representations just as words are *vehicles of the circulation of ideas* (see Fleck 1979, 107, 109). Thus, they show the same alterations in the expression of their contents as the former do. With regard to this thesis, Fleck mainly offers examples of visual representations in handbook science and in popular science. Both instances are characterised by the fact that the corresponding ideas already underwent the process of legitimisation in the correlated thought collective. Thus, there is no more discussion about the presented topics. Ideas – either stated in verbal descriptions or visualised in pictorial representations – are presented as facts.

Additionally, in the context of popular science Fleck emphasises that, as the audience are laymen, a particular emotional vividness is inherent to its mode of presentation (see ibid., 115). Popularisation aims at *convincing* not at careful argumentation and the balancing of reasons. Thus, images are often chosen to present ideas in a simplified and easily understandable way (see ibid., 114), exploiting the characteristic *persuasiveness of visual representations*. Fleck discusses this phenomenon with regard to an "illustration representing the hygienic fact of droplet infection. [...] The evil bacilli in the shape of little devils are flying from his open mouth. [...]" (ibid., 117). Obviously, the image that he talks about transmits the message of an immediate danger of being infected by the sick man's coughing little devils. Additionally, as Fleck explains, there is also a *symbolic meaning* inherent in the picture, namely "the conceptions of immunological theory with its images of bacterial attack and defense" (ibid.).

This last aspect is of special interest to us as it points out that the characteristics of the illustration are not only the result of deliberate decisions of how to present the ideas best with regard to a particular target audience. They also originate in beliefs about the object of research, held by the scientist, which are the result of the circulation of ideas within the scientific community. Once certain ideas have been transformed into a kind of visual depiction, they may also become binding for the expert (see ibid., 117). In this sense, the *image* in the above example *corroborates the conception of diseases as vicious attacks of bacilli*. Here we can see the special impact of scientific images on experts, a fact that encourages Fleck's claim that visualisations form a constitutive part of the thought exchange. The results of this influence may be that the researcher completely loses sight of aspects which once were omitted for the sake of simplicity or that she will overemphasise other features that originally had been prepared solely for the sake of a better understanding. Hence, there is a *feedback loop* within the collective triggered by visualisations of popularised ideas.

Summing up all the scattered hints about scientific images in Fleck's work reveals two aspects relevant to his account: Firstly, he takes these visual representations – most of all scientific illustrations – to be of special importance and interest to a comparative epistemologist who wants to learn more about similarities and differences of thought styles. Secondly, he thinks that visual representations are of significant importance in the context of science itself, because they influence the conduct of research by the described feedback loops, i.e. the selection of research objects and the ways to ask questions about them.

Let us now come back to our initial concern about the diversity of visual representations in science.

4.2 Communicative Purposes and Image Diversity

Downes lists a full range of different types of visual representations in science. Furthermore, he makes us aware of the fact that they do not only vary with respect to their appearances but also differ with regard to their functions (see Downes 2012, 117). Although being convinced that "images are an indispensable part of science" (ibid.), he is reluctant to agree with proposals accounting for these phenomena by way of suggesting a unifying, representation-based explanation. Here, Fleck's theory of scientific communication offers a fruitful alternative, explaining the diversity in design and function as a consequence of social mechanisms in science.

We can take advantage of his suggestions in two alternative ways. Firstly, we can conceive of the *developmental stages of a depiction* as being correlated with the development of the respective idea. Such a development might either consist in a stepwise refinement of a single image, e.g. starting from a sketch and working it out to a detailed drawing or painting, or in using different types of depiction, e.g. drawing, diagram, and computer graphic, to represent different levels of cognition. Secondly, we can regard scientific images as *certain modes of presentation*, i.e. as the scientist's attempt to communicate a hypothesis to a particular target audience aiming at information, legitimisation, popularisation, or propaganda.[xxxi] Whereas in the former case, modifications of the idea and the image go hand in hand, the idea stays fixed in the latter case and the scientist only looks for an appropriate way to communicate it.[xxxii] We will discuss both alternatives in greater detail below.

The following analysis will show how visual representations vary with respect to different social contexts of their usage. The alterations of design will be obvious; however, there might be difficulties to understand the changing functional roles of images. As my approach aims at an application of *Fleck's theory of scientific communication*, it might be objected that there is only one function of images discussed here, namely the one of communication.[xxxiii] As a rejoinder I want to emphasise the fact that communication serves different purposes. Communication is not a monolithic, but a multifaceted phenomenon.[xxxiv] This is also what Fleck shows for science; communicating ideas does often imply more than simply transmitting previously fixed data. *Information* might be only one intended aim. And in the same way as linguistic expressions serve more than one purpose in the context of communication, so do visual representations. In this sense, it would be better to say that *within the context of communication* words and images serve their different purposes and functional roles to support the speaker's intended aims.

Taking a closer look at the visual domain of science now, will make clear that the very same effects that affect linguistic expressions in scientific communication, which have been analysed in sections (3.1) and (3.2) of this paper, also influence visual representations in this context.

(1) Visualisations can be regarded as *an integral part of the cognitive process*: Here we make use of Fleck's explanations concerning the developments of scientific ideas. Such a process starts with rough hypotheses and ends with stating facts. Fleck shows how this works with regard to linguistic expressions. Cautious claims develop into bold statements. Can the same be shown with regard to visual representations?

The starting point of this process in the visual domain might be the scribbling of first ideas and testing of different ways to represent them visually. The scientist's first intuitive ideas about her research object (entity, process, etc.) might be accompanied by a rough conception in a visual form, also expressing her insecurities and questions. After that, the testing of hypotheses will come along with designing and rejecting different images (or at least parts of them). Thus, trial and error affect both – the idea and its visual design.

Evidently, such a process of reasoning including visualisations, i.e. *visual thinking*, will only seldom be accessible to an external observer.[xxxv] Normally, ideas are not communicated until the scientist has worked out first results she holds worthwhile to present – and this is where journal science starts. In having access to the remnants of the scientists' visual thinking only historians of science might be an exception when analyzing the formers' notebooks. In this sense, Edward R. Tufte[xxxvi] presents some interesting examples.

To illustrate the way how, in Fleck's sense, an idea and its visual representation develop hand in hand, I will discuss Tufte's case study about John Snow's discovery of the transmission way of the cholera disease during an epidemic in London in 1854 (see Tufte 2010, 27-37). At that time (a couple of years ahead of the detection of the bacterium *Vibrio cholera*) different hypotheses were suggested to explain how the disease might spread among its victims (see ibid., 29). Bearing this in mind, Tufte describes how Snow developed his idea that polluted water from an official town pump was the source of the epidemic by displaying death rates and locations of water supplies on a map (see fig. 1).

To see how Snow's hypothesis was developed with the aid of visual means, we have to take into account that he did not use just one map but produced several ones with regard to different historical cholera epidemics (see ibid., 34). These different maps then allowed him to eliminate divergent explanatory approaches concerning the disease's transmission ways. In this sense, he had data to plot at his disposal, namely addresses of victims' residences and death rates with respect to the disease of 1854. However, one might explain the clustering of death events completely differently, e.g. by social status, living conditions, typical jobs, food supply, etc. Thus, the causal link that Snow discovered between polluted water and death rates was a new fact. And this breakthrough was enabled by using the maps that revealed this fact to his eyes. In comparison to all other possibilities, the explanation that the disease was somehow related to the Broad Street pump and, hence, to polluted water seemed to be the best explanation of the clustering of death events and this explanation was suggested and supported by the visualisation of the data.

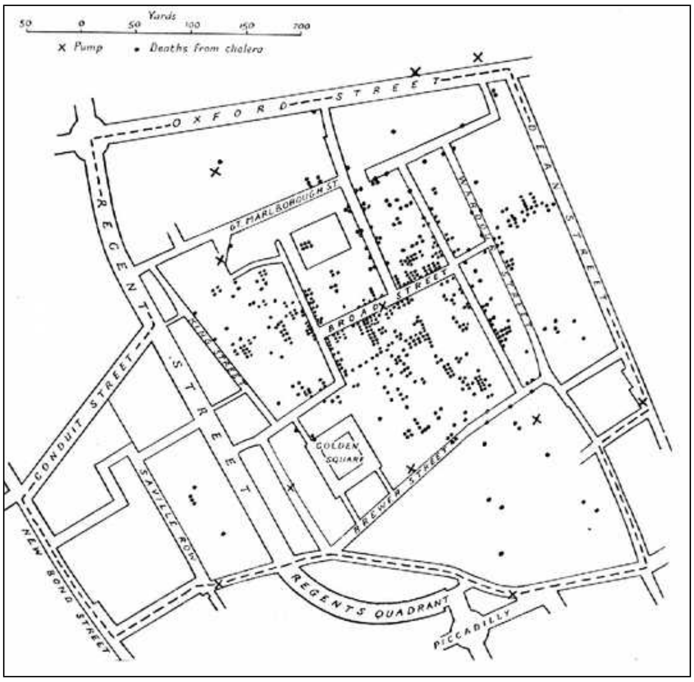

Fig. 1 A variant of the original map drawn by Dr. John Snow (1813-1858); source: http://commons.wikimedia.org/wiki/File:Snow-cholera-map.jpg; Original map published in Snow, John: *Snow on cholera: being a reprint of two papers*. New York: The Commonwealth Fund; London: H. Milford, Oxford University Press, 1936, p. 109.

Tufte states that “[t]his map reveals a strong association between cholera and proximity to the Broad Street pump, in a context of simultaneous comparison with other local water sources and the surrounding neighbourhoods without cholera” (ibid., 30).[xxxvii] The example makes clear that working with the map, i.e. the visual arrangement of data, allowed Snow to develop an idea about the potential source of the disease and to suggest means to stop its spreading, namely to remove the handle of the Broad Street pump, which also allowed him to test his hypothesis and, in the end, proved it to be true.

The above example illustrates the intertwined development of an idea and its visual representation. This first alternative to invoke Fleck’s theory to account for the diversity of scientific images is also discussed by Alexander Vögtli and Beat Ernst (see Vögtli and Ernst 2007, 107ff.). However, by joining Uwe Pörksen’s view, their proposal includes more than the steps of the cognitive process discussed so far. They also make use of Fleck’s concepts of vademecum and popular science. Pörksen points out that often a developmental history of visual representations in science can be detected, starting with *sketches* via *schemas* to *depictions* in handbooks and textbooks up to *canonical depictions* in popular science. Furthermore, he argues that we can regard these visual developments as analogous to the different kinds of verbal representations, which Fleck mentions (see Pörksen 1997, 105ff.).

Vögtli and Ernst elaborate on Pörksen’s text. According to them, *sketches* are of a purely hypothetical nature. These images function as thought experiments and are not meant to be published (see Vögtli and Ernst 2007, 108). Such images might, for example, entail question marks in case the author is still not sure whether certain parts are connected or not. In this sense, these images also express their producer's insecurities.

Schemas are more elaborated than sketches. The drawing is clearer and explanations or a caption are added to guide the observer. Nonetheless, they are more or less hypothetical in nature. What does 'hypothetical' mean in this context? The best way to grasp this aspect seems to be by considering the most common case, namely the use of diagrams. Normally they show measurement results, error bars included. These visualisations are meant to be distributed among peers for discussion. In this sense, they are part of the hypothesis presented in the paper which will be checked with regard to its plausibility by the community of peers reading and discussing the article. Thus, the term 'hypothetical image' means that this visual representation is as fallible as the verbal thesis in the text and, therefore, is also open for reinterpretation which is emphasised by certain graphical elements such as error bars, dashed lines, etc. In this sense, images belong to the circulation of thoughts within the esoteric circle and are parts of journal articles (see ibid.).

Beyond that, Vögtli and Ernst think that *depictions in a handbook* or textbook are normally modified copies of schemas (see ibid., 108f.).[xxxviii] Two aspects are relevant to these modifications. Firstly, depictions which appear in textbooks are prepared for education, i.e. didactic elements such as arrows, etc. are added (see ibid., 109). Secondly, the type of depiction may change. Vögtli and Ernst claim that whereas in journal articles diagrams seem to be the predominate kind of visual representations, in textbooks we will find more *naturalistic pictures* (see ibid.). The following depiction might illustrate this point (see fig. 2). It is part of a textbook of biology, admittedly meant to address the broader public, nonetheless the main features about visualisation that it reveals can also be found in textbooks for students (see e.g. illustrations in Markl 2011). What strikes the eye here is the naturalistic background

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in which the frogs at the bottom are placed. Adding such a background is not necessary but contributes a lot to a lively presentation.

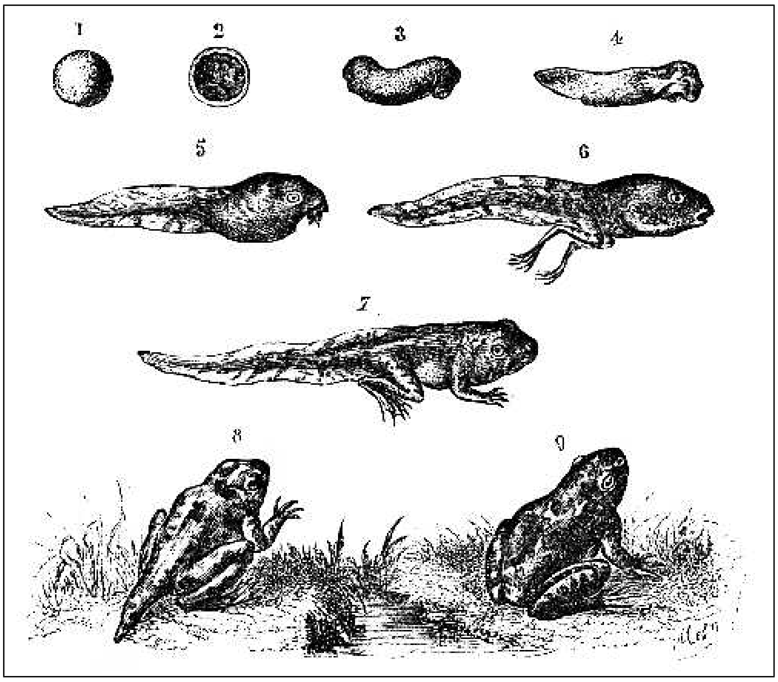

Fig. 2 Life cycle of a frog; source: Figuier, Louis and Gillmore, Parker (eds.): *Reptiles and birds: a popular account of their various orders, with a description of the habits and economy of the most interesting*. London: Cassell & Co., 1883, p. 21. Online edition available under: https://archive.org/details/reptilesbirds00figu.

Additionally, Vögtli and Ernst claim, that what is typical of depictions in textbooks is the elimination of pictorial aspects expressing insecurities such as dashed lines. Consequently, the schematic nature of the image is turned into a depiction that creates the impression of regarding a three-dimensional, solid body. The producer of the image thereby tacitly accepts that the presented idea appears as being corroborated. With regard to the above example this means that *the hypothesis concerning the life circle of frogs expressed in the depiction is true, the depicted entities exist and they really look like this in the wild.* [xxxix]

Canonical pictures used in popular science appear even more naturalistic than depictions in textbooks (see ibid., 110). Sometimes they even enter the field of entertainment, e.g. in advertisements or movies, and most of them are not taken seriously by the scientists (see ibid., 111).[xl] A convincing example in this context, that Vögtli and Ernst discuss, are depictions of (or animations and movies of) dinosaurs. We are all familiar with depictions such as the following (see fig. 3). Some of us might claim that they know how dinosaurs looked like – but actually we don't. All that is left of this ancient world are skeletons and maybe footprints, but, for example, claims about texture and colour of skin, are mere speculations today. This might also be a reason why many scientists are sceptical, if not worried, about science documentaries that mix science fiction elements with scientific results (see e.g. "Walking with Dinosaurs" produced by the BBC in 1999). Although a lot of speculation is involved in such movies, their producers present their contents as scientific facts and the images presented become canonical even though they are speculative in nature.

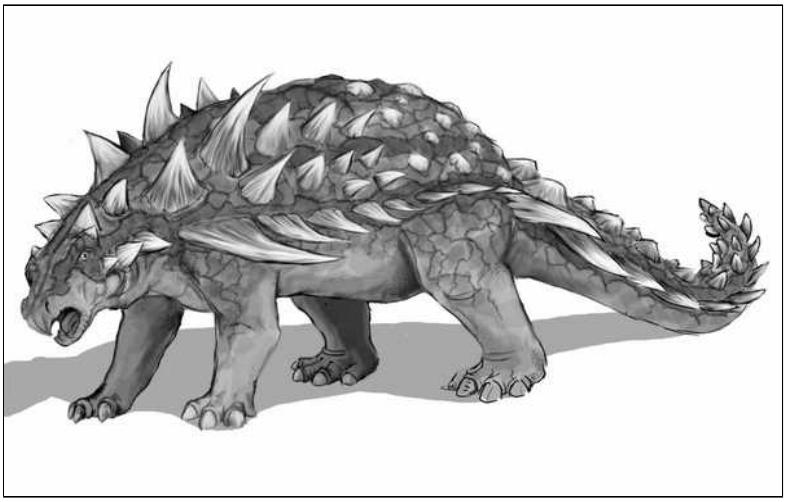

Fig. 3 Reconstruction of a Gastonia dinosaur; source: http://commons.wikimedia.org/wiki/File:Gastonia_burgei_dinosaur.png.

Obviously, Vögtli and Ernst take this developmental process of visualisations to be *unidirectional*, from sketches to canonical depictions. They do not consider the feedback loops between the esoteric and the exoteric circle triggered by these popular depictions. We should, however, add this important aspect in Fleck's sense here, as he conclusively points out the crucial influence of these popular visual representations on the expert's work.

(2) Let us now turn to the second way of using Fleck's account of scientific communication for a better understanding of the diversity of visual representations in science. Here developing the underlying scientific idea and working out its visual representation are (more or less) distinct processes – i.e. we cannot regard them as an intertwined continuous development such as in the first case. In this sense, this approach diverges from Fleck's account as he thinks that the development of an idea and its representation *always* goes hand in hand. However, this assumption seems to be exaggerated as the following analysis is supposed to show.

In this second context visual representations are chosen, because they are thought of being the *best presentation mode for a particular target audience*. Especially, considerations about the assumed level of background knowledge on the part of the audience will determine what kind of visual representation seems to be appropriate. The idea to be presented, however, will stay the same – though in some instances feedback loops between the different levels of scientific communication might provoke changes in the original idea. Moreover, considerations about the intended audience may also imply assigning a certain function to the chosen visual representation. Addressing laymen may fall into line with the intention to use visualisations to persuade the audience, or attract their attention, or to trigger an emotional response. In the context of discussions with academic peers, visualisations might be used to offer an overview about a topic, i.e. to be a heuristic means, to inform about certain results, and maybe also to attract attention, etc.

As an example consider the announcement of the discovery of *the most remote galaxy* (called “UDFy-38135539”) in October 2010. The details of this case study will show how scientific images are chosen to support two different communicative aims, namely *popularisation* and *information*, as Fleck labelled them.

The mentioned discovery was made public in two different ways: on the Internet in *Spiegel online* (http://www.spiegel.de/wissenschaft/weltall/geschichte-des-universums-astronomen-erspaehen-methusalem-galaxie-a-724247.html) for the interested public and in the journal *Nature* (see Lehnert et al. 2010) addressing the scientific community. Here we can keep track of how visualisations vary when different readerships are addressed. Whereas the *Nature* article was supplemented by four diagrams referring, for example, to the spectrographic analysis of the galaxy’s near-infrared emissions, three completely different images were attached to the article for laymen. This is what they showed: The first was a result of a computer simulation which was said to depict the universe at the time when the galaxy’s light started its travel. The second one was a collage of two photographs of the galaxy taken by the *Hubble Space Telescope* showing the position of the galaxy in the *Ultra Deep Field*. And the third one was a photograph of the *Very Large Telescope* in Chile which was the source of the above-mentioned spectrographic analysis. Apparently, these three images were meant to give the reader an impression of the facts explained in the text, i.e. where to look for the galaxy in the night sky, how to imagine the early universe and what the instrument used for the discovery looked like.

Why did the journalists not just reuse the diagrams that were published in *Nature*? Without doubt, the writer of the *Spiegel* article believed that they would not be appropriate in this context. Such diagrams are not easily comprehensible, they have to be interpreted and one may reasonably assume that laymen do not have the relevant training to do so correctly. In this sense, the author chose representations which he thought would be in accordance with the assumed level of background knowledge of the average *Spiegel* reader – and this is just what Fleck says in his statement about the act of *popularisation* cited above. Moreover, the addressed audience seemingly lacks the competence to critically check the presented results. They simply accept what the specialist tells or shows and this is precisely what Fleck claims they would do (see Fleck 1936, 86).

Besides this, the example also illustrates what happens in the case of *information*, that is, in the case of communication between scientific peers. The authors of the *Nature* article provided four diagrams showing the results of their analysis. Obviously, this is an instance of Vögtli and Ernst's claim that scientific images may serve as visual proofs (see Vögtli and Ernst 2007, 72) – though it would be better to talk about visual *evidence* here. Visual representations make research results accessible. They often present the most important information of the article. This thesis – also held by Perini (see Perini 2010, 134, 140) – is, for example, supported by the fact that some of the world's major research centres in particle physics have implemented a new database called "INSPIRE" that extracts figures from the corresponding articles and makes them independently available and searchable via their captions (http://www.projecthepinspire.net/).

To make visual representations part of the article means offering the audience the opportunity to see for themselves, to repeat and check the experiment and the correlated data. Therefore, sufficient background knowledge on the part of the readership is presupposed by the article's authors. As Fleck claims, "[o]ne can talk about an informing statement only for the case when its recipient has specific confidence in the cognitive abilities of the sender (cognitive confidence) and simultaneously the full possibility of checking the contents" (Fleck 1936, 86). Thus, the above example shows how considerations about the intended audience influence the presentation of scientific results in different media. However, the underlying scientific fact, namely the discovery of the mentioned galaxy is not affected by the different modes of presentation. In this sense, we can point out that in some instances Fleck's thesis about scientific communicative practices is too strong. He believes that each communicative act also changes the idea (see Fleck 1979, 109f.), whereas the above example shows that this is not the case. Obviously, at least in some instances, scientists are able to *keep the content constant while changing its form of presentation*.

Let us take a look at an example of *propaganda* now. Otto Neurath's attempts to communicate statistical data of common concern to uneducated people can be regarded as an instance of propaganda via visualisations (see Neurath 1991). The key to his account is "ISOTYPE" (International System of TYpographic Picture Education). "ISOTYPE" was introduced as a means to communicate difficult statistical data about economic or social concerns to the members of the working class in an easily understandable way. The audience was not supposed to comprise educated readers or informed laymen (see e.g. Neurath 1927, 1929, 1931). Accordingly, the visual display of the data had to be rather simple. Symbols had to be used which could be recognised easily in different contexts (see Neurath 2010, ch. 5, and examples on the following website: http://gerdarntz.org/isotype). Neurath was aware of the fact that this way of data communication also meant to omit certain details, i.e. simplification and apodictic valuation play a role. This is exactly what Fleck claims for the case of propaganda. Nonetheless, Neurath was of the opinion that it would be better for his audience to have a rough idea about what was going on in their environment than to have no knowledge at all (see Neurath 1931, 185).

Thus the above examples make plain another feature of scientific communication that Fleck does not take into account. Not all ideas are visualised and transferred by the scientist herself. There are public relations officers working for universities or research centres who are engaged in transmitting results in accordance with the intended audience. Moreover, there are science journalists like the ones mentioned in the *Spiegel* example. Graphic designers might be involved, such as in the example of "ISOTYPE", and many more people might play a role. The teamwork of those people once more emphasises the social nature of science, as it is crucially involved in knowledge distributing processes.

Additionally, as the second alternative also seems to be the more common one, the noticed social influence becomes even more relevant to our correct understanding of science. Ignoring its influence would block explanations concerning cognitive processes in this context. It seems, for example, reasonable to assume that at least in some instances, discussions between scientists and designers also help to shape the presented idea. By explaining what the essentials are which shall be transmitted, the scientist might become aware of some aspects that are still underdetermined and have to be further elaborated. In this sense, there will be a feedback loop, too, providing for further developments of the correlated idea. This feedback loop, however, is inter-collective in nature and, thus, illustrates Fleck's thesis of an exchange between different thought collectives and the correlated modification of the transmitted idea.

Moreover, this kind of teamwork can occur, at least partly, within the scientist herself. There are lots of design manuals and guidebooks (see e.g. Carter 2013, Frankel and DePace 2012, Tufte 2011) attempting to improve presentations prepared by scientists. Taking these advices seriously also relocates the above-mentioned discussion between scientist and designer within the former's mind while she becomes an exoteric member of the thought collective of design.

Furthermore, these guidelines highlight the fact that what can be presented and how is not only dependent on the audience's background knowledge but also on the *mode of the presentation*. This becomes clear when considering e.g. Matt Carter's advice, tackling the difference between figures and tables: "Tables display data (numbers or words) organized in rows and columns. Unlike figures, tables usually show data in their unprocessed, rudimentary

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form. The key to designing a great table is to arrange information clearly and logically so that data are easily accessible and comprehensible to an audience" (Carter 2013, 85).

Additionally, the *context of presentation* can be of relevance. A simple example concerns the choice of colours. If the target medium will not be printed in colour, it can be crucial to change the image respectively. Different coloured parts can e.g. be marked in greyscales which will normally highlight the relevant contrast better than merely printing the original colour graphic in black and white.

All of these aspects – considerations about the target audience, further teamwork, mode and context of presentation – may influence the appearance, but also the functional role of visual representations involved in the act of communication. Contrary to the first case, however, a change in appearance does not necessarily imply a correlated change of the underlying thought, although certain feedback loops can trigger further developments here, too. Yet both alternatives that make use of Fleck's theory offer the possibility to explain the diversity of scientific images as a result of social mechanisms, namely of communicative acts.

5 Résumé

The purpose of this paper was to suggest an alternative response to the initial challenge posed by Stephen M. Downes. He points out that there is a diversity of scientific images – both with regard to their appearances and to their epistemic functions – which calls into question any project aiming at a unifying, representation-based account of visualisations in science.

My proposal to solve this puzzle was to use Ludwik Fleck's theory of scientific communication processes to account for this diversity. Especially, his considerations about the influence of both the different *modes* and *aims* of communication on the content transmitted proved to be fruitful in this context. Regarding visual representations as proper parts of communicative acts allows an explanation of their alterations analogous to the one put forward by Fleck with respect to the adjustment of linguistic expressions.

Two different alternatives of applying Fleck's theory to the domain of scientific images were suggested. The first possibility showed that the developmental process of ideas and their visual representations can be deeply intertwined. In this case, the respective level of the cognitive process appeared to be decisive for the function and appearance of its visual companion. However, the more common possibility seems to be the second one. Here the developments of the idea and of its visual representation are distinct processes, although feedback loops might link them at certain stages. In this context, we saw that the main source of the visual diversity was the attempt to adapt the idea to an assumed level of the audience's background knowledge, to the mode, and to the context of presentation. Furthermore, the discussion of the presented examples made plain that, at least in such instances, Fleck's claim that any case of communication implies also a change in meaning is too strong. Nonetheless, both alternatives once more revealed the relevance of the social setting of science.

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INSPIRE: http://www.projecthepinspire.net/, accessed 30/01/2014

[i] In the following text, I will use the terms 'visualisation', 'visual representation' and 'image' interchangeably.

[ii] A detailed discussion of these theoretical approaches is offered by Scholz 2009, ch. 2 and 3.

[iii] Perini (2010) makes a suggestion in this way by highlighting the explanatory capacities of a semiotic conception of visual representations to solve the diversity problem (see ibid., 139ff.).

[iv] An introductory overview concerning Fleck's theory correlated with important facts about his life is presented by Leszczyńska 2009.

[v] Helpful introductions to his work are offered by Schäfer and Schnelle 1980, and Sady 2012. Further additional information – letters, testimonies, etc. concerning Fleck's life, his discussions with scientific peers and critics, and newly translated articles – is presented in Werner and Zittel 2011.

[vi] Concise summaries with regard to Fleck's conception of thought collectives are offered by Sady 2012, ch. 3 and Zittel 2012, 62ff.

[vii] The *set of beliefs* which these people might share belongs to what Fleck calls "thought style".

[viii] Philosophical analyses of this concept are presented by Mößner 2011, Sady 2012. Beyond that, Zittel (2012) also offers an historical and genealogical approach of Fleck's concept of style.

[ix] Claus Zittel (2012) and Wojciech Sady (2012) also discuss the notion of mood in Fleck's theory.

[x] A more detailed analysis is presented in Mößner 2011.

[xi] Michael Hagner (2012) explains the relevance of *gestalt psychology* to Fleck's theory of perception and its similarities to Michael Polanyi's theses in this context. The link between Fleck's theory of perception and gestalt psychology is also discussed in a special issue of "NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin" vol. 22 (1/2) 2014. Moreover, Ilana Löwy (2008) discusses the possible origin of Fleck's conception of scientific observation in the Polish scientific community of his time.

[xii] In this sense, Wojciech Sady states that "[a]n expert sees differently than a layperson because she went through a special training during which she was familiarized with many examples [...]" (Sady 2012, ch. 5).

[xiii] Of course, one has to be careful here with the strong thesis that "Fleck adopted Kant's thesis" as there are no supporting references mentioned in Fleck's work.

[xiv] In accordance with this, Katarzyna Leszczyńska (2009) points out that one of Fleck's important insights was that the cognitive processes in science leading to a true proposition do not differ that much from processes leading to scientific errors (see ibid., 31f.).

[xv] Fleck does not explicitly mention the involved parties here. First and foremost, he connects this communicative aim with the individual's detachment from the communicated thought (see Fleck 1936, 86). However, his examples of this process (see e.g. Fleck 1979, 120f.) suggest that it is a discussion between experts.

[xvi] As with regard to other instances too (e.g. the boundaries between esoteric and exoteric circle), there is a problem of demarcation here. Unfortunately, Fleck does not explain why and how this difference between *information* and *legitimisation* appears. His suggestion of a separate discussion seems to be plausible, though further investigations on the topic are necessary – but beyond the scope of the current analysis.

[xvii] Zittel thinks that scientific training and other kinds of initiating a pupil into a given thought style also belong to the realm of propaganda (see Zittel 2012, 64). Fleck remains silent about this topic. It can be contested, however, that he would agree with Zittel's claim. A hint to support my critique here can be seen in the fact that Fleck conceives of textbooks which are necessary for educational purposes as belonging to the esoteric circle of a certain thought collective. This categorising excludes them, however, as proper media of propaganda which, according to Fleck, cannot appear within this realm of science. The point is that propagating an idea means that the recipient's cognitive

shortcomings with respect to the prevalent thought style are taken for granted by the communicating party. Therefore, the aim of this communicative act is not understanding in the same sense as it will be required of students when introduced to their teacher's research domain. Laymen are not expected to be able to repeat an experiment or to notice what is of importance to members of a certain collective during scientific observations – contrary to students. Laymen who are the audience of propaganda will remain what they are – laymen.

[xviii] Admittedly, it can be asked whether a genuine case of propaganda can ever take place. Fleck himself takes it for granted that there are overlaps between the different purposes of communication and that seldom, if ever, the mentioned purposes appear in their pure form (see Fleck 1936, 88). However, there seems to lurk a greater difficulty here. Fleck also points out that communication – as performed during an act of propaganda – always leads to the construction of a new thought collective including the communicating parties. Consequently, they will form a *new common collective* during their exchange, whereas the concept of propaganda seems to presuppose that they belong to *different* communities. I owe this point to Ludger Jansen.

[xix] In this context, Fleck also introduces the term *incommensurability* (see Fleck 1979, 62). This difficulty of translation and understanding arises when the members of the two communicating collectives are too far away from each other. The distance between both can be meant in a temporal or (and) a spatial sense, thus "[...] a lack of understanding manifests itself not only where a physicist and a metaphysician or astrologer meet [this would be the spatial distance, as these thought styles belong to totally different topics, NM], but also when today's scientists read the works of their ancestors from the distant past [this is the temporal distance, as the people involved belong to different stages of one developing thought style, NM]" (Sady 2012, ch. 8). Fleck's theses about diachronic and synchronic problems of understanding are discussed in greater detail in Mößner 2011.

[xx] Instead of *vademecum* I will mainly use the more common term *handbook* in this article.

[xxi] A detailed analysis of Fleck's conception in comparison to Thomas S. Kuhn's ideas about the relevance of textbooks in science is offered by Brorson and Andersen 2001.

[xxii] A serious critique with regard to the collective authorship, defended by Fleck, is put forward by Henk van den Belt (2011). In a detailed examination of one of Fleck's empirical case studies, namely the development of the Wassermann reaction, van den Belt argues for an interactionistic interpretation of the process. Contrary to Fleck who emphasises that in the end no individual inventor of the new serological method can be discerned and, thus, the thought collective has to be given the credit for its invention, van den Belt points out that in some instances Fleck wrongly neglected the crucial role of the individual researcher. In this sense, he states that *the interaction between different scientists* has to be taken into account here as an explanation for certain developmental stages. Otherwise these instances will remain unexplained in Fleck's theory that merely emphasises the role of the collective. In this sense, van den Belt also highlights the relevance of the social setting of science but, nonetheless, keeps a crucial part for the individual to play here.

[xxiii] An interesting overview of attempts focusing on images and pictures in different meta-disciplines of science (history, sociology, philosophy) and Fleck's place therein is offered by Dommann 2004.

[xxiv] As completeness is beyond the scope of this article, I only want to present some crucial aspects here.

[xxv] Coming to know about these differences is the crucial virtue of Fleck's *comparative epistemology* (see Fleck 1936, 98; Fleck 1979, 38). In this context Ilana Löwy (2008) states: "Fleck's epistemology [...] may also be seen as an attempt to radically question the ways we perceive and interpret external reality" (ibid., 382).

[xxvi] A sophisticated investigation of photography in science is offered by Wilder 2009.

[xxvii] The concept of objectivity is a somewhat delicate matter in Fleck's work as he is of the opinion that a judgement of objectivity can only be made correctly within a particular thought style but not externally. He thinks the same about the

concept of truth (see Fleck 1979, 100). Consequently, Fleck is often regarded as defending a kind of relativism. Especially many art historians who investigate the development of scientific visualisations interpret Fleck in such a relativistic way (see e.g. Zimmermann 2009; Bredekamp et al. 2008). This is not the place to discuss this difficulty in detail (Fleck denies being a relativist, see Fleck 1979, 100). Let me just mention Markus Seidel's article who tackles this problem thoughtfully by interpreting Fleck's theory as a *relational stance* comparable to Karl Mannheim's line of reasoning (see Seidel 2011).

[xxviii] Lorraine Daston and Peter Galison (1992) claim that scientific illustrations were meant to represent different phenomena at different times, though in each instance these images were regarded as objective depictions by contemporary scientists. Daston and Galison point out that *objectivity* itself is not a fixed concept, but simply one under construction, including and stressing different aspects at different times.

[xxix] That Fleck's thesis is too strong seems to be suggested by the discussion of his own example. If the photographer has a choice to depict a certain entity differently this also means that she has different ways of access to this entity at her disposal – not just the ones suggested by the predominant thought style. She is not blind to alternative ways of seeing the object. I owe this point to an anonymous reviewer.

[xxx] More recently Zittel (2014) and other authors of "NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin" vol. 22 (1/2) 2014, analyzed this aspect in more detail.

[xxxi] Admittedly, overlaps between both methods might occur rather frequently.

[xxxii] Admittedly, the explanatory benefit of Fleck's theory might be greater with respect to the former case than to the latter, as the second instance seems to be closer to common-sense expectations. Nonetheless, in the philosophical discussion Fleck's account is of importance here, too, as it helps to point out the relevance of social mechanisms in shaping the results of scientific cognitive processes.

[xxxiii] I want to thank the journal's editors for making me aware of this difficulty.

[xxxiv] This is the core idea of speech act theory, namely that we can perform different illocutionary acts with a particular linguistic expression.

[xxxv] Thus, the mentioned hypothesis is hard to prove as it might only be accessible via the scientist's corresponding testimony that may or may not be reliable. I owe this point to Helmut Pulte.

[xxxvi] Tufte is no historian, but taught courses in statistical evidence, analytical design, and interface design.

[xxxvii] This is only an abbreviated version of the story. Tufte discusses in greater detail which elements in Snow's line of reasoning are of particular importance to make his argument sound.

[xxxviii] Obviously, they do not make the difference between *handbook* and *textbook* here, as Fleck suggests. Depending on the scientific discipline this seems to be correct as in some instances handbooks are used for educational purposes and no particular textbooks are produced in those contexts.

[xxxix] Vögtli and Ernst do not argue for this point separately. As scientific practitioners they solely appeal to their peers' experiences with respect to scientific education and training. They emphasise that in such contexts the presentation of facts is preferred to showing the trials and errors of research itself (see Vögtli and Ernst 2007, 109f.).

[xl] It has to be added that from Pörksen's point of view some visual representations may also skip one or two steps in this developmental schema. As an example he discusses the development of genetics in biology and its accompanying visualisations. For instance, the schema of the double helix, firstly published in a journal article, directly made its way into textbooks and popular science without being significantly modified (see Pörksen 1997, 123f.).