Pierluigi Graziani, Ivana Matteucci and Sabrina Moretti

CRITICAL THINKING AND CREATIVE COMMUNICATION

WORDS, IMAGES AND NETWORKS

EXPERIENCES FROM THE URBINO POT 2023-2025
«UNIVERSITIES, SCHOOLS AND TERRITORIES
NETWORKING FOR CULTURAL HERITAGE»

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This volume documents the experience of the Urbino POT, carried out within the framework of the national network «Universities, Schools and Territories in Network for Cultural Heritage», with a specific focus on issues related to contemporary communication. The Urbino project was primarily implemented through a cycle of orientation seminars and laboratories delivered by University of Urbino faculty in upper secondary schools that addressed key topics such as critical thinking, artificial intelligence, the role of images in communication, digital well-being, and online expertise, employing an interactive and workshop-based approach in line with POT methodological guidelines. The volume mirrors the project's main areas of intervention and frames orientation as a continuum from interpretive competence to epistemic responsibility and civic agency. It aims to equip students and teachers with tools to critically interpret communication languages and consciously inhabit today's informational and relational environments.

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SECTION 3
COMMUNICATING AND LIVING: RELATIONSHIPS, WELL-BEING AND RESPONSIBILITY

INTRODUCTION

Pierluigi Graziani, Ivana Matteucci and Sabrina Moretti

POTs (Guidance and Tutoring Plans) in Italy

POTs (guidance and tutoring plans), promoted by the Italian Ministry of University and Research (MUR) and launched with the MUR Decree no. 1047/2017, are strategic national projects aimed at improving student guidance toward university and reducing school dropouts. They work in synergy with PLSs (scientific degree plans) to facilitate the school-to-university transition, support informed choices, and monitor students' careers. The main objectives of the POT are to improve guidance, promote gender balance, reduce dropouts, and support the discovery of knowledge for access to university courses. The activities of the POT, like workshops, self-assessment courses, internships, meetings with experts, and specialised tutoring, often integrated with digital platforms, are addressed to secondary school students (guidance) and first-year university students (tutoring). The POT assumes a methodology based on the active role of students and teachers (training), covering various areas, including natural sciences, and humanities.

The projects aimed at students in their final two years of secondary school propose targeted activities which, using innovative and interactive methods, help them develop an awareness of their vocations, aptitudes and career aspirations, resulting in more informed career choices. Self-assessment programmes, university experiences, and workshops for skill recognition and vocational development are some of the tools implemented for effective guidance. POTs are also projects with secondary school teachers. In this case, school and university teachers, through training sessions and meetings, aim to jointly design and implement specific classroom teaching activities to

increase students' knowledge and provide them with a study methodology and a multidisciplinary approach.

Guidance and tutoring plans (POTs) provide a second area of intervention regarding tutoring activities. Specific tutoring activities for students enrolled in the first or second year of a bachelor's or single-cycle master's degree programme are aimed specifically at those who have encountered initial learning difficulties. Initiatives are also aimed at tutors to provide them with the basic tools needed to identify difficulties and guide students towards the most appropriate forms of support. Monitoring activities are developed to identify the most effective tutoring methods.

The Urbino POT: Experiences, Data, and Guidance Practices

This volume arises from the activities of the guidance and tutoring plan (POT) developed on the Information, Media and Advertising course at the University of Urbino Carlo Bo, as part of the national network «Universities, Schools and Territories Networking for Cultural Heritage». The project is grounded in a shared understanding of cultural heritage—both tangible and intangible—as a driver of individual and collective growth and as a privileged medium for supporting students in their transition from upper secondary school to university. From this perspective, guidance is not simply about information delivery; it becomes a formative process that fosters inclusion, participation, and a more conscious relationship with learning and future professional paths.

Within this national framework, involving over thirty Italian universities and several humanities-oriented degree programmes, the Urbino POT developed a distinctive path focused on contemporary communication: words, images, digital networks, critical thinking, diversity, and digital well-being. The central premise is that students' educational choices—and their broader civic engagement—are increasingly shaped by the communicative environments in which they live: platforms, feeds, audiovisual narratives, algorithmic recommendations, and hybrid ecosystems of expertise and misinformation. Thus, supporting guidance also means supporting interpretive competence: learning to decode, evaluate, and responsibly navigate today's informational and relational spaces.

Activities: Seminars, Workshops, and Guidance Practices

The Urbino project was primarily implemented through a cycle of guidance seminars and workshops delivered by the University of Urbino faculty in upper

secondary schools. These seminars and workshops addressed key topics such as critical thinking, artificial intelligence, the role of images in communication, digital well-being, and online expertise, employing an interactive and workshop-based approach in line with POT methodological guidelines.

Student evaluation questionnaires paint a very positive picture. Participation was largely school-mediated, confirming that the seminars and workshops were effective institutional guidance tools capable of engaging even students with limited initial motivation. At the same time, the perceived quality of the experience was consistently high. Students reported strong appreciation and satisfaction across seminars; they evaluated the speakers' communicative style and interactivity extremely positively and recognised the future usefulness of the skills and perspectives acquired. From a guidance standpoint, the data suggest that these activities function less as immediate «decision-making» devices and more as practices of clarification and awareness-building, reducing uncertainty and strengthening students' sense of agency.

In addition to school-facing initiatives, the project also paid attention to tutoring and in-course guidance. Aggregated questionnaire data indicate that most incoming students do not require additional remedial support; tutoring services are used by a small minority, but those who engage with them rate them positively. Qualitative responses highlight difficulties that are mainly organisational and methodological—time management, workload, schedule sustainability, and adapting to university pace—confirming the first year as a crucial transition phase. These findings strengthen the case for proactive, low-threshold support measures that can intercept latent needs early on and accompany students beyond the pre-enrolment stage, when difficulties often become visible only after the semester begins.

Structure of the Volume and Integrated Chapter Preview

The book offers a systematic account of the Urbino POT experience by weaving together empirical evidence, educational practices, and theoretical reflection. Organised into three thematic sections—*Understanding and Decoding; Knowing and Believing;* and *Communicating and Living*—the volume mirrors the project's main areas of intervention and frames guidance as a continuum from interpretive competence to epistemic responsibility and civic agency.

The first section, *Understanding and Decoding: Words, Logic and Images*, opens by foregrounding the social dimension of education. **Sabrina Moretti** frames schools as relational ecosystems and introduces social capital as a set of resources embedded in networks—resources that can support academic performance, inclu-

sion, well-being, and a sense of belonging. Drawing on social network analysis as a methodological lens, the chapter suggests ways in which relational structures can be mapped and interpreted to better understand how classroom dynamics, peer ties, and broader school communities shape students' educational experience.

From this relational foundation, the section moves to the semiotic and educational challenge of visual communication. **Tiziana Migliore** addresses a recurring gap in students' education: learning to «read» images with the same rigour applied to texts. Building on experiences with secondary school students, the chapter highlights how visual semiotics and rhetoric can support the interpretation of figurative and formal elements, clarifying the cognitive, sensory and pragmatic effects of images across domains such as political communication, science, law, and advertising—especially in contexts where photography intersects with emerging AI practices.

The second section, *Knowing and Believing: Media, Expertise and Disinformation*, shifts from decoding to epistemic questions: how knowledge is produced, filtered, legitimised and contested in platformed environments. **Valeria Donato** reframes critical thinking for an age of algorithmic mediation, presenting algorithms not as neutral tools but as socio-political and cultural artefacts shaping visibility, subjectivation, and the circulation of information. Through a discussion of informational disorder and a focused case study on TikTok, the chapter argues for an infrastructural understanding of critical thinking—one attentive to the technological, economic, and cultural conditions that govern what becomes «knowable» and credible online.

Within this context, **Stefano Brilli** explores the transformation of expertise and credibility in digital platforms. Starting from the disintermediation of traditional authorities and the emergence of new cultural intermediaries, the chapter presents the workshop «Esperti Online», designed to help students reflect on visibility dynamics, trust crises, and platform logics. Combining a conceptual framework with a replicable educational pathway—culminating in debate-based activities—it invites learners to interrogate sources, publics, styles, platform strategies, and explicit or implicit monetisation models that shape contemporary credibility. The section then returns to the visual field in a decisively contemporary register.

Chiara Spaggiari examines images as information within today's media ecosystems, focusing on the critical competences required to address AI-generated imagery, deepfakes, and visual misinformation. Building on Gillian Rose's

analytical model (production, image, circulation and audience; and technological, compositional and social modalities), the chapter links meaning-making to epistemic questions about captions, context, and the contested status of photographic evidence, and proposes classroom activities aimed at fostering systemic, interpretive, multimodal, and reflexive visual literacy.

Elisabetta Zurovac closes this section by explicitly connecting these literacies to the field of digital ethics. Drawing on the Urbino POT experience, the chapter maps key issues—including platformisation and surveillance capitalism, onlife identities and algorithmic selves, and persistent digital divides—and argues that purely protectionist approaches or individual-responsibility narratives are insufficient. Instead, it frames algorithmic literacy as a democratic competence and proposes pedagogical strategies that position students as reflective agents capable of questioning, understanding and imagining transformations of the systems shaping their digital lives.

The third section, *Communicating and Living: Relationships, Well-being and Responsibility*, turns from evaluation and critique to sustainability, focusing on the educational, relational and civic conditions that enable responsible participation in contemporary societies—including the forms of literacy that sustain democratic life.

Monica Tombolato reframes scientific literacy as a safeguard for democracy through a PISA 2025–aligned perspective on curriculum design. The chapter argues that epistemological naivety often reduces science teaching to inert content, detached from its procedural and epistemic dimensions. It therefore proposes a combined process/spiral model—integrating content, and procedural and epistemic knowledge within core scientific practices and Bruner's spiral structure—and outlines differentiated procedural principles for primary and secondary teacher training to support vertical curricular alignment.

Ivana Matteucci addresses the challenge of defining and pursuing digital well-being in a context where the unintended consequences of digital disruption have become increasingly visible. The chapter conceptualises well-being as the capacity to retain the benefits of digital environments while reducing their problematic aspects—from techno-stress to addictive dynamics—paying particular attention to the «dark sides» of hypercommunication. It outlines strategies, competences, social literacy practices, and dedicated tools that can support a healthier relationship with digital technologies, thus bringing the volume to a close on an explicitly practical and responsible horizon.

Across its sections, the volume does not present a mere collection of individual essays. Rather, it offers a coherent space for shared reflection: documenting a concrete educational experience while proposing conceptual and pedagogical tools for rethinking university guidance in the context of contemporary communication.

CHAPTER 2

Analysing and Interpreting Images in Communication

Tiziana Migliore

In these pages, I will report the experience of meeting 50 students from the Liceo Mamiani in Pesaro and discussing with them the issue of the role of images in communication. On two Wednesdays, December the 6th and December the 13th 2023, I was welcomed by classes 5H and 5F of the linguistics course, and by class 3B of the human sciences course at Mamiani for three hours of teaching and two of workshops. These socialising activities, organised within the framework of the orientation and tutoring plan (POT), are useful for introducing secondary school students to didactic and research work done at universities. Lecturers go to upper secondary institutes and clarify the aims and methods of their disciplines, by developing themes of potential interest for the younger generations.

In my case, it was Sabrina Moretti, the POT coordinator in our Department of Communication Sciences, Humanities and International Studies (DISCUI), who suggested the topic of images to me. I would like to thank her for this advice because, until then, I had not realised how much schools lacked preparation in the semantic capital of images. Indeed Italian and foreign education systems do not include the study of visual «language». Artistic and art history disciplines, which are the most closely related subjects, teach techniques or provide a chronological explanation of periods, authors, trends and movements. The fact that images have always been and are *social signs* is neglected. As a *semiotician*, I examine visual representations taking into account the ways in which they create and convey *meaning*, as symptoms of their culture of production, of their status and genre. Since images in information diffusion are a topic of daily consumption, all through the encounter curiosity regarding them overcame the impulse to ask directly what people do in universities. A sort of

«parliament» of opinions arose in the classroom, which I hope students found as fertile for them as it was insightful for me.

Communication Sciences

I wanted to begin my lesson with an overview on the interpretation processes that would help contextualise my presence at Mamiani. In talking with these students, it was a priority for me to demonstrate how the courses offered at the University of Urbino are valuable not only for their professional future, but for their lives. Faced with today's authoritarian management of technology, which goes so far as to think it can replace democratic governments, and given the increasingly sophisticated ways in which digital creators distort and falsify the information, receiving messages can no longer be a superficial behaviour. No one is born an analyst, but now everyone needs to gain knowledge and improve their skills so as not to read naively what emerges from the media.

The degree in communication studies—I explained to the Mamiani students—is an invention of Umberto Eco. After being an official at RAI for seven years, this philosopher and famous novelist, who is the most celebrated intellectual of the second half of the 1900s, instituted semiotics in 1975 at the University of Bologna as a frontier discipline. Some in the class remember him for *The Name of the Rose*, but, as an intellectual and university professor, Eco believed that a «science» was necessary to defend the audiences from the traps of manipulation. Providing users with concepts, methods and tools for analysis is still a mission for semioticians, who also educate those who will produce communication toward the responsibility of form and the conscience of the word (Barthes 1966). According to Eco's project, other disciplines could train communication experts: sociology, anthropology, linguistics, psychology and history. The label of «sciences» in the faculty that Eco established is not intended to mimic the work of the so-called «hard sciences», known as exact or natural sciences (mathematics, biology, physics and chemistry), but to promise rigour, coherence and exhaustiveness in the formulation of theories and inquiries, in laboratory practices, and in discovery and legitimisation procedures.

Actually, if the first experiment in communication sciences was carried out in 1992 in Bologna (see Aa.Vv. 2024), other degrees related to this field of study followed throughout Italy. At Uniurb it has existed since 2005, while the tradition of semiotic research here dates back much further, to 1971, the year in which Pino Paioni, Paolo Fabbri and Rector Carlo Bo founded the second International Centre for Semiotic Studies in the world (after the Tartu-Moscow School) at the University of Urbino. In 2017, this important institution of the

city was named after Umberto Eco, who was a regular participant and organiser of activities at the Centre. I tried to instil pride in these young students from the Marche region, by explaining to them that a second wave of humanism was born in Urbino, after the first with Federico da Montefeltro in the 15th century, when the world's greatest intellectuals of the second half of the 20th century began to come here for the Centre's initiatives. Among many, Italo Calvino took part in the former semiotic seminars, focused on the subject of narrativity (1967-68). In three letters to Paolo Fabbri (Calvino, 1971) he explicitly declared that he was inspired by them to write *Il castello dei destini incrociati* (1969, *The Castle of Crossed Destinies*). The «castle» is Palazzo Ducale. Also a passage of *Le città invisibili* (*The Invisible Cities*) mentions Urbino: «A palace, that instead of rising within a city's walls contains within its own walls a city, can be nothing but Urbino» (Calvino, 1972, Eng. transl.: 124).

The degree programme in communication sciences at Urbino, together with the Centre for Semiotic Studies, directed by Gianfranco Marrone and which I have the honour of coordinating, is a point of reference for all those who want to become «model readers», for themselves and above all for others. Indeed, at Uniurb, the exploration of meanings in communication has a strong commitment to social engagement. Analysing media dynamics not only enables students to understand how they can grow their acumen, but fosters an ethical reflection on this increasingly complex world. So as not to forget that Urbino is the birthplace of the *Città ideale*, teachers at this School accurately showcase the spread of hate phenomena, both online and offline, and underline the value of the movements for social justice, for gender equality, for the defence of marginalised cultures and the environment. In short, we care for the world and strive to induce this same civic duty in the students we guide towards various career paths.

Images: The Impression of Immediacy

The original title of the lesson at Mamiani was *Senza parole: il ruolo delle immagini nella comunicazione* (*Without Words. The Role of Images in Communication*). It implies that images are not inferior or subordinate to verbal language, but have an autonomous capacity for meaning. Rather, nowadays we are all quite convinced that images have a greater impact than words. When asked «Why do you think this happens?», one of the students replied that «images are more immediate». Still it is crucial to disclose how this effect is produced.

Therefore the lesson started with a debate on the sense of immediacy that images generate. I led the students to dismantle the impression of naturalness and understand that these processes are not automatic. We are fine participants

CHAPTER 5

Images as Information: Visual Literacy in the Age of AI-Generated Imagery

Chiara Spaggiari

Introduction to Visual Culture and Communication Theory

Vision constitutes a fundamental dimension of human experience, communication, and the very possibility of knowledge, both at the phylogenetic and ontogenetic levels. Long before the invention of writing, images functioned as symbolic tools through which humans organised reality, transmitted knowledge, and established social bonds. This primacy of vision is equally evident in individual development. As John Berger notes in *Ways of Seeing* (1972, 7), «seeing comes before words. The child looks and recognises before it can speak» . Visual perception thus precedes verbal language and orients subsequent processes of symbolisation, operating as a primary mode of engagement with the world.

Looking, however, is not a passive reception of visual stimuli but an active and relational practice of knowledge. It is shaped by perceptual skills, embodied experience, and sociocultural frameworks that guide attention and interpretation. From this perspective, the image can be understood both as a conceptual category and as a cultural object, functioning as the objective correlate of vision within communicative processes.

To define the image theoretically, W. J. T. Mitchell (1994) proposes a crucial distinction between *picture* and *image*. A picture refers to a material and physical object—something that can be displayed, stored, or circulated on a specific support. An image, by contrast, denotes a visual and representational entity that may exist mentally or formally and that can manifest across different media. The same image can therefore appear in multiple pictures, migrating across supports while maintaining a degree of recognisability.

This distinction is complemented by the notion of *medium*, a polysemic concept referring to the intermediary that enables communication by giving form to content. As Régis Debray (2000) observes, a medium may indicate a process of symbolisation, a social code of communication, a material support of inscription, or a device of dissemination. Each of these dimensions contributes in specific ways to the production of meaning. Images can thus be considered media in all these senses: as symbolic forms, as culturally learned practices, as material supports ensuring preservation, and as public modes of dissemination. When an image circulates on platforms such as Instagram or TikTok, it changes not only in format but also in audience, speed, visibility regimes, and possibilities for interaction.

The act of giving form to content through a medium is closely related to the concept of information. Within communication theory, information is not a property of signs themselves but the outcome of recursive cognitive and social processes. As Gregory Bateson (1972) famously states, information is «a difference that makes a difference»: a sign becomes informative only when it is selected and interpreted by an observer within a specific context.

From the 1990s onward, the study of vision and the sociocultural role of images gained renewed centrality with the formulation of the iconic turn (Boehm, 1994) and the pictorial turn (Mitchell, 1994), in parallel with the diffusion of digital technologies. These perspectives recognise images as forms governed by logics not reducible to verbal language and as active agents in the construction of reality and knowledge (Gemini, 2021), particularly within digital communication ecosystems (Boccia Artieri & Gemini, 2026).

Within this framework, visual culture studies (Pinotti & Somaini, 2016) provide a key reference for visual literacy (Messaris, 1995). After the visual turns, images are increasingly approached through a post-semiotic and post-representational lens, no longer understood solely as signs referring to an external referent, but as outcomes of complex interactions among visuality, technical apparatuses, institutions, discourses, bodies, and figurative forms. Spectatorship itself emerges as a deep cognitive and sociocultural practice, comparable to reading as an operation of decoding, interpretation, and meaning attribution (Esposito, 2022). Visual literacy therefore concerns not only the decoding of visual content, but also critical awareness of the conditions through which the visible is produced, circulated, and rendered meaningful.

Iconosphere in Digital Communication

From the 1990s onward, the notions of *infosphere* and *iconosphere* became central to understanding the digital communication ecosystem within the

network society described by Castells (2002). The infosphere (Floridi, 2009) refers to the environment in which information circulates through both human and artificial processes, while the iconosphere designates its visual dimension, in which images operate as informational data, symbolic commodities, and political devices.

Within this space, image circulation is sustained by continuous sharing on digital platforms by social media users, prosumers, and increasingly by institutions and news organisations.

Over the past decade, however, this circulation has been increasingly regulated by platforms and algorithmic infrastructures that organise visibility in selective, personalised, and user-oriented ways, determining who can see what, when, and under which conditions.

Visual information in networked digital ecosystems is therefore deeply intertwined with computational logics of selection and access, which directly affect the production, circulation and intelligibility of images in the contemporary iconosphere.

These dynamics are embedded in broader processes of *mediatisation* (Boccia Artieri, 2015; Hepp & Couldry, 2013), understood as a long-term meta-process through which technologically mediated communication becomes constitutive of social life. The pervasiveness of digital media reshapes everyday communication, integrating media into the social fabric through the interplay of infrastructures, user practices, and agency (Gemini & Brilli, 2023). In this phase of deep mediatisation, communication increasingly relies on automated, data-driven processes, making infrastructures and data production systems central.

Within this framework, *mediatisation* configure a what is called nowadays *platform society* (van Dijck, Poell & de Waal 2019), in which information, social relations, and cultural production are organised through algorithmic architectures that embed norms, values, and power asymmetries, shaping regimes of visibility and meaning.

Constructing the Spectatorial Gaze and the Meaning of Images

To develop a reflection on visual literacy in digital culture, it is necessary to become aware of the conditions through which images produce social meaning within communication circuits. This requires questioning both the ways in which the spectator's position is constructed and the ways in which the image itself is constructed. These dynamics are distinct but inseparable in the production of visual meaning.

Stuart Hall and Cultural Studies

The conditions through which images acquire social meaning are closely linked to theories associated with the discursive, post-semiotic, and post-representational turn, which challenged the idea of representation as a simple reflection of reality. Within this framework, a key reference is the work of Stuart Hall and the tradition of cultural studies (1997), which, drawing on Michel Foucault, articulate a historical and social conception of meaning.

From this perspective, Hall develops the *encoding/decoding* model, which conceptualises communication as a non-linear process. In the encoding phase, producers of visual messages inscribe meanings using available cultural codes. In the decoding phase, spectators interpret these meanings from their own social, cultural and perceptual positions. Meaning is therefore not contained within the image itself but is produced through the interaction between image and observer. It becomes a site of negotiation, shaped by power relations and by dominant, negotiated, or oppositional readings. Moreover, drawing on Foucault's (1966) analysis of *Las Meninas* (1656), Hall argues that images operate as a *dispositif* that constructs the spectator's position within representation: the observer is implicated in the relationship with image, emerging as an effect of the discursive functioning of representation itself.

These references help clarify how, in contemporary visual culture studies concepts such as gaze, spectator and spectatorship exceed the simple act of *seeing*. *Looking* means occupying a reciprocal, culturally and politically constructed position. From this perspective, it is useful to distinguish between two complementary approaches: *address*, which examines how an image constructs its ideal spectator, and *reception*, which analyses how real spectators actually interpret images, sometimes aligning with and sometimes resisting dominant discourses (Sturken & Cartwright, 2017). At the core of this dynamic lies the relation between looking and being looked at, between the seeing subject and the visible object. [1]

Gillian Rose's Model

Building on an awareness of spectatorship and the role of the gaze in meaning-making, Gillian Rose (2022) proposes a heuristic model for image

[1] For this reason, feminist and postcolonial theories are crucial, as they have shown how power relations are inscribed in the gaze and how it contributes to the production of differences, hierarchies, and cultural identities (see also Berger, 1972).

analysis that highlights both the specific effects of images and the social conditions of their production and circulation.

Rose's multi-sited model identifies four dimensions through which images acquire social meaning (Fig. 5.1). The site of production concerns technologies, formal choices, and social, cultural, and political-economic contexts shaping representation, including the identity positions of image-makers. The site of the image focuses on internal composition, such as visual elements, codes, and genres, which guide perception and interpretation. The site of circulation addresses the modes and infrastructures through which images are distributed and made visible, today strongly shaped by digital platforms and algorithms. Finally, the site of audiencing emphasises the active role of the spectator in meaning-making. Drawing on the concepts of *address* and *reception*, Rose highlights how publics interpret, rework, or resist proposed meanings, particularly within participatory digital culture, where viewing often also entails production.

Each of these sites can be analysed through three complementary modalities. The technological modality examines tools, devices and infrastructures that produce and mediate images. The compositional modality focuses on visual construction, form and aesthetic qualities. The social modality investigates the practices, institutions, and social relations involved in producing, circulating and interpreting images.

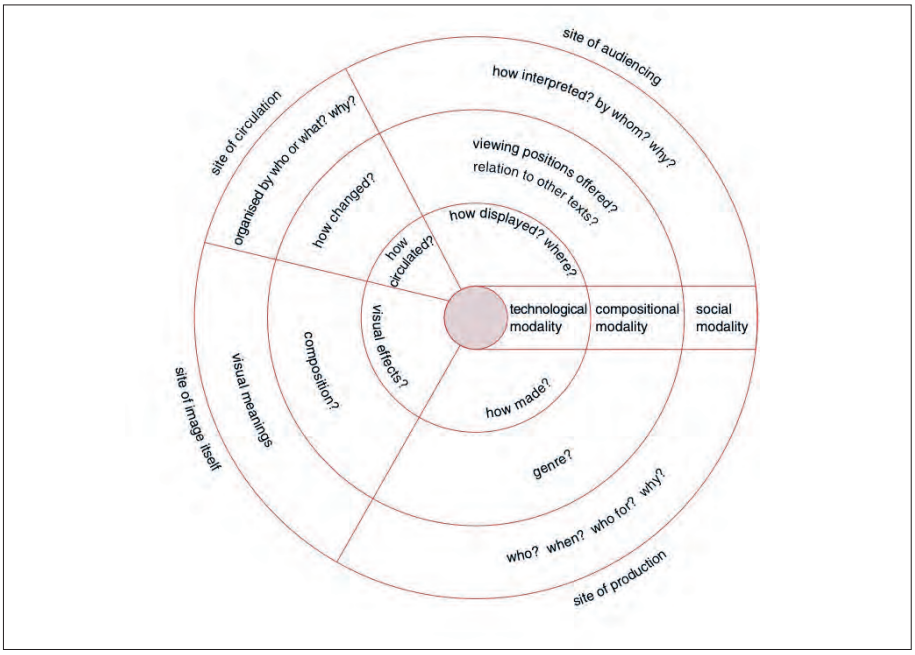

Fig. 5.1 Multi-sited model proposed by Gillian Rose (2022, 25).

CHAPTER 7

Science Education as a Safeguard for Democracy: A Combined Process/ Spiral Model for PISA-Aligned Curricula

Monica Tombolato

Conceptualising Teacher Competency: The Interplay of Variables in PISA-Aligned Science Curriculum Design

In contemporary STEM-oriented societies, science education is essential for training future scientists and raising awareness among individuals living in the Anthropocene—the first geological epoch defined by human impact on the planet (OECD, 2023). Scientific research and technological innovation have produced a worldview that significantly differs from common sense. While this progress has improved the quality of life, it has also generated fear and distrust among those who lack an understanding of scientific processes. To reduce harmful behaviours stemming from misconceptions about global challenges such as climate change and societal health, educational systems worldwide must deliver effective science education. This education should enable future generations to distinguish facts from opinions, manage ambiguity, and combine diverse information sources.

The 2025 Programme for International Student Assessment (PISA) Science Framework supports this objective. According to the framework, a 15-year-old school leaver prepared for life in modern society should be able to: a) explain phenomena scientifically; b) construct and evaluate scientific enquiry designs and critically interpret scientific data and evidence; and c) research, evaluate and apply scientific information for decision making and action. To develop these domain-specific competencies by the end of compulsory education, typically at age 15 or 16, students must become familiar with scientific knowledge and engage confidently with science as a collective human endeavour.

Achieving this educational objective requires a paradigm shift in science curriculum planning. Throughout most of the 20th century, upper secondary science curricula focused narrowly on laying the groundwork for the professional training of a select few scientists and engineers. Teachers primarily sought to equip students with fundamental concepts, laws and theories in order to identify those suited to a «scientific career». Little attention was paid to encouraging all learners to understand the methods and rationales underlying the generation of trustworthy scientific knowledge. Although this perspective has developed in response to today's challenges, the goal of equipping all citizens—not only future scientists—to competently address scientific issues remains unfulfilled.

Many educational systems have progressively adopted the PISA framework as a global benchmark for curricular reforms. In Europe, for example, Germany introduced National Education Standards (Neumann et al., 2010), and Portugal and Estonia implemented reforms that emphasised teacher professional development and pedagogical autonomy to meet PISA objectives (European Commission, 2022). Portuguese reforms aim to enhance teachers' professional development to continuously improve teaching methods, while Estonia has adopted policies that give teachers greater autonomy in curriculum design, enabling them to tailor instructional strategies to improve student performance. In Asia, countries such as Singapore and Japan have consistently refined their educational models to maintain excellence in skills measured by international assessments, with Singapore implementing professional development programmes that prioritise collaborative teaching and cooperative learning to enhance classroom practices (Wu, 2025). A similar trend is emerging in developing nations such as the Philippines, where recent research (Faustino et al., 2024) focuses on designing science curricula that align with national standards and PISA expectations, while identifying best practices consistent with international benchmarks to strengthen student learning.

Despite extensive reform efforts, PISA results show that suboptimal scientific learning is still a widespread global issue, including in Italy. In 2015—the last year science was the major domain before the ongoing 2025 cycle—Italian 15-year-olds scored an average of 481 on the science scale, significantly below the OECD average of 493. This downward trend continued in subsequent assessments: 468 compared to 489 in 2018 and 477 compared to 485 in 2022. To interpret these results properly, it should be borne in mind that PISA assesses «cumulative learning that has taken place since birth» (OECD, 2016, 271) and that multiple studies (e.g., Kalkan et al., 2020; Mostafa et al., 2018; Oreskes, 2019) have confirmed a strong correlation between classroom practices and student performance. Specifically, Kalkan et al. (2020) analysed PISA 2015 data from several countries, including Italy, and identified teacher-related fac-

tors—such as the capacity to adapt instruction to students' needs—as primary predictors of scientific literacy in the Italian context. This evidence suggests that advancing teacher training at all levels can generate considerable benefits throughout students' schooling (Darling-Hammond et al., 2017). Such a perspective becomes even more compelling when drawing on Bateson's (2000) theory, which is strongly influenced by Bertrand Russell's theory of logical types, to conceptualise/clarify the different levels of learning involved in acquiring PISA's scientific competencies.

The Anglo-American anthropologist Bateson distinguishes two complementary, simultaneous levels of learning: «proto-learning» (Learning I) and «deutero-learning» (Learning II). Deutero-learning is in context to proto-learning, as both are complementary components of the human learning process. Specifically, deutero-learning concerns the (mostly implicit) learning of the context in which proto-learning occurs (Lutterer, 2012). In fact, the manner in which proto-learning occurs shapes our worldview, consequently influencing how we think and act. For example (Lutterer, 2012), while learning to «ride a bike» (proto-learning, i.e., explicit and direct learning), an individual simultaneously acquires implicit knowledge about the world and of how things occur (deutero-learning, i.e., implicit and indirect learning). As Baldacci (2012) observes, the habits developed through deutero-learning can be assimilated to the «enduring attitudes» defined by Dewey (1938/1953, 48) as stemming from «collateral learning». According to Dewey (1938/1953), teachers often focus only on the explicit disciplinary content, but a deeper collateral learning occurs in the form of lasting dispositions (mental habits and emotional responses) that shape how a person navigates the world and future challenges.

In this context, deploying PISA competencies requires both sound scientific knowledge and the cultivation of specific scientific dispositions (habits of thought and action). These competencies can be understood as medium- to long-term outcomes of a complex interaction between proto- and deutero-learning levels (Baldacci, 2024). However, as the manner in which proto-learning occurs influences our (in this case, scientific) worldview, the development of these scientific dispositions fundamentally depends on what is taught and how it is taught.

Adopting this conceptual framework entails two learning-level constraints (C) that must guide a teacher's didactic actions:

C1. The contextual constraint: Since deutero-learning occurs within the context of proto-learning, the choice of what and how to teach (with regard to proto-learning) directly influences the dispositions (deutero-learning) that develop concurrently. Therefore, these didactic choices must be consistent with the scientific dispositions necessary for effective engagement with the three PISA scientific competencies.

C2. The temporal constraint: Because deutero-learning develops over the medium- to long-term, it cannot be fostered through isolated activities. Instead, a science curriculum must include these dispositions as primary objectives from the earliest stages of schooling.

Accordingly, this paper tackles the following research questions:

– RQ1. What conditions must a science curriculum fulfil in order to comply with the contextual and temporal constraints (C1 and C2) that are key to developing PISA scientific competencies? Furthermore, which curriculum model best satisfies these conditions?
– RQ2. How should pre-service and in-service teacher training be enhanced to address the professional development requirements arising from the implementation of this curriculum model?

To answer these questions, science curriculum design is interpreted as a specific form of didactic transposition (Chevallard, 1985; Martini, 2011, 2018). Within this framework, curriculum design comprises the choices teachers make to transform scholarly and expert knowledge into knowledge suitable for teaching and learning. These choices concern *what* and *how* to teach to achieve learning objectives encompassing both proto- and deutero-learning.

As is well established in the literature (e.g., Friedrichsen et al., 2011), teachers' didactic choices are far from «neutral»; they are value-laden acts (Pajares, 1992) in which the *what* and *how* of teaching reveal largely implicit beliefs regarding the nature of science, the goals of science education, and the processes of teaching and learning. To transition teachers' didactic choices towards conscious decision-making, we propose a conceptual model that specifies the variables to be considered when designing a science curriculum (Fig. 7.1), positing the following logical dependencies:

a) The epistemological and pedagogical variables (teacher's conception of science and educational purpose of science teaching, respectively) are mutually independent (no relationship). This indicates that a specific conception of science does not necessarily dictate a particular educational purpose. Therefore, these represent two distinct areas of choice for teachers.
b) The learning objective variable (teacher's selection of learning objectives) is influenced by the epistemological and pedagogical variables (direct relationship). This means that the selection of learning objectives conveys both a specific conception of science and a specific purpose attributed to its teaching. Therefore, the definition of these objectives is always epistemologically and pedagogically oriented.
c) The learning level constraints variable (constraints on logical types of learning) is influenced by the learning objective variable. This indicates that

learning objectives can belong to different logical levels—proto-learning and deutero-learning—and that this logical specificity places constraints on teachers' didactic choices.

d) The didactic variable is influenced by the learning objective variable (direct relationship) and, consequently, by the epistemological, pedagogical, and learning level constraints variables (indirect relationship). This means that teachers' choices about what and how to teach must be consistent with the epistemologically and pedagogically oriented learning goals. Therefore, such choices must be consistent with the conception of science and the educational purpose underlying the selection of these goals, as well as with the constraints imposed by the logical types of learning to be promoted.

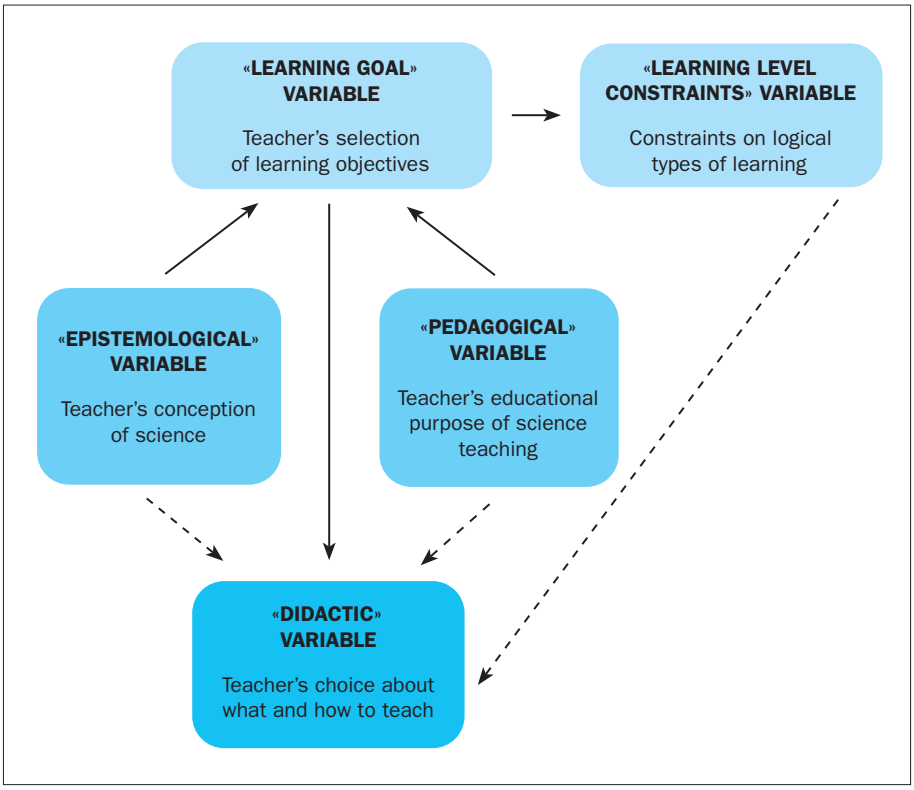

Fig. 7.1 Conceptual model of variable relationships in science curriculum design.

Based on these relationships, the following corollaries are derived, progressing from a general premise on teacher competency to a specific claim regarding PISA-aligned instruction: