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Articles Section

Systemic Suitability in Processes of Knowledge Production and Dissemination: An Extension of Didactic Suitability and the Onto-Semiotic Approach

Idoneidade Sistêmica em Processos de Produção e Disseminação do Conhecimento: Uma Ampliação da Idoneidade Didática e do Enfoque Ontossemiótico

Idoneidad Sistémica en Procesos de Producción y Diseminación del Conocimiento: Una ampliación de la Idoneidad Didáctica y del Enfoque Ontosemiótico

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Abstract

This study aims to assess the relevance of the Ontosemiotic Approach (OSA) for analyzing the emergence and diffusion of knowledge in disciplines beyond mathematics. The theoretical framework introduces the notion of an activity system, within which three processes are distinguished for analytical purposes: the production, dissemination, and control of knowledge. In order to evaluate the quality of activity systems, the analytical tool of systemic suitability is proposed as an extension of the concept of didactic suitability. Methodologically, the study adopts a transdisciplinary case study focused on water management in the Albufera of Valencia, examining five interdependent activity systems. The findings reveal semiotic conflicts among technical, scientific, and local forms of knowledge, showing that management effectiveness depends on coherence across the six facets proposed within the framework of systemic suitability. The study concludes that the OSA provides analytical tools that complement other frameworks for epistemic integration and normative evaluation in contexts of high socio-ecological complexity. It also demonstrates the potential of the analyzed context for the design of problem situations in mathematics education, including mathematical modelling, ethnomathematics, and transdisciplinary STEM projects.

Keywords: Onto-semiotic Approach. Systemic Suitability. Transdisciplinarity. Water Management.

Resumo

Este trabalho tem como objetivo avaliar a pertinência do Enfoque Ontossemiótico (EOS) para analisar a emergência e a difusão de conhecimentos em disciplinas distintas da matemática. A fundamentação teórica introduz a noção de sistema de atividade, para cuja análise se distinguem os processos de produção, disseminação e controle do conhecimento. Para avaliar a qualidade dos sistemas de atividade, introduz-se a ferramenta idoneidade sistêmica como uma extensão do conceito de idoneidade didática. Metodologicamente, emprega-se um estudo de caso transdisciplinar sobre a gestão hídrica na Albufera de Valência, analisando cinco sistemas de atividade interdependentes. Os resultados revelam conflitos semióticos entre saberes técnicos, científicos e locais, evidenciando que a eficácia da gestão depende da coerência entre as seis facetas propostas pela idoneidade sistêmica. Conclui-se que o EOS oferece ferramentas analíticas que complementam outros referenciais para a integração epistêmica e a avaliação normativa em contextos de elevada complexidade socioecológica. Além disso, demonstra-se o potencial do contexto analisado para o design de situações-problema na educação matemática, incluindo a modelagem matemática, a etnomatemática e os projetos STEM transdisciplinares.

Palavras-chave: Enfoque Ontossemiótico. Idoneidade Sistêmica. Transdisciplinaridade. Gestão Hídrica.

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Resumen

Este trabajo se propone evaluar la pertinencia del Enfoque Ontosemiótico (EOS) para analizar la emergencia y difusión de conocimientos en disciplinas distintas de las matemáticas. La fundamentación teórica introduce la noción de sistema de actividad para cuyo análisis se distinguen los procesos de producción, diseminación y control de conocimientos. Para valorar la calidad de los sistemas de actividad se introduce la herramienta idoneidad sistémica como una extensión de la idoneidad didáctica. Metodológicamente, se emplea un estudio de caso transdisciplinar sobre la gestión hídrica en la Albufera de València, analizando cinco sistemas de actividad interdependientes. Los resultados revelan conflictos semióticos entre saberes técnicos, científicos y locales, evidenciando que la eficacia de la gestión depende de su coherencia entre las seis facetas que propone la idoneidad sistémica. Se concluye que el EOS ofrece herramientas analíticas que complementan a otros marcos para la integración epistémica y la evaluación normativa en contextos de alta complejidad socio-ecológica. Asimismo, se muestra el potencial del contexto analizado para el diseño de situaciones-problema en educación matemática, incluyendo modelización, etnomatemática y proyectos STEM transdisciplinares.

Palabras clave: Enfoque Ontosemiótico. Idoneidad sistémica. Transdisciplinariedad. Gestión Hídrica.

1. Introduction

The Onto-Semiotic Approach (OSA) in Mathematics Education emerged as a response to the diversity of philosophical, psychological, and educational theories concerning the nature of mathematics and its teaching-learning processes, among which dilemmas and contradictions frequently arise. Godino e Batanero (1994) identified the problem of articulating epistemological and psychological approaches in mathematics didactics, a proposal that led to a first ontological and semiotic approximation of mathematical activity and its emergent objects.

More recent work (Godino; Batanero; Font, 2007; Font; Godino; Gallardo, 2013; Godino; Batanero; Font, 2019), addresses directly the question of the nature and emergence of mathematical objects, adopting an anthropological (Wittgenstein, 1953), pragmatist (Peirce, 1931-58) and sociocultural (Vygotsky, 1978) perspective. Within this framework, the activity of subjects engaged in problem-solving constitutes the central element in knowledge construction, grounded in the following epistemological principle:

> Mathematics is a human activity centered on the resolution of certain types of problem-situations. The realization of this activity is made concrete through the enactment of systems of practices by means of which responses to the problem-situation are generated (Godino; Batanero; Font, 2019, p. 39).

An ontological principle is likewise assumed: there is no mathematical activity without objects, nor objects without activity. Various classes of objects participate in these practices, fulfilling distinct roles: instrumental/representational, regulative (establishing rules governing practices), explanatory, and justificatory. Given the generality of the notions of practice and object, as well as the diversity of possible sequences of practices (processes), the OSA proposes a typology of basic objects and processes, operationalized through the onto-semiotic configuration tool, which enables detailed analyses of mathematical activity.

The question concerning the nature of knowledge—what does it mean to know a mathematical object?—is addressed from a semiotic standpoint. Within the OSA, knowledge is defined as the set of relationships that a subject (individual or institution) establishes between objects and systems of practices; these relationships are modeled through the notion of the semiotic function. This is understood

as the correspondence between an antecedent object (expression, signifier) and a consequent object (content, meaning), established by a subject according to a criterion or rule of correspondence.

Recent research has examined the extent to which this epistemological modeling is exclusive to mathematics or whether, conversely, it can be applied relevantly and productively to other disciplines, including the didactics of experimental sciences (Godino, 2025b), physics (Godino, 2025a) and biology (Godino, 2026). The possibility of extending onto-semiotics to any human activity—whether academic, technical, or professional—is likewise under investigation.

The present work aims to introduce this expanded vision of the Onto-Semiotic Approach, encompassing ontological, semiotic, epistemological, and cognitive components related to knowledge production, as well as components concerned with its dissemination and regulation. Specifically, it develops the notion of systemic suitability of knowledge production and dissemination processes, which extends the didactical suitability framework originally elaborated for the evaluation of instructional processes.

Following the theoretical motivation, the paper presents the expanded conception of the OSA and of didactical suitability before developing an illustrative application of these tools to a transdisciplinary case study: water management in the Albufera de València. This problem-situation involves five activity systems that can be analyzed through onto-semiotic tools to reveal their intrinsic complexity. Such analysis enables the identification of semiotic tensions and conflicts, the recognition of which proves fundamental for optimizing management processes in contexts characterized by high uncertainty and actor diversity. The paper also includes a section demonstrating the potential of the Albufera water management context for mathematics education, specifically for the design of problem-situations in mathematical modeling, ethnomathematics, and transdisciplinary STEM projects. The study of convergences and complementarities with other theoretical frameworks employed in inter- and transdisciplinary research is left as an open question.

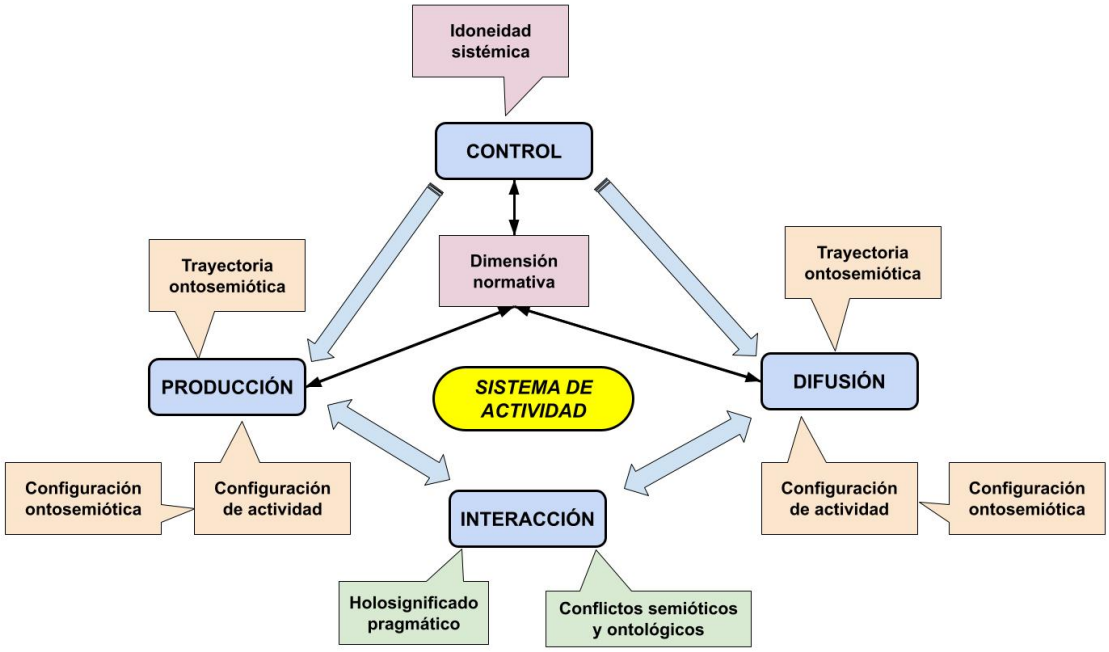
The work is conceptual-analytical in nature: it does not contribute new empirical evidence obtained through primary fieldwork, but rather draws on a corpus of published documents on the case to illustrate the analytical pertinence of the Onto-Semiotic Approach. Water management in the Albufera de València is employed as a sufficiently documented and paradigmatic illustrative case, one that enables demonstration of the descriptive and explanatory capacity of OSA tools in a context beyond their original domain of development.

2. The OSA as a Theoretical Framework for Disciplinary, Inter- and Transdisciplinary Research

For disciplinary, inter-, and transdisciplinary research, the OSA offers a set of tools that enable detailed description of how practices, objects, and meanings are produced, circulated, and transformed within an activity system. This perspective is particularly valuable in epistemically heterogeneous contexts, where knowledge integration requires understanding not only the contribution of each discipline but also how disciplines construct their objects and negotiate their meanings.

Figure 1 synthesizes the conceptual architecture of the OSA in its expanded version for the analysis of activity systems. Within this framework, problem-posing and problem-solving, as well as the professional and research tasks that constitute the motive of the activity, take place in dynamic systems whose evolution is articulated through processes of knowledge production, dissemination, interaction, and regulation.

Figura 1 – Expanded model of the Onto-Semiotic Approach for the analysis of activity systems



Source: Author's own elaboration

In the original OSA formulation, problem-solving occupies a central role in the emergence and evolution of mathematical knowledge. In the expanded perspective proposed here, these processes are interpreted more generally as knowledge production processes within any activity system. Analogously, the teaching and learning of mathematical content can be interpreted as knowledge dissemination processes, whether occurring in formal educational contexts or in other professional or institutional settings. Furthermore, the evaluation of educational processes, characteristic of didactical analysis, can be interpreted more broadly as a process of regulation of knowledge production and dissemination. These processes are additionally characterized by complex interactions among the various dimensions and components that configure activity systems.

This expanded model responds to the need to analyze phenomena in which knowledge construction results from the co-evolution of heterogeneous agents, practices, institutions, and semiotic systems, rather than being confined to the internal activity of a single discipline.

In this expanded OSA formulation, the terms *activity system* and *community of practice* are employed in an articulated but non-interchangeable manner. The concept of activity system derives from Cultural-Historical Activity Theory, where it constitutes the basic unit of analysis of human action mediated by tools, norms, and social relations (Engeström, 1987; Engeström; Sannino, 2021). This conceptual convergence enables the articulation of onto-semiotic analysis with a well-established tradition

of study of mediated social practices. Each community of practice is understood as the collective subject of an activity system; nevertheless, the analytical emphasis falls on the latter as a structured unit of mediated action, in which relevant factors include not only identity and membership—dimensions characteristic of the concept of community of practice (Wenger, 1998)—but also the division of labor, the rules governing action, and the internal tensions driving its transformation.

It should be noted that the expanded OSA is not confined to the analysis of a single activity system in isolation. In inter- and transdisciplinary research contexts, multiple activity systems typically coexist, overlap, and enter into relation, giving rise to phenomena that are only comprehensible at the level of inter-system interaction. The case of water management in the Albufera de València, developed in this article, illustrates precisely this situation: five interdependent activity systems are identified—agricultural water management, lagoon fisheries management, the institutional water governance system, the scientific-environmental ecosystem system, and urban and industrial water management—which do not operate in isolation but rather overlap, cooperate, and enter into conflict, producing divergent meanings concerning water, territory, and the lagoon ecosystem.

Figure 1 identifies the principal OSA constructs employed as analytical tools to describe and explain how objects and meanings emerge, are transformed, and circulate within activity systems and communities of practice. Specifically, the analysis of knowledge production and dissemination processes is conducted through the tools of *onto-semiotic trajectory* and *activity configuration*, within which the *onto-semiotic configuration* is nested; interaction processes are analyzed through the constructs of *pragmatic holomeaning* and *semiotic* and *ontological conflicts*; and regulation processes through the construct of *systemic suitability*. Furthermore, the *normative dimension* occupies a transversal position in the model, given that it both regulates and is regulated by the three processes of production, dissemination, and regulation. These tools are briefly described below within the context of the expanded OSA.

2.1 Onto-Semiotic Trajectory

In the original OSA, teaching and learning processes are analyzed through the notion of didactical trajectory, understood as the sequence of didactical configurations through which mathematical meanings are constructed and transformed in an educational-instructional process. In the expanded framework proposed here, the processes of knowledge production and dissemination in broader activity systems can be analyzed through the notion of *onto-semiotic trajectory*, understood as the evolution of configurations of objects, practices, and meanings through which knowledge circulates among different subjects and communities of practice. This trajectory is not limited to discursive or representational transformations but also entails the mobilization of practices, artifacts, and institutions that participate in the social construction and circulation of knowledge.

In Figure 1, the onto-semiotic trajectory is presented as the primary analytical tool for studying knowledge production and dissemination processes in activity systems. These trajectories reveal how a hydrological model, for example, acquires new meanings as it is reinterpreted.

2.2 Activity Configuration

In the original OSA, the notion of *didactical configuration* was developed as a unit of analysis for teaching and learning processes, defined as any segment of mathematical and didactical activity bounded by the beginning and end of the resolution of a problem-situation or task (Godino, 2024). Each didactical configuration integrates three articulated components: an epistemic configuration (the system of institutional mathematical practices and objects mobilized), an instructional configuration (teacher and student roles, resources, and interaction patterns), and a cognitive-affective configuration (the personal meanings and dispositions of the subjects involved). In the expanded framework proposed here, this construct is generalized under the designation of *activity configuration*, understood as any segment of a knowledge production or dissemination process—educational or otherwise—bounded by the beginning and end of the resolution of a situation or task within an activity system.

The activity configuration thus constitutes the unit of analysis of the onto-semiotic trajectory: just as a didactical trajectory is articulated as a sequence of didactical configurations, an onto-semiotic trajectory can be analyzed as the succession of activity configurations through which knowledge is produced, transmitted, appropriated, and transformed among subjects and communities of practice. The didactical configuration consequently becomes a particular case of the activity configuration, applied to activity systems of an educational nature.

2.3 Onto-Semiotic Configuration

In the expanded OSA, the onto-semiotic configuration transcends its original formulation centered on mathematical activity to become the fundamental analytical instrument for processes of knowledge production and dissemination in any activity system. An onto-semiotic configuration refers to the network of problems, operative and discursive practices, and material and representational objects that constitute an activity system oriented toward the resolution of a situation or task (Font; Godino; Gallardo, 2013). This construct describes the internal architecture of any scientific or professional activity by integrating the problems that orient the actions performed by the actors, as well as the primary objects involved—languages, concepts, propositions, procedures, and arguments—while also accounting for the semiotic processes that transform these objects and the norms and values that regulate their validity.

These configurations are articulated through five dualities: expression/content, token/type, unitary/systemic, ostensive/non-ostensive, and personal/institutional, which facilitate the analysis of how meanings are stabilized or transformed during an activity(Godino; Batanero; Font, 2007). In interdisciplinary research, this construct enables the comparison of heterogeneous epistemic configurations without reducing one to another. In water resource management, for instance, hydrology, rural sociology, and ecological economics construct different objects under the same term: "water resource." The onto-semiotic configuration enables a precise description of these differences and their possible articulations.

The onto-semiotic configuration admits two modes of application depending on the scale of analysis. At the micro level, it is applied to the analysis of a specific activity configuration—that is, a delimited segment of the onto-semiotic trajectory bounded by the beginning and end of the resolution

of a specific situation or task; in this use, the onto-semiotic configuration appears nested within the activity configuration, as represented in Figure 1. This construct can equally be applied at a global scale—macro use—taking as its object of analysis the totality of an onto-semiotic trajectory. This is the use illustrated in Section 4, where the process of knowledge production in the agricultural water management system of the Albufera de València is examined.

2.4 Pragmatic Holomeaning

Pragmatic holomeaning refers to the integrated articulation of the meanings that a construct acquires across diverse contexts of practice (Godino; Burgos; Gea, 2022). Rather than denoting an essential meaning, it represents a dynamic network of uses, interpretations, and values. This construct is crucial for interdisciplinary research because meaning is always situated and pragmatic: a concept such as "system" or "representation" acquires significance through the specific problems it helps to resolve within a discipline. Consequently, epistemic integration requires the negotiation of these meanings as they circulate among communities. For example, the concept of "environmental flow" carries distinct implications for hydrologists, managers, and local communities; pragmatic holomeaning reconstructs this diversity in order to clarify its impact on decision-making.

2.5 Semiotic and Ontological Conflicts

In inter- or transdisciplinary contexts, discrepancies among actors are not limited to differences in the interpretation of signs or representations—what the OSA has traditionally termed *semiotic conflicts*—but may also involve deeper divergences concerning the nature of the objects and phenomena under consideration. In such cases, one may speak of *ontological conflicts*, or more generally of *onto-semiotic conflicts*, in which disputes over meanings become intertwined with disputes over the entities those meanings purport to describe. For example, in water management:

- For a hydrologist, the "water resource" is a quantifiable flow.
- For an agricultural community, water may be part of a cultural and territorial system.
- For a public policy framework, it may constitute an economic or strategic asset.

Here the conflict concerns not only how water is represented, but what kind of entity water is within each practice.

2.6 Systemic Suitability

Systemic suitability is an analytical construct employed to evaluate the overall quality of an activity system across six dimensions: epistemic, ecological, mediational, interactional, cognitive, and affective-axiological. This evaluation extends beyond the mere technical correctness of proposed solutions, taking into account the overall coherence of the activity system within its social, cultural, and institutional context. It enables analysis of the extent to which a proposal adequately integrates diverse forms of knowledge while maintaining its social legitimacy and cultural coherence. For example, a water management plan may be technically sound yet socially unviable; systemic suitability enables an integrated evaluation of these distinct facets.

The systemic suitability construct is proposed as an extension of the notion of didactical suitability, widely employed in mathematics education research (Malet; Giacomone; Repetto, 2021). The same six analytical dimensions are retained, but applied to activity systems broader than teaching and learning processes. From this perspective, didactical suitability can be interpreted as a particular case of systemic suitability applied to educational activity systems. This extension was suggested in Godino (2024), where it is noted that the notion of suitability can be applied not only to didactical activity but to different types of human activity, establishing a bridge between scientific-technological research and reflective practice.

2.7 Normative Dimension

Every activity system is regulated by a set of norms, conventions, and meta-norms that condition which practices are valid, how they are to be carried out, and according to what criteria they are to be evaluated. In the original OSA, this regulatory framework has been studied under the designation of the normative dimension, which encompasses both explicit norms—laws, regulations, disciplinary definitions—and implicit norms—habits, conventions, and tacit contracts—operating in educational processes (D'Amore; Font; Godino, 2007; Godino *et al.* 2009).

In the expanded OSA, the normative dimension retains its transversal character and is applied to the full range of activity systems: norms not only regulate dissemination processes—determining, for example, which forms of knowledge are legitimate to transmit and how they are to be appropriated—but also production processes—establishing the validity criteria for knowledge within a community of practice—and regulation processes—defining the standards against which systemic suitability is evaluated. In turn, the processes of production, dissemination, and regulation may themselves modify prevailing norms: a new scientific result may transform the conventions of a discipline, a well-established dissemination practice may institutionalize new meta-norms, and the critical evaluation of an activity system may prompt the revision of its regulatory criteria. This bidirectionality between the normative dimension and the other processes accounts for its central representation in Figure 1, connected by double-headed arrows to the processes of production, dissemination, and regulation.

2.8 Toward an Onto-Semiotics of Knowledge Systems

The expansion of the Onto-Semiotic Approach proposed in this work extends its reach beyond the analysis of mathematical activity and teaching-learning processes. Within this framework, the OSA can be interpreted as a system of tools for studying the production, circulation, and interaction of knowledge across diverse activity systems. From this perspective, the approach points toward an *onto-semiotics of knowledge systems*, understood as an analytical framework for studying the emergence, transformation, and articulation of objects and meanings across different communities of practice. This approach converges with work in Science and Technology Studies that analyzes the production and circulation of knowledge in diverse social contexts, as proposed by the concept of *knowledge circulation* (Secord, 2004), as well as with studies on the integration and evaluation of inter- and transdisciplinary research (Klein, 2008).

3. Case Description: Context and Activity Systems

The analysis focuses on the activity systems developed by distinct collectives that interact in the water management of the *Huerta* and the *Albufera de València*. Each system produces knowledge, practices, and meanings oriented toward resolving the problems that motivate its action. To illustrate the methodology of onto-semiotic analysis, this territory is employed as a case study, recognized by the FAO (Food and Agriculture Organization of the United Nations) as a Globally Important Agricultural Heritage System (GIAHS) for its sustainable and dynamic character, the product of a historical dialogue between human communities and the ecological environment (García Álvarez-Coque; Bigné, 2020). Within this socio-ecological context, five interdependent activity systems coexist:

- Agricultural water management
- Lagoon fisheries management
- Institutional water governance system
- Scientific-environmental ecosystem system
- Urban and industrial water management

These systems do not operate in isolation: they overlap, cooperate, enter into conflict, and produce divergent meanings concerning water, territory, and the lagoon ecosystem.

3.1 Agricultural Water Management

The oldest and most structuring activity system is that of agricultural water management, based on the capture and distribution of flows from the Turia and Júcar rivers through a complex network of irrigation channels of medieval origin. Rice constitutes the dominant economic and ecological driver of the territory (García Álvarez-Coque; Bigné, 2020). The Valencian irrigation institutions represent one of the most long-standing examples of communal water management in Europe, with centuries of institutional continuity (Martínez-Sanchis; Viñals, 2015). The Irrigation Community of the *Acequia Real del Júcar*, whose origins date to the thirteenth century, is a key actor in flow regulation and irrigation coordination. This system is characterized by the coexistence of generations: older farmers transmit inherited hydraulic knowledge, while younger ones incorporate monitoring technologies and new environmental sensibilities (García Álvarez-Coque; Bigné, 2020). Agricultural activity not only produces food but also shapes the territorial, economic, and linguistic identity of the surrounding area.

3.2 Lagoon Fisheries Management

Lagoon fisheries management constitutes another activity system with deep historical roots. Fishing communities maintain centuries-old customary rights and practices adapted to the ecological cycles of the lagoon. Their activity depends critically on the hydraulic regime imposed by agricultural irrigation and by the regulation of the outlet channels (golas), which generates recurrent tensions between the two systems (Boelens; Claudín, 2015). Fishers interpret water levels, lake quality, and inflow and outflow dynamics as essential conditions for species reproduction and the continuity of their activity. Their local ecological knowledge constitutes a fundamental component of the socio-ecological system of the Albufera.

3.3 Institutional Water Governance System

Water governance in the Albufera is structured as a complex institutional system, characterized by the coexistence of overlapping competencies and divergent visions (Jégou; Sanchis-Ibor, 2019). This system includes:

- the Júcar River Basin Authority (*Confederación Hidrográfica del Júcar,* CHJ), responsible for basin management and flow allocation;
- the Drainage Board (*Junta de Desagüe,* JDA), which regulates lake levels and the flooding or drainage of rice fields;
- the *Generalitat Valenciana*, responsible for management of the Natural Park and wastewater treatment infrastructure;
- the surrounding municipalities, particularly the city of València, the historical owner of the lake (Palop Guillem, 2016).

This institutional system produces regulations, hydrological plans, operational decisions, and coordination frameworks that profoundly condition the remaining activity systems.

3.4 Scientific-Environmental System

The scientific-environmental system integrates research teams, conservation bodies, and environmental organizations such as SEO-BirdLife (Spanish Ornithological Society) and *Acció Ecologista-Agró*. Its activity is oriented toward monitoring the ecological quality of the wetland, generating diagnostic assessments, proposing restoration measures, and advocating for ecosystem integrity (Boelens; Claudín, 2015). This system produces ecological models, environmental indicators, and interpretive frameworks that influence institutional decision-making and public debate. Its role is particularly significant in a context of eutrophication, biodiversity loss, and increasing anthropogenic pressure.

3.5 Urban and Industrial Water Management

Urban and industrial water management constitutes an activity system centered on wastewater treatment, sanitation, discharge control, and the management of urban and industrial hydraulic infrastructure. Inputs of treated wastewater, urban runoff, and industrial discharges condition the water quality and ecological status of the lake. This system includes both public operators and private companies, as well as industrial sectors within the metropolitan area. Its role is critical for reducing the nutrient and contaminant loads reaching the wetland (Jégou; Sanchis-Ibor, 2019).

4. Knowledge Production Process: Onto-Semiotic Configuration

Each activity system addresses the water management challenges of the Albufera de València in a distinct manner and implements its own operative and discursive practices according to its specific value system and responsibilities. In this section, by way of illustration, the onto-semiotic configuration tool is applied to the agricultural water management system.

4.1 Water Management Challenges

For those engaged in agricultural water management, the central concern is ensuring an adequate and high-quality water supply to complete the rice cultivation cycle. Critical problems include the reduction of available flows in the Júcar and Turia rivers—with estimated losses of approximately 40% over recent decades—and increasing competition with urban and industrial uses. During dry periods, rising salinity levels and uncertainty in supply schedules are sources of particular concern. At the institutional level, this system advocates for the preservation of its historical allocation rules, founded on local autonomy and consensus, in response to the growing intervention of external bodies(Palop Guillem, 2016; Jégou; Sanchis-Ibor, 2019).

4.2 Operative Practices

In agricultural water management, the response to problems of resource availability, quality, and timing is articulated through a highly structured sequence of practices, the product of centuries of accumulated experience (Martínez-Sanchis & Viñals, 2015). The process begins with water intake from the main irrigation channels, regulated by sluice gates and flow dividers (*partidores*) that enable gravity-fed irrigation from higher to lower levels (García Álvarez-Coque; Bigné, 2020). Distribution is organized through strict rotation schedules supervised by key figures such as the *síndicos* and *sequieros*[1], responsible for ensuring equity and compliance with customary norms. Once water reaches the plots, farmers apply controlled submersion techniques, maintaining fields flooded for most of the rice cultivation cycle in order to sustain the biological processes of the wetland (Martínez-Sanchis; Viñals, 2015). This management includes critical phases such as the *perellonà* (winter flooding) and the *eixugó* (drainage prior to harvesting), regulated through control of the *golas* or outlet channels to the sea (Palop Guillem, 2016). Collective maintenance of the hydraulic network—the *mondas*—is likewise essential to prevent silting and ensure water flow. At present, these ancestral practices are combined with innovations such as level sensors and remote monitoring systems aimed at improving water use efficiency (García Álvarez-Coque; Bigné, 2020).

4.3 Material and Representational Resources

The operative practices of the various activity systems rely on a diverse set of material objects, technical instruments, and linguistic expressions that enable the organization, communication, and coordination of water management within this complex socio-ecological system. These resources are not ancillary: they constitute an essential component of the activity, as they shape the possibilities for action, the modes of interpretation, and the forms of knowledge legitimation.

In agricultural water management, the activity is sustained by a historical hydraulic infrastructure—irrigation channels (acequias), sluice gates, flow dividers, and drainage ditches (*azarbes*)—which serves as the physical support for water distribution and has been largely designated as Cultural Heritage of Interest (*Bien de Interés Cultural*) (García Álvarez-Coque; Bigné, 2020). To traditional manual tools, such as spades and hoes, was historically added the carved stone marker bearing the royal coat of arms, used to gauge the *lluent* water level and determine the opening of the *golas*. Technical developments

[1] *Síndicos* are elected representatives of the irrigation communities. Their primary function is to organize, coordinate, and oversee water distribution within each community or irrigation channel. *Sequieros* are the operational officers of the irrigation system: whereas the *síndicos* determine what is to be done, the *sequieros* are those who carry it out

subsequently introduced pumping systems—initially steam-powered and later electric—which proved fundamental for managing the *tancats*[2] situated below sea level (Palop Guillem, 2016). At the representational level, this system employs traditional units of measurement such as the f*ila* (a unit of flow) and the Egyptian cubit (for embankment width), which reflect a millennia-old agronomic heritage and lend legitimacy to communal decisions. These elements, alongside contemporary digitized records, allow for the continuity of a communal management system grounded in consensual authority (García Álvarez-Coque; Bigné, 2020).

4.4 Discursive Practices

Water management in the Albufera de València is expressed not only through material practices and technical procedures but is also sustained by a network of discursive practices that orient action, legitimize decisions, and shape the identity of each activity system (Boelens; Claudín, 2015). These discourses are articulated through concepts and propositions that function as operative truths, generating differentiated grammars of meaning. The resulting visions tend to oscillate between productivist and conservationist positions, reflecting structural tensions within the socio-ecological system (Jégou; Sanchis-Ibor, 2019).

The discourse of agricultural water management is articulated around a traditional hydraulic worldview, linked to the "rice culture" and to the historical legitimacy of communal institutions (García Álvarez-Coque; Bigné, 2020). Concepts such as "clean water"—understood as water of low salinity and free of urban contaminants—and "fair allocation," based on rotation schedules and historical proportionality, structure its identity (Peris-Albentosa, 2015). The central propositions emphasize that water management is "crucial for agricultural prosperity" and that, without strict control of water levels and schedules, the rice fields would become "sterile wastelands." This discourse appeals to the consensual authority of irrigation institutions and to the idea that the survival of the Huerta depends on the preservation of its historical rules (Peris-Albentosa, 2015).

4.5 Values and Norms

Water management in the Albufera de València cannot be understood solely through the operative practices or the discourses that each activity system mobilizes. Underlying these actions is a framework of values and norms that orient conduct, legitimize decisions, and sustain the collective identity of each community (García Álvarez-Coque; Bigné, 2020). As Ostrom (2009), notes, shared rules do not merely regulate behavior but create community—a process in which the stability of the system depends on narratives, beliefs, and practices mutually reinforcing one another to produce a robust governance structure (Aggarwal; Anderies, 2023; Boelens; Claudín, 2015).

The core values of agricultural water management revolve around equity, collective responsibility, and respect for tradition. Among the most significant norms are strict compliance with irrigation rotation schedules—essential for matching demand to an irregular flow regime—and the obligation of mutual assistance, known as "*agua de gracia*" (water of grace), activated when extreme need is identified in a given holding (Peris-Albentosa, 2015). This normative framework sustains an ethic in which water

[2] A *tancat* is an agricultural enclosure bounded by embankments or levees that isolate it from the lake.

is a common good and its management a moral responsibility that defines belonging to the community (García Álvarez-Coque; Bigné, 2020; Boelens; Claudín, 2015).

5. Regulation Processes: Systemic Suitability

Evaluating the quality of water management in this territory requires a tool capable of capturing its complexity. The systemic suitability construct offers precisely such a framework: an analysis that integrates the epistemic, ecological, mediational, interactional, cognitive, and affective-axiological dimensions to assess the overall coherence of an activity system. Applying this approach to the Albufera enables an understanding not only of whether management functions, but of how it functions, for whom, and with what consequences. The tool is applied below to the five activity systems involved in water management in the Albufera de València.

5.1 Agricultural Water Management System

The systemic suitability of the agricultural water management system is defined as the degree to which this activity system is optimal for achieving a balanced adaptation among agricultural productivity, the sustenance of the wetland ecosystem, and the maintenance of the collective identity of the irrigation community, given the available technical resources and the socio-ecological context of the Albufera de València. The application of this tool across each dimension is as follows:

- *Epistemic suitability*: This refers to the degree of robustness and coherence of the knowledge mobilized, which in the Valencian case is characterized as hybrid knowledge. It articulates traditional hydraulic knowledge of medieval origin—such as the use of the fila and the Egyptian cubit, and gravity-fed irrigation—with modern digital monitoring technologies (Martínez-Sanchis; Viñals, 2015). Suitability is high when the consensual authority and local autonomy that have enabled the equitable management of this resource over centuries are respected (Peris-Albentosa, 2015).
- *Ecological suitability:* This evaluates the degree of alignment between hydraulic management (rice flooding and drainage cycles) and the needs of the wetland. Suitability is achieved when cultivation acts as a "green filter" and maintains the environmental conditions necessary for avifauna and biodiversity. Nevertheless, this dimension is compromised by threats such as salinization, climate change, and the intensive use of agrochemicals (Palop Guillem, 2016).
- *Mediational suitability*: This assesses the adequacy and maintenance of the hydraulic infrastructure—irrigation channels, drainage ditches, sluice gates, and tancat embankments—that structures the landscape. High suitability implies the efficient use of water to stabilize resource supply and demand, and the correct operation of the golas to regulate lake levels (Palop Guillem, 2016).
- *Interactional suitability*: This evaluates the quality of coordination through nested institutions, such as the Irrigation Communities, the Water Tribunal (Tribunal de las Aguas), and the Drainage Board (Junta de Desagüe). The system is suitable when it enables decentralized self-

governance and rapid, low-cost conflict resolution based on consensus, although this may be undermined by informational opacity in decision-making (Jégou; Sanchis-Ibor, 2019).

- *Cognitive suitability*: This refers to the effectiveness of intergenerational transmission of local ecological knowledge and irrigation norms. Suitability depends on the capacity of younger farmers to appropriate inherited knowledge and adapt it to new environmental and technological demands (García Álvarez-Coque; Bigné, 2020).
- *Affective-axiological suitability*: This measures the degree of commitment and social legitimacy that irrigators confer upon the system, grounded in values such as equitable distribution, collective responsibility, and respect for tradition. These values sustain the cultural and linguistic identity associated with the rice landscape (Peris-Albentosa, 2015).

5.2 Lagoon Fisheries System

The systemic suitability of the lagoon fisheries activity system is defined as the degree to which this activity system is optimal for achieving a balance among artisanal fishing productivity, the preservation of the lagoon's "ecological pulse," and the strengthening of community identity, given the available technological resources and the power asymmetries in the governance of the Albufera de València. The application of this tool across each dimension is as follows:

- *Epistemic suitability*: This evaluates the robustness of local ecological knowledge, which is grounded in the direct and long-standing observation of water levels, turbidity, and species behavior in the lake (Boelens; Claudín, 2015). This system possesses a specialized vocabulary in Valencian that encodes centuries of empirical knowledge irreducible to technical languages. Suitability increases with the recent incorporation of systematic catch records, which serve as a translation bridge toward scientific language (Spadaro; Vallerani, 2023).
- *Ecological suitability*: This is the most internally valued dimension, as the health of the lake constitutes the very condition of possibility for fishing. Suitability is achieved when the water inflow and outflow regime enables the reproduction of species such as eel (anguila) and grey mullet (llisa) (Boelens; Claudín, 2015). Nevertheless, this dimension is severely compromised by advanced eutrophication and anoxic episodes that cause mass fish mortality (Jégou; Sanchis-Ibor, 2019).
- *Mediational suitability*: This measures the adequacy of the artifacts and technologies employed, ranging from traditional vessels (albuferencs) and fixed (redolins)[3] or mobile (mornells) fishing gear to sustainable innovations such as electric boat prototypes designed to reduce pollution and noise within the park (Spadaro; Vallerani, 2023). It also encompasses the need for dredging of the golas to facilitate biological exchange with the sea.
- *Interactional suitability*: This evaluates the quality of internal and external coordination. Whereas at the internal level the Fishing Community of El Palmar (Comunitat de Pescadors de El Palmar) has maintained autonomous and participatory governance since the thirteenth century (Spadaro; Vallerani, 2023), at the external level suitability is structurally low due to

[3] A *redolí* is a fixed fishing station within the Albufera. Each *redolí* constitutes a delimited area of the lake where a fisher is entitled to set traditional fishing gear (such as the *mornell*, *paranza*, *gànguil*, etc.) throughout an entire year.

the exclusion of fishers from water decision-making bodies such as the Drainage Board, a situation that constitutes epistemic and political injustice (Jégou; Sanchis-Ibor, 2019).

- *Cognitive suitability*: This refers to the effectiveness of oral and intergenerational transmission of practical knowledge and community norms. Although high within the collective, overall suitability is threatened by the lack of generational renewal and by the fact that the situational knowledge of fishers is frequently treated as "unverifiable opinion" by official institutions (Spadaro; Vallerani, 2023).
- *Affective-axiological suitability*: This measures commitment to values of equity, solidarity, and local autonomy, materialized in ceremonies such as the sorteig dels redolins for the fair allocation of access to the resource. For this system, water is not merely a resource but a living medium and a powerful activator of the cultural identity and collective memory of the territory (Spadaro; Vallerani, 2023).

5.3 Institutional Water Governance System

The systemic suitability of the institutional water governance system is defined as the degree to which this set of bodies and regulatory frameworks is optimal for coordinating the competing demands of use and conservation, achieving adaptive governance that is transparent, coherent with environmental legislation, and legitimate in the eyes of the social actors of the Albufera de València. The application of this tool across each dimension is as follows:

- This evaluates the robustness and representativeness of the technical and legal knowledge employed in decision-making. Suitability is high when the system integrates hydrological plans and precise scientific parameters to define ecological flows, but is diminished by the hegemony of a technical-normative language that excludes local knowledge and generates situations of epistemic injustice (Jégou; Sanchis-Ibor, 2019).
- *Mediational suitability*: This assesses the sufficiency of financial resources and infrastructure for environmental management. It includes the functioning of wastewater treatment plants (EPSAR), green filter systems, and the water monitoring network necessary to stabilize resource supply and demand. Suitability is diminished by financial inertias and barriers to mobilizing human resources within the park authority (Palop Guillem, 2016).
- *Ecological suitability*: This measures the degree to which institutional objectives ensure compliance with the quality standards of the Water Framework Directive. The system is deemed suitable when policies succeed in mitigating eutrophication and adapting to climate change scenarios—such as sea-level rise and salinization—that threaten the integrity of the wetland (Jégou; Sanchis-Ibor, 2019).
- *Interactional suitability*: This evaluates the quality of coordination within the complex "puzzle of overlapping jurisdictions." High suitability would require overcoming current administrative fragmentation through the creation of bridging organizations and mediation mechanisms that prevent informational opacity, particularly within key bodies such as the Drainage Board (Jégou; Sanchis-Ibor, 2019).

- *Cognitive suitability*: This refers to the capacity of the institutional system for iterative learning and the updating of the mental models held by its managers (Michaels et al., 2026). The system is suitable when it is capable of transitioning from a "control of nature" vision toward a systemic understanding of socio-ecological dynamics, enabling information on the state of the lake to be translated into timely management actions (Aggarwal; Anderies, 2023).
- *Affective-axiological suitability*: This measures the coherence of the system with values of social justice, transparency, and heritage respect. Suitability is high when institutions are perceived as legitimate by citizens and succeed in reconciling the "idyllic landscape" of collective memory with the challenges of a new and more equitable hydro-social paradigm (Spadaro; Vallerani, 2023).

5.4 Scientific-Environmental System

The systemic suitability of the scientific-environmental system is defined as the degree to which this activity system is optimal for generating robust knowledge, monitoring biophysical dynamics, and orienting restoration strategies toward a state of long-term resilience and sustainability, integrating the complexity of ecosystem services within the context of global change in the Albufera de València. The application of this tool across each dimension is as follows:

- *Epistemic suitability*: This evaluates the quality, depth, and representativeness of the scientific knowledge generated about the wetland. Suitability is high when multiscale and multidimensional models are employed that capture the interconnections among supporting, regulating, provisioning, and cultural services (Jorge-García; Estruch-Guitart; Aragonés-Beltrán, 2023). It entails transitioning from a "theoretical and global" scale to a "participatory and local" one, recognizing that the prioritization of ecosystem services is influenced by the professional backgrounds of researchers. It also encompasses the capacity to project future scenarios based on variables such as sea-level rise and water availability (Palop Guillem, 2016).
- *Ecological suitability*: This refers to the degree to which scientific activity promotes the maintenance of essential ecological processes and the recovery of biodiversity. The system is suitable when its proposals succeed in reducing lake hypertrophy, restoring submerged macrophyte meadows, and mitigating the loss of environmental value caused by metropolitan urban expansion (Rodrigo-Ilarri *et al.* 2025).
- *Mediational suitability*: This assesses the availability and adequacy of technological tools and financial resources for research. It includes the use of continuous monitoring networks, geospatial databases such as CORINE Land Cover and the World Settlement Footprint for detecting land-use changes (Rodrigo-Ilarri *et al.* 2025), as well as green filter infrastructure (constructed wetlands) functioning as living laboratories for water re-naturalization (García Álvarez-Coque; Bigné, 2020).
- *Interactional suitability*: This measures the quality of dialogue and cooperation among academia, public administrations, and civil society. High suitability requires overcoming the fragmentation of the "jurisdictional puzzle" through the creation of bridging organizations

and permanent observatories that facilitate mediation between conservationist and productivist frameworks (Jégou; Sanchis-Ibor, 2019).

- *Cognitive suitability*: This evaluates the capacity of the scientific system to promote iterative learning and the updating of mental models concerning the ecosystem. The system is suitable when it enables agents to understand that the Albufera is an open and non-linear socio-ecological system, and that the recovery of the "idyllic landscape" of the 1960s must be adapted to the new realities of salinization and climatic uncertainty (Jégou; Sanchis-Ibor, 2019).
- This measures ethical commitment to conservation and environmental justice. It is grounded in values of biocentrism and in the promotion of a "blue transformation" that ensures social equity and the health of the lake's living organisms (Jégou; Sanchis-Ibor, 2019). Suitability is high when science not only produces data but also reinforces the collective identity and pride of Valencian society toward its natural heritage (Spadaro; Vallerani, 2023).

5.5 Urban and Industrial Water Management System

The systemic suitability of the urban and industrial water management system is defined as the degree to which this activity system is optimal for balancing metropolitan supply demands and industrial efficiency with the minimization of "deferred" environmental impacts on the wetland, ensuring effective waste treatment and resilience to hydrological risks in a context of accelerated urban expansion. The application of this tool across each dimension is as follows:

- *Epistemic suitability*: This evaluates the robustness of the technical and engineering knowledge applied to urban water cycle management, traditionally based on linear flow models and technical regulatory frameworks. Suitability increases when technical knowledge integrates geographical factors and sociocultural perceptions, recognizing that water management is not a neutral process but one shaped by the professional backgrounds of managers (Jorge-García; Estruch-Guitart; Aragonés-Beltrán, 2023).
- *Ecological suitability*: This assesses the impact of urban and industrial activity on the trophic status and biodiversity of the lagoon. The system is deemed suitable when it succeeds in mitigating the "collateral damage" derived from activities external to the wetland—such as inputs of heavy metals (zinc, mercury) and nutrients that cause eutrophication (Jégou; Sanchis-Ibor, 2019). Low suitability is reflected in the decline of the Weighted Environmental Index (WEI) due to land artificialization, which reduces aquifer recharge and increases vulnerability to flooding and extreme climatic events (Rodrigo-Ilarri *et al.* 2025).
- *Mediational suitability*: This assesses the adequacy of infrastructure, analyzing the transition from grey infrastructure (pipes and sewage systems that fragment the water cycle) to green infrastructure (constructed wetlands, permeable surfaces, and green filters). It includes the effectiveness of the Western Collector (Colector Oeste) and wastewater treatment plants (EPSAR) in absorbing wastewater and preventing direct discharges into the lake during heavy rainfall events (Jégou; Sanchis-Ibor, 2019).

- *Interactional suitability*: This evaluates the quality of coordination within the "puzzle" of metropolitan jurisdictions. The system is suitable when it overcomes informational opacity and enables emergent governance based on interdependence networks, where formal rules are stabilized through dialogue with other sectors such as agriculture and fisheries (Aggarwal; Anderies, 2023; Jégou; Sanchis-Ibor, 2019).
- *Cognitive suitability*: This refers to the capacity of managers to update their mental models in the face of climatic uncertainty. Suitability depends on iterative learning that transforms the traditional "control of nature" vision into an understanding of the wetland as a dynamic socio-ecological system, thereby avoiding maladaptive solutions based on erroneous perceptions of the hydrological cycle (Aggarwal; Anderies, 2023).
- *Affective-axiological suitability*: This measures the degree of social and ethical responsibility of the urban system with respect to the degradation of the Albufera. Suitability is high when water management promotes the right to a healthy environment and the recognition of the lake's heritage value, transforming water from a mere "waste product" into an activator of cultural identity and civic recreation (Spadaro; Vallerani, 2023).

5.6 Conflicts and Contradictions in Systemic Interaction

The Albufera de València is not merely a natural ecosystem but a complex of overlapping jurisdictions and conflicting visions operating over a profoundly anthropized territory (Jégou; Sanchis-Ibor, 2019). Wetland governance should not be understood as the external imposition of technical rules, but as an emergent phenomenon in which the contradictions among the belief systems and practices of diverse actors determine the stability or collapse of the socio-ecological system (Aggarwal; Anderies, 2023).

Having analyzed the systemic suitability dimensions of the five principal actors—agriculture, fisheries, institutions, science, and urban management—a reality marked by fragmentation and structural onto-semiotic conflict emerges.

5.6.1 The priority conflict: "Water for rice" versus "Water for the lake"

The point of greatest friction lies in the interaction between the ecological suitability of the fisheries and scientific systems and the mediational suitability of agriculture. The Drainage Board (JDA), controlled exclusively by the rice-farming sector, monopolizes water level management through a hydraulic calendar adapted solely to cultivation phases (Jégou; Sanchis-Ibor, 2019). This hegemony generates chronic water asynchrony and informational opacity, as the JDA does not routinely make public information on water levels and pumping operations. This situation is particularly detrimental to the fishers of El Palmar, who, despite holding historically formalized rights dating to the thirteenth century, are excluded from key decision-making processes—a situation that constitutes testimonial and political injustice within a geography of unequal power (Boelens; Claudín, 2015). Meanwhile, the scientific system warns that this management prioritizes productivism over the recovery of macrophytes and water transparency (Jégou; Sanchis-Ibor, 2019).

5.6.2 Competing legitimacies: Legal pluralism and consensual authority

A deep contradiction exists at the epistemic dimension of the systems. Whereas the agricultural and fisheries systems operate under a centuries-old "consensual authority" and local autonomy that has proven exceptionally effective in defusing internal conflicts through participatory mechanisms, the institutional system seeks to impose a technical-normative language grounded in state hydrological plans (Jégou; Sanchis-Ibor, 2019; Peris-Albentosa, 2015). This collision creates a scenario of legal pluralism in which actors appeal to different normative frameworks according to their strategic interests. The institutional system frequently perceives local knowledge as "anomalous" for failing to conform to its technical categories, while overlooking the fact that the prioritization of ecosystem services is statistically influenced by the professional and sociocultural backgrounds of the agents involved (Jorge-García; Estruch-Guitart; Aragonés-Beltrán, 2023).

5.6.3 The city versus the wetland: Scales of responsibility and "collateral damage"

The interaction between urban-industrial management and the wetland reveals a mismatch in ecological and axiological suitability. The expansion of the Valencia metropolitan area has recorded a 70% increase in urban surface area between 1990 and 2018, significantly reducing the environmental value of the territorial matrix (Rodrigo-Ilarri *et al.* 2025). This deterioration is described as "collateral damage" derived from industrial and urban activities external to the wetland but within its catchment area, introducing nutrients and heavy metals that chronically sustain hypertrophy. The result is a structure of mutually evaded responsibilities, in which local systems bear the costs of degradation generated by a conurbation of more than one million inhabitants (Palop Guillem, 2016).

5.6.4 Divergence in mental models of nature

Conflicts also stem from the cognitive dimension and from opposing mental models concerning the desired state of the wetland. Although most actors share the Albufera of the 1960s as an "idyllic landscape frame" or reference boundary object, their interpretations diverge: for the scientific system, it represents a biodiversity benchmark to be recovered, whereas for fishers and farmers it evokes an era of high productivity and clear waters (Jégou; Sanchis-Ibor, 2019). The absence of a "shared roadmap" prevents these systems from updating their perceptions in response to the new challenges of climate change and salinization, which threaten the very viability of rice cultivation in the tancats by the year 2050 (Palop Guillem, 2016).

5.6.5 Synthesis

Resolving these conflicts requires activating the transformative capacity of the Albufera by intentionally shifting the system toward shared and reflexive governance. This entails overcoming administrative fragmentation through the creation of bridging organizations that mediate between conservationist and productivist frameworks (Jégou; Sanchis-Ibor, 2019). Alliances such as the dynamic conservation linked to GIAHS recognition demonstrate that it is possible to integrate the farming community, academia, and civil society in order to transform historical inertias into a shared language that ensures the long-term sustainability of the wetland (García Álvarez-Coque; Bigné, 2020).

6. Potential of the Albufera Context for Mathematics Education

The extension of didactical suitability toward systemic suitability not only enables the analysis of complex water management processes but also offers a fertile framework for the design of problem-situations with high educational potential. The activity system of the Albufera de València, with its network of interdependent variables and its diversity of actors, constitutes a research scenario in the sense of Skovsmose (2013) with multiple levels of application in the mathematics classroom.

6.1 Mathematical Modeling and Quantitative Variables

The agricultural, fisheries, and scientific-environmental activity systems operate on variables that enable the construction of functional mathematical models connected to real sustainability problems. The regulation of water levels in the lake and the management of the outlet structures—the golas and perellons—allow for the formulation of problem-situations concerning flows, volumes, and rates of change that link differential calculus to ecological management. Complementarily, the monitoring of salinity and aquifer conductivity provides real data series for work in descriptive and inferential statistics, enabling students to assess ecosystem health through the analysis of temporal and spatial trends. This type of context corresponds to the approach of mathematical modeling as an educational practice (Blomhøj, 2004), in which the process of model construction is as relevant as the numerical result obtained.

6.2 Ethnomathematical Perspective in Traditional Systems

The agricultural and fisheries activity systems of the Albufera contain a notable ethnomathematical dimension (D'Ambrosio, 1990). The use of traditional units of measurement such as the fila de agua and the fanecada, as well as the historical allocation algorithms employed by the irrigation communities and the Water Tribunal, exemplify how local culture encodes quantitative solutions to problems of equitable resource distribution. Incorporating these contexts into the classroom promotes a dialogue between academic and local knowledge that enhances the affective-axiological and mediational suitability of the teaching process, while simultaneously contributing to the recognition of cultural heritage as a legitimate source of mathematical knowledge.

6.3 Teacher Education and Transdisciplinary STEM Projects

From the perspective of teacher education, water management in the Albufera constitutes a suitable prototype for the design of transdisciplinary STEM projects. In this context, systemic suitability operates as a meta-didactical tool that assists educators in identifying semiotic conflicts—recognizing, for example, that the concept of ecological flow acquires pragmatically distinct meanings for a fisher, a farmer, and an ecologist—and in articulating diverse disciplines by integrating biology, technology, engineering, and mathematics as a common modeling language. Engagement with this type of context in both initial and continuing teacher education enables educators to experience the complexity of real-world problems, where solutions are not purely numerical but require a joint assessment of the various dimensions of systemic suitability, thereby preparing students for the exercise of critical and reflective citizenship.

7. Conclusions and Perspectives

In this work, we have examined the extent to which the assumptions and tools of the Onto-Semiotic Approach (OSA) are pertinent for analyzing the emergence and dissemination of knowledge beyond the domain of mathematics, encompassing disciplinary scientific knowledge, professional knowledge, and local knowledge. Following the presentation of OSA tools linked to the processes of production, dissemination, and regulation within activity systems, the water management of the Albufera de València territory was selected as a case study. This constitutes a socio-technical-ecological system of considerable complexity, involving professional knowledge from diverse communities of practice as well as scientific knowledge from disciplines such as ecological economics, rural sociology, and hydrology. The preceding section has demonstrated that the Albufera de València case also constitutes an educational resource with notable potential for mathematics education. The problem-situations derived from water management allow for the articulation of mathematical modeling, an ethnomathematical perspective, and transdisciplinary STEM projects within contexts of high social and ecological relevance.

Due to space constraints, the onto-semiotic configuration tool has been applied exclusively to the agricultural water management activity system (Section 4). Its application to the other four identified activity systems would enable the deployment of the notion of pragmatic holomeaning to make explicit the articulation among the partial meanings implicated in the water management of the territory. Such analysis would contribute to identifying semiotic and ontological conflicts among actors and disciplinary perspectives, as well as to deepening understanding of the complexity of the socio-technical and socio-ecological problem under consideration.

The possibility likewise remains open for comparative studies with other theoretical frameworks applied to this same problem domain, such as the Social-Ecological Systems (SES) approach, which analyzes the interdependence between ecological dynamics and social processes. These frameworks have proven fundamental for understanding phenomena such as resilience, adaptability, and polycentric governance in environmental contexts (Ostrom, 2009; Folke, 2016). Although SES frameworks provide a common language for analyzing the co-evolution of human and natural systems, their emphasis on modeling and formalization tends to relegate to a secondary plane the semiotic, cultural, and evaluative dimensions that also influence decision-making and the construction of shared meanings.

Science and Technology Studies (STS) constitute another relevant theoretical pillar. Through concepts such as sociotechnical networks, infrastructures, mediation, and co-production, STS demonstrate that complex problems require analysis of how human and non-human actors are integrated into hybrid configurations (Latour, 2005; Star; Griesemer, 1989; Jasanoff, 2004). This perspective has significantly influenced interdisciplinary studies, where distributed agency and the social construction of research objects are emphasized (Newell, 2013). Nevertheless, although STS describe with considerable depth the sociomaterial dynamics of these assemblages, they generally offer fewer explicit tools for normative evaluation or for epistemic integration across disciplines.

In this regard, the OSA and the expanded notion of systemic suitability can provide a complementary analytical framework for studying the production, circulation, and evaluation of knowledge

in complex contexts of interaction among disciplines, professions, and local knowledge systems. The development of broader and comparative empirical studies will allow for a more precise assessment of the scope and limitations of this proposal in the analysis of knowledge production and dissemination processes in socio-technical and socio-ecological systems.

AI Use Statement:

During the preparation of this work, the author used the artificial intelligence tools Gemini and NotebookLM to search for documentary sources, suggest translations, and refine the writing for greater clarity and precision. AI did not participate in the conceptualization of the research objectives or methodology. Following the use of these tools, the author reviewed and edited the content as necessary and assumes full responsibility for it.

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