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The role of visualization in the construction of biotechnological knowledge

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ABSTRACT. Biotechnological knowledge, as their rise and development clearly show, are characterized by the essential role that their structural ways of forming and imagining spaces and spatial relationships do play in defining the physical and chemical properties of macromolecules of living systems. This work is based on the hypothesis that visualization in biotechnological fields is not only a "way of being" but also a "way of knowing" with peculiar characteristics related to the structural and relational nature of biological objects.

1. Aim and methodology

The aim of this research was to deepen the understanding of the main features of the construction processes concerning biotechnological knowledge in a private funded scientific laboratory, as well the understanding of the multifarious role played by visualization. Specific goal was to analyze the collected mate-

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rial stemming from the narratives of researchers' everyday work, thus triggering a series of epistemological reflections.

For this purpose, an ethnographic research was made in a drug discovery company, a company that makes research and development on new active ingredients to treat diseases related to the central nervous system, particularly in its Therapeutic and Discovery divisions. First of all, a literature review was carried out of a study of existing literature on these topics. The fieldwork research phase was conducted during three months, in the period fall-winter 2006-07. Some tools of ethnographic research used to collect the corpus of data were: the narrative interview (Bruner, 1990; Bocchi, Ceruti, 1993), non-participant observation of laboratories and semi-structured observation of meetings group. Both textual and visual data (Keats, 2008) were collected: images, pictures, photos, papers, articles and power point presentations, emails, notes, texts mentioned by the interviewed researchers. Reflections written in a diary of fieldwork, in which dialogues and meaningful experiences collected in these months of deep immersion in everyday life of a laboratory were recorded, were added to the materials collected too.

People involved in my study were heads of laboratories of the company, the vice-president of the section of research and development, and some researchers who have volunteered. The final corpus was composed of: 24 hours of interviews, 390 photographs, 75 articles and power point presentations. The materials were finally analysed using the classical content analysis (Bauer, Gaskell, 2000), that allowed us to link the theoretical paradigm used as out reference, the constructivist one adopted in epistemological analysis of complex systems (Bocchi, Ceruti, 1985) with a preliminary analysis of data. Furthermore, we used the techniques for qualitative analysis led by software (Kelle, 2000) to proceed to the construction of the coding sheet, which allowed the content analysis of the whole corpus. The program chosen for content analysis was Atlas-TI, which permits to treat a heterogeneous corpus of data: both textual and visual ones.

2. Cognitive acts

The constructivist view of complex systems and behaviours (Bocchi, Ceruti, 1985) intends to frame the problem of knowledge in an epistemological vision characterized by simultaneous attention both to the constitutive conditions concerning the validity of knowledge, and to the access conditions, concerning the diachronic, historical and contextual characteristics consenting the emergence of knowledge from the interaction between an observing subject and an observed object (Ceruti, 1989). Access knowledge points to the actual conditions through which the subject acquires various forms of knowledge in a temporal processes. Biotechnological knowledge has been observed as an ongoing process, not a static thing, just according this enlarged epistemological perspective, and our analysis was instrumental in revealing cognitive processes operated by the researchers during their everyday work aiming at nucleating and developing this or that item of biotechnological knowledge. They enlarge the ways through scientific knowledge can be produced, that are no more limited to a too narrow picture of the classic deductive-hypothetical method. The focus of our research cannot but shifting from studying the "method" to studying the "thinking" that underlies the meaning and the uses of scientific method.

Regularities called "cognitive acts" has been identified (Varela, 2000) from a comparisation of the literature of cognitive sciences (Varela, 1989, 1992; Piaget, 1967, 1983, 1993; von Foerster, 1981; Deacon,1997; Montuori, 1998). The term of cognitve acts refers to a process, or to a mental operation (Piaget, 1993), that allows the researchers to organize, to edit and interconnect the perceived stimuli, when they relate to the object. A researcher exploring the investigated object allows in this way the emergence of a new coherence, of a new meaning that can be related to the new scientific data. We could use Piagetian terms too, speaking about the ability to perform mental operations on the object (Piaget, 1993). The term "act" is to emphasize the fact that these operations consent the researcher to "make something" contributing to the global construction of a mature scientific knowledge. Cognitive processes that we intend to define as “cognitive acts” are: the perception of a phenomenon; the production of new ideas; the sensory manipulation of an object; the act of making an experience; the interpretation of data; the sharing of them. The relevance of these cognitive acts has been estimated by the frequency of quotations. The first one is the interpretation process with 639 quotations; the second one is the sensory manipulation of the object with 507 quotations. Then we find the sharing with 139 quotations, the act of making an experience with 116 quotations, the perception of a phenomenon with 110 quotations, and the production of new ideas, with 26 quotations.

Each of these cognitive acts can be found several times in a same process of knowledge construction, their presence is neither linear nor smooth and can take place in every phase characterizing the discovery: the identification of a molecular structure; the construction of an active substance, a drug, in the laboratory; the later validation of the active substance itself.

3. Visualization as an epistemological tool

Visualization has always been a key tool in biotechnological research and the multiplicity of roles that it covers was clearly apparent from the very first interviews we conducted. Researchers consider it mainly in terms of a tool allowing the representation of data (373 quotations), but it plays often also the role of a new evidence from which to consolidate new knowledge (239 quotations). It plays a key role also in the manipulation of data (184 quotations), allowing the discovery of further aspects of knowledge at first glance often unrecognizable. Visualization plays also a selective role (45 quotations), allowing a researcher to select the most relevant observations for the development of a new knowledge and finally it helps the processes of communication between researchers (28 quotations).

Images are indeed used as a scientific data in every laboratory we visited. They are considered, in other words, as a "reliable and objective" base to which deductions, inferences and reflections can be anchored. There are different reasons underlying this idea, but the main one is to make data detectable, such as the cultivation of steam cells that must be properly prepared to be analyzed using specific software. Furthermore, images allow researchers to refer to morphological and contextual aspects that characterize the object of analysis as data too. Morphological aspects, for instance, permit to understand immediately which phase of life a cell is passing through. Visual data permits also to represent molecules in a two-dimensional and three-dimensional way, thus obtaining important information on their structural conformations and their spatial orientations. These data are essential because it is according the three-dimensional shape of a molecule that the specific properties of a molecule are defined and can change over time. All these aspects do render visualization a very promising tool for improving knowledge: researchers becomes able to observe from different points of view the data on which to base their analysis, their evaluations and their inferences: in other word, the very dynamics that underlies the validation of knowledge. The results of our research can highlight how visualization contributes in particular to the processes of perception, manipulation and interpretation.

Visualization is also a tool that allows researchers to create different representations of the same data. The concept of representation is used here as a “thick” concept: there is no representation without a prior interpretation by "an interpreting subject" who represents a series of data, rearranging them according to his own interpretative framework. It’s only through such interpretative frameworks the researcher can select the most reliable version of the data, in order to construct a knowledge that can be defined as scientific in due time. From the analysis of materials we collected is clear how the visualization of data, allowed by the researchers' interpretative processes, carries out various functions that can be categorized as evaluation, targeting and manipulation functions. The first one permits a more accurate assessment of the analyzed data. It uses interpretative mechanisms such as the "translation" or the "deduction" to verify the importance of those data within a particular research project. The second function allows researchers to select and then "reduce" the complexity of data at their disposal, which are often too many to show at first glance the most promising perspective for a process of consolidation and implementation. On the other hand, the third function permits a proper handling, whether real or virtual, of the data.

Visual representation is thus a key factor in the construction process of all the representations that, handled and analyzed, provide researchers a core of experiences needed for the corroboration of scientific knowledge. Just as these include this broad series of functions, visualizations allow to represent data from different points of view, creating a "redundancy of evidences" aiming at defining the new knowledge as scientific. Again, the visualization proves to be a tool that acts on the epistemological level of knowledge construction even leading the researchers to create new criteria for classification of data (Rando et Al, 2010). The results of our research highlight how “visualization as an instrument of representation” contributes to the various processes of interpretation, manipulation and perception of scientific knowledge.

Another feature of visualization we deem very relevant is that it can be used as a handling tool to manipulate data. The capacity of viewing is one of the main ways that allows the perception of the data’s characteristics and their analysis and then permits to "explore" and know them better. The exploratory possibilities of researchers are expanded by the sense of sight. In this context the role of treatment emerges in all its importance. It allows the "change of status" of data, for example, from a numerical form (figures, tables) to a graphical one (trends, charts), or from a visual representation (2D images, 3D structures) to a visual selection of numerical data that occurs through the use of color (color code techniques). The results of our research highlight how “visualization as a handling tool” contributes to the processes of consolidating scientific bases, thanks to multifarious validations guided by experience.

Visualizations, finally, allow a better and clearer communication. Researchers frequently use them as essential means to share observations, ways of thinking and real knowledge. It is considered an ideal tool to synthesize concepts, and many researchers can thus be inclined to affirm that "the image contains more of the data per se." There are several uses of an image when it assumes a function for sharing communication, and these depend strongly on the context in which it is used: it can be used as a proper language in a disciplinary community, where researchers have a common backgrounds and common skills. The image of a chemical structure, for example, is much clearer then the formula in which the same structure can be specified. On the other hand, the image can lead, thanks its clarity and immediacy, in an interdisciplinary context, to an easier understanding of concepts often far from the specific background of a researcher. An image, finally, gives a significant help in an international context, where misunderstandings can often occur at the linguistic level. The results of our research highlight how "visualization as a communication tool" contributes also to the processes of interpretation and sharing of scientific knowledge.

4. Conclusions

Biotechnological knowledge is a distributed knowledge that emerges from the relationship between minds, material objects of research and technologies. Visualization has multiple functions and contributes to their construction in epistemological terms. It acts as a real 'externalized retina' (Lynch, 1985) allowing the construction of graphs and orientation spaces for researchers. It is a filter that allows the "discovery" of new data, permitting the observer to reorganize and recategorize knowledge.

Visualization permits, better than other tools such as words, numbers, etc., to focus on the data in such a high level of complexity as the biological one. While numbers help to better focus on simple or abstract information, images allow a more complete and integral view of the qualitative aspects of biological objects of research.

In the biotechnology space can also be observed a particular role played by the numbers and images in the development of knowledge. The "principle of truth" that regulates biotechnologists increasingly tends to include visual and qualitative criteria too. These criteria are characterized by: hybridity, that is the combination of different models of representation (visual, verbal, numerical, symbolic, etc.); multi-modality, that is the combination of information derived from different sources or that invoke different sensory modalities of knowing; plasticity, because the same data can be interpreted and handled for very specific and contextual explorations.

Finally, visualization and its interaction with technology allow researchers to implement an "abstract manipulation" of research data. This type of knowledge construction has the same characteristics of both the Piagetian sensorimotor and formal level (Piaget, 1993). The interaction between the researcher, or in other word the subject, and the object of research, allows, through visualization and visual technology, the development of a specific form of knowledge and a new meta-level of thought: the sensory-motor formal level.

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