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The Nature of Graphic Sciences and their (In)Discipline

Mitchell (1994) highlights how the current era is characterized by the 'pictorial turn', that is, a growing interest in visual culture. The pictorial turn and the digital turn — fostered by the development of ICTs and by social practices of ubiquitous, real-time interaction and communication — go hand in hand in a process of changing modes of intelligence, correlated with a shift in ways of knowing: we have witnessed a gradual transition from a learning model founded on a culture of books and writing — which favoured alphabetic vision and a type of intelligence characterized by sequence — to one that integrates listening and non-alphabetic vision, typical of a simultaneous mode of intelligence. Consequently, the cognitive paradigm has evolved: we have moved from a system based on linearity to one dominated by the simultaneity of stimuli and their parallel processing.
In this context, vision and drawing take on a central role. It emerges how representation can serve as common interpretive keys for different disciplines, each of which operates according to different theories, methodologies, and tools, and in relation to diverse cultural frameworks.
In this sense, the sciences concerned with visual representation explore drawing not merely as a technical-productive issue, but as an all-encompassing sphere of vision, thought, and action. It follows a reflection on the nature and role of those disciplines founded on the graphic sciences: they possess profound disciplinary characteristics, yet at the same time, they appear as a meeting ground for scholars from various sectors.

Keywords:
Graphical Sciences; Graphic Thinking; Graphical Intelligence; Interdisicplinarity

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THE GRAPHICAL SCIENCES

Over the years, what could generally be called an 'iconic' or 'visual' turn has developed in fields that take images as their object of study, thereby suggesting the possibility of outlining a set of sciences — which we might collectively call 'visual sciences' — that have images and their cultural context as their field of application. Thus, while Mitchell already outlined the birth of a science of images with his 'Iconology,' Bertoline (1998) prefigures the rise of a new discipline named 'Visual Science', even expressly citing Negroponte's 'Being Digital' (1995) in relation to the emergence of computer graphics, the resulting transformations in ways of thinking, behaving, and working, and the shift from a culture based on oral and written communication toward a visual one: "Converging technologies, such as computer graphics, information technology, and the web, are contributing to a renaissance in graphics. This renaissance in graphics is coupled with the emerging re-thinking of the role of visualization in basic human intelligence. Converging Technologies, a renaissance in graphics, and better understanding of the role of visualization in human cognition are the catalyst for an emerging discipline called visual science" (Bertoline, 1998, p.182).
Bertoline bases 'Visual Science' on three pillars: spatial cognition (spatial relationships, classification, sequencing, transformations and rotations, visualization—understood as the ability to construct, manipulate, and interpret images in the mind—and the relationship between the whole and the parts); imaging (production of static or dynamic images, graphic design, sketching); and geometry (plane, solid, and descriptive).
In general, we are in a context where the theme of the 'visual' — a deliberately general, all-encompassing expression of eminently cultural value and broad epistemological significance — has fully become part of the scientific and cultural debate and is perceived by scholars as a benchmark topic in disciplinary reflections. Among these is archaeology, whose practice has always found a necessary and natural reference in drawing, not only for the documentation of sites, remains, excavations, and findings, but also for their interpretation, reconstruction, and communication.
Opgenhaffen (2021), also citing Mitchell's 'pictorial turn,' traces a brief history of archaeology re-read through a visual lens and speaks explicitly of 'Archaeology as a Visual Discipline,' though specifying that by this expression he does not mean archaeological visualization as an integrated part of the general discipline of archaeology, nor as a new discipline or sub-discipline. In particular, he highlights how visualization in archaeology is a method of understanding rather than a simple mode of representing remains, while simultaneously being correlated to an interpretive act ('creative turn') that 'doubles' the destructive activities of excavation into creative practices. At the same time, the author also emphasizes how visualization practices, by concretely describing artifacts through the visual and relating reconstructions of the past to them, can foster a 'material turn' aimed at the concreteness of objects
In this context, Cardone (2016), recalling Bertoline, proposes the definition of 'Visual Sciences' (using the plural), a concept taken up and developed by Cicalò (2020a), who speaks of 'Graphic Sciences.' Unlike Bertoline, who prefers the adjective 'visual,' Cicalò leans toward the term 'graphic' to highlight the role played by image production in this field of study; indeed, Cicalò considers the expressions 'Visual Science' by Bertoline, 'Image Science' by Mitchell, and his own 'Graphic Sciences' as all equally valid and, on the whole, referable to the same field of investigation of "production, perception, visualization, reading and interpretation of images. Although they represent different approaches and disciplinary traditions, they are often used as synonymous. [...] terms so different in meaning are so interconnected and [...] it is impossible to investigate one of them

Fig. 1 - Drawing from vision.

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without consider the others. Visual Science, Image Science and Graphic Science, are often used as synonymous despite the fact that the words they are composed of have profoundly different meanings" (Cicalò, 2020, p. 4). As if a diaspora had dispersed these issues across numerous disciplines, causing the loss of an archaic, initial unity, Cicalò identifies two main lines of research today: one pedagogical, and another referable to cognitive psychology and the psychology of perception.

GRAPHIC THINKING

In 1966, Balchin and Coleman coined the term 'graphicacy' to mean the intellectual ability required for the communication and understanding of relationships that cannot be conveyed solely through verbal means or mathematical notations, but are instead conducted through visual representations, such as maps, photographs, tables, and graphs. In particular, the authors, whose speculations are specifically focused on the educational field, argue that graphic ability should be placed alongside reading/writing and mathematical notation as a complement to communication skills, dedicating space to its instruction from childhood within the framework of broader and more integrated educational goals.
The maieutic role of drawing, which is participatory and founded on a profound act of observation (looking through drawing), represents an idea and an approach to knowledge and communication that has always been an essential part of the architect's practice. For example, McKim (1972) speaks of 'externalized thinking' through drawing, which offers the following advantages: it provides direct sensory involvement that acts as sensory nourishment, or 'food for thought'; it fosters serendipity (the happy mistake, the unexpected discovery); it generates a sense of immediacy, topicality, and action; and it produces a result that can be the object of critical observation (p. 46).
Laseau (1980) distinguishes between 'Visual Thinking' — primarily explored by psychology — and 'Graphic Thinking,' describing the latter as a cyclical process that involves what can be considered the actors of the process itself—rather than mere phases—: the eye, the brain, the hand, and the drawing (pp. 8-11).
Ching (1990) clearly conveys the sense and character of representation in the relationship between vision, drawing, understanding, knowledge, and communication: "Drawing relies on a clear vision. It also requires thought whic, in turn, builds understanding. Drawing cannot be detached from seeing and thinking about fundamental nature of the subject matter being represented. The knowledge and understanding gained through drawing from life directly enhances our ability to draw from imagination. Just as thought can be put into words, ideas can be made visible in a drawing to promote visual thinking and further stimulate the imagination. Once what is seen or imagined is made visible in a drawing, the image takes on a life of its own and communicates graphically. However eloquently or crudently, all drawings speak to the eye" (p. 5).
According to these reflections, Nelms (1957) wrote: "If you have enough skill with a pencil to write your own name, you can make drawings [...]. They may be crude, and they certainly do not pretend to be artistic. Nevertheless, their value is provided by the fact that each of them served its purpose in a work of major importance. Practical drawings are mental tools. Once you have learned to make them, you will find that they are useful in solving problems as saws and hammers are useful in carpentry" (p. 1).
Pallasmaa (1996) criticizes the dominance of the sense of sight in contemporary culture to reaffirm a multisensory approach not based on intellectual and verbal knowledge, but on embodied processes of non-conceptual wisdom, where our body plays an essential role. Pallasmaa revisits and develops this concept in 'The Thinking Hand' (2009): "Western consumer culture continues to project a dualistic attitude toward the human body. On the one hand we have an obsessively aestheticised

Fig. 2 - Drawing as a way of observing.

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Fig. 3 - Drawing to reconstruct.

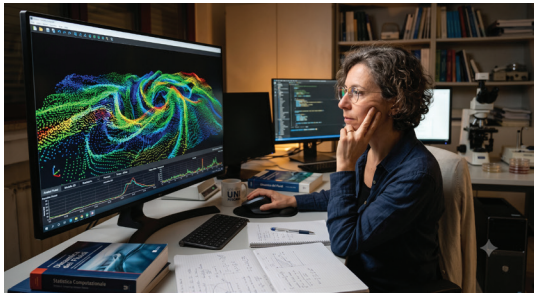

Fig. 4 - Visual computing: imaging a phenomenon.

and erotiticised cult of the body, but on the other, intelligence and creative capacity are equally celebrated as totally separate, or even exclusive individual qualities. [...] Educational practises usually provide some degree of physical training for the body, but they do not acknowledge our fundamentally embodied and holistic essence. [...] Traing of the hand is provided in courses that teach elementary skills in the handicrafts, but the integral role of the hand in the evolution and different manifestations of human intelligence is not acknowledged. [...] We are connected with the world through our senses. The senses are not merely passive receptors of stimuli, and the body is not only a point of viewing the world from a central perspective. Neither is the head the sole locus of cognitive thinking, as our senses and the entire bodily being directly structure, produce and store silent existential knowledge. The human body is a knowing entity. Our entire being in the world is a sensuous and embodied mode of being, and this very sense of being is the ground of existential knowledge" (p.11-13).
Tversky (2019) suggests that thought is not based so much on language, but rather that movement and space are the foundations of our thought mechanism. This concept, which relates hand and mind, can find concrete expression in drawing. Therefore, the gesture of drawing appears as an integral part of the ideational process. According to her thesis, spatial cognition constitutes the primary architecture of the mind, to which other functions, including language, refer. Since cerebral evolution favoured movement in space and physical interaction with objects long before the advent of language, the neuronal areas dedicated to spatial management are 'recycled' to process abstract thought.
In conclusion, the act of drawing corresponds to the brain's spatial mechanisms, providing a cognitive methodology to support thought, especially when referring to spatial systems that are not fully experienceable or describable through verbal language. This principle has general validity and can also be applied to the tracing of diagrams related to logical and operational flows.
Therefore, the body, the nervous system, and the muscles possess their own knowledge and capacities, independent of intellectual thought and language — a judgment and a 'know-how' that, in art, craftsmanship, and sport, are integral parts of the human dimension. Thus, the hands of the surgeon, the craftsman, and the draftsman act with precision, according to their own embodied wisdom and a synergistic, unconscious, and inseparable fusion of eye, hand, and mind. In this way, sketching and drawing correlate external physical reality with perception, thought, and imagination through the motor act of the hand and its muscle memory. This entails 'embodied thinking' and 'embodied memory' — a mode of thinking where the uncertainty of what will be produced constitutes value and represents the expression of existential knowledge. An embodied thought where learning and practice — and thus the capacity for knowledge — are rooted in the mechanisms of so-called mirror neurons and in the neurosciences (Gallese, Guerra, 2015).

GRAPHICAL INTELLIGENCE

Cicalò (2020b) formulates the concept of 'Graphic Intelligence,' drawing on Gardner's well-known theory of multiple intelligences (1983), which criticizes the evaluation of skills solely within linguistic and logical-mathematical domains. In this sense, intelligence is not understood as a single capacity, even though separate analysis is instrumental for analyzing a continuum [1].
Cicalò defines graphic intelligence as the ability to integrate the use of eye, mind, and hand to solve problems and create effective products aimed at the acquisition of new knowledge. This represents a paradigm shift: thinking of graphic skills as a form of intelligence involves shifting the focus from the product (the image) to the process that led to the production of the image.
This involves an integrated correlation between visual thinking and graphic thinking, where the thinking hand possesses the mind's gaze. It is believed that this process can be described in phases, distinguished only for instrumental and didactic purposes, as they are strongly interrelated in reality: in the case of drawing something placed in front of the observer, there is the observation of physical reality, the processing of the mental image, the drawing, the observation of the drawing and the comparison with the mental idea, the comparison between the mental idea and the object one wishes to draw, the drawing/redrawing/correction/addition of details, etc. It is an iterative cycle. In practice, these phases blur into one another with a synergistic and continuous integration

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between eye movement, vision (object to be represented/drawing), mental ideation, imagination, and the kinesthetic activity of the drawing hand. In the case of drawing a mental image (ideational or memory-based drawing), the object to be depicted and the drawing coincide; one referent is lost, but the process remains unchanged.
Certainly, the careful, trained, and conscious preliminary observation of what one wishes to represent remains a necessary condition; however, no less secondary is one's personal graphic vocabulary (for instance, how to draw eyes with different expressions), experience, and training — according to a sort of muscle memory of the hand — as well as our own culture. When we use drawing to think, understand, and know (whether it be an external physical reality or a line of reasoning), we do not know a priori what drawings the hand-shaman will produce on the page: rationally, these are partly uncontrolled images, which offer even unexpected figures. And these drawings assume, almost agalmatically, an existence of their own, with which we are called to confront ourselves and engage in dialogue. Therefore, in the magic circle of 'observer–hand–drawing,' the graphic product demands an inversion of the traditional causal relationship between the author (and their hand) and the work: in this heuristic path, the image begins to question the human, challenging their ideas, their knowledge, and their know-how.

Fig. 5 - Confronting the idea with the outcomes.

VISUAL COMPUTING

Moles (1966) proposes an 'Informational Theory of the Scheme' and explains how the relative quantity of information increases drastically when using descriptive forms with a lower level of iconicity compared to the original; thus, for what is intrinsically three-dimensional, representation with 3D models helps to improve not only visualization or information storage, but above all its definition, organization, representation, and understanding.
Visual Computing is an interdisciplinary field of computer science that deals with acquiring, processing, analyzing, synthesizing, and visualizing data in graphic or visual form.
Thus, in visual computing, the role of the model is not that of a mimesis of reality, but rather to allow for a simulation of reality: to enrich our experience by providing us with more experience than we could have without the mediation of visualization, in an empirical relationship with reality (Maldonado, 1992). Therefore, even if the model simplifies reality, it is precisely this abstraction that allows us to interpret the world and create new projects. Visual computing is an analysis technique based on the visual representation of data. It facilitates the study of large quantities of data and complex systems of heterogeneous data (textual, visual, audio, etc.). This data can derive from various types or phenomena, even non-visual ones. Visual computing consists of the representation of three-dimensional digital environments, where there is a complex interaction of a large number of agents simulating different types of data and information. Data images provide information, and through the manipulation of images, we can observe, interact with, calculate, and control data and information, and create new knowledge (Card et al., 1999).
In particular, regarding visualization, Ware (2000) writes "Until recently, the term visualization meant 'constructing a visual image in the mind' [...] But now it has come to mean something more like a graphical representation of data or concepts. Thus, from being an internal construct of the

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mind, visualization has become an external artifact supporting decision making" (p.1).
He emphasizes that visualization can foster understanding: it provides comprehension of large quantities of data and emergent properties; it flags obvious problems with collected data; it connects features of large-scale and small-scale data; and it fosters the development of interpretive hypotheses (p. 2). Regarding data visualization, Ware identifies four fundamental phases: "The collection and storage of data itself; the preprocessing designed to transform the data into something we can understand; the display hardware and the graphics algorithms that produce an image on the screen; the human perceptual and cognitive system" (p.3).
Drawing has always played an essential role in the study of phenomena, thanks to its characteristic of being an eminently heuristic tool: thanks to drawing, one represents the mental idea, and in performing this operation, the graphic representation makes explicit aspects that would otherwise be unassessable or unpredictable, which, once placed on paper, can be examined and reflected upon. Representation is an iterative process of hypothesis and validation—that is, of representation and comparison of the visualization with the perception of reality.

CONCLUSION

A drawing is a visual representation created by tracing graphic marks — dots, lines, textures — with reference to a visual language based on shared conventions, rules, and symbols. Therefore, drawing consists of creating visual artifacts, understood as products that communicate through images, without excluding integration with other media. Technical drawings, in particular, are accompanied by captions, legends, and numerical indications, specifically relating to dimensions, distances, and measurements.
Drawing plays various roles: primarily, it is a method and tool for developing ideas — that is, for thinking; secondarily, it is a vehicle for communicating what has been conceived (design drawing) or for describing the reality that surrounds us (survey drawing).
In this sense, the usual dichotomy between artistic drawing and technical drawing is defined by different purposes, modes of representation, and tools. The heuristic role of drawing is unique, as it is configured as a mode of reflection and communication. In particular, 'freehand' drawing participates in both spirits: aimed at the technical expression of a form or landscape, it can make use of the expressiveness of artistic tools and techniques to render the representation vivid and best convey the values and characteristics of what is being drawn.
Therefore, the characteristics of a drawing are influenced by the goals of the representation and, at the same time, by the values and characteristics of what one wishes to draw. Furthermore, one must distinguish between subjective drawings—that is, those created by the draftsman for themselves (even if they may also be appreciated by others)—and drawings traced for others.
But above all, the fundamental characteristic pertaining to the graphic sciences is finding theoretical-methodological application in fields that combines visual dimensions and representation. Very often, in the sciences, the issue of the relationship between disciplines is discussed; it is a concept variously declined in the different forms of interdisciplinarity, multidisciplinarity, transdisciplinarity, and co-disciplinarity. Without going into the merits of these aspects, the fact remains that the graphic sciences are constituted as an activity founded on scientific principles and specific methodologies, which in turn are drawn upon by other fields of research and knowledge.
Therefore, one might suggest the idea that drawing, by its nature, presents a common field of action among multiple disciplines: it can be a discipline itself but also a place where other disciplines operates in close contact and on the same subject, dialogue and engage, finding the opportunity to exchange and hybridize ideas, concepts, tools, and methodologies, which each discipline absorbs, changes and then adopts.

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NOTE

[1] Intelligence is intended as the ability to solve problems or create products that are valued within a cultural context. Gardner proposes seven forms of intelligence: linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, intrapersonal, and interpersonal. In particular, spatial intelligence refers to accurate mental visualization, to the mental transformation of images, and in a certain sense, it can be related to the aforementioned visual thinking; however, it is only partially referable to graphic expression and thought, even if Gardner's description is generically inclusive, speaking of a form of intelligence that allows one to perceive visual or spatial information, to process such information, and to mentally recreate visual images — crucial skills for architects, sculptors, and engineers, and useful for interpreting graphs and tables or creating conceptual maps. The expressions 'spatial' and 'visual' are implicitly used to include the concept of graphic production and graphic thinking, and therefore Gardner includes graphic abilities within spatial intelligence, leaving one to assume that he did not have personal experience in drawing.

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