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The Notions of Education and Research

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ABSTRACT

This article starts examining the concept of "notion" as a semantic system encompassing both denotations and connotations that are generated by different linguistic contexts. Then, notions like "education" and "research" are analyzed using two approaches: (1) the etymological approach, which provides the general meaning, i.e. the root of the semantic branches generated by their historical evolution, and (2) the systemic approach, which explores their general meaning based on what is common to all systems, which is its telos (objective, purpose).

The term "education" originates from Latin roots meaning "to nourish" and "to lead out," reflecting its development from child-rearing to formal learning. As a teleological system, education is a "preparation for life" in the context of societal needs, integrating empirical reasoning, creativity, and interdisciplinary perspectives.

Similarly, "research" derives from the French "recercher," emphasizing an iterative process aligned with the well-known "trial and error" general method. As a cybernetic process, research involves continuous feedback, refining knowledge, and fostering understanding. This iterative nature enhances transdisciplinary communication and is exemplified by very effective methods for understanding and, hence being able to explain, like the Feynman technique, which proved its effectiveness for explaining Quantum Mechanic to College Freshmen.

Education and research form an interdependent, cybernetic system of continuous feedback, evolving goals, and adaptive learning. Their relationship exemplifies second-order cybernetics, where research informs education, and educational advancements refine research methodologies. This dynamic interplay supports knowledge development and the deepening of understanding, especially for the researchers who identified new knowledge. In this case, the new knowledge is a product of active and reiterative thinking.

1. THE TERM NOTION

We are using the term "notion", in this article, not as a vague or imprecise mental concept but in its linguistic sense—that is, as a set of denotations and connotations that a word may carry across different linguistic contexts. So, by referring to the "notion of education", we would be referring to the set of its denotations and connotations. Being the word "education" *common* to its different denotations, it communicates them. So, the word "notion" would be a related or relatable set, which by definition it would be a "system", a "semantic system". A similar situation happens with the "notion of research". Given that these relationships can vary in their degree of belongingness we propose that the sets associated with *education* and *research* may be considered fuzzy sets, and since they are related sets, then the word "notion" would mean a semantic system or, more precisely, fuzzy semantic systems.

Each of these two approaches provides a ***general meaning*** from which predicates can be applied to different specific meanings or senses of words:

1. *The Etymological Approach* views the etymology of a word as the root from which its subsequent denotations and connotations emerge. Through abductive reasoning, plausible specific senses may be derived for the ***species*** from the etymological root, i.e- the ***genus***. In this context, Predicate Logic allows us to attribute general predicates of the genus to its derived species. Thus, while the genus provides a broad foundational meaning, each species also possesses specific predicates reflecting its particular sense. Which would be added to the genus predicates.

2. *The Systemic Approach* is inherently a transdisciplinary one that recognizes that mental and linguistic realities, as well as natural and artificial systems, are structured as interconnected systems. Consequently, it enables the identification of a general genus within education and research, from which predicates applicable to its species can be logically derived. This approach, also, leverages Predicate Logic or Categorial Logic—both foundational to Formal Predicate Logic and naturally employed in human language—to systematically relate the general meaning to its specific disciplinary contexts.

The above approaches support interdisciplinary communication on transdisciplinary notions by integrating the specific senses (meanings) contributed by individual disciplines. These disciplinary senses add specific predicates to the general predicates derived from the genus. In this way, the specific predicates that emerge within a disciplinary context enrich the transdisciplinary notion or concept, ensuring its adaptability to diverse perspectives.

Since these meanings are not fixed but exhibit varying degrees of membership and relevance across different contexts, the related

sets of predicates can be considered fuzzy sets[1]. Furthermore, when we account for the relationships in these sets, they may be understood as fuzzy semantic systems. This perspective allows for the application of the Systems Approach, where the *inherent flexibility of such systems facilitates the dynamic integration of disciplinary insights, enhancing both the coherence and applicability of transdisciplinary communication.*

2. THE NOTION OF EDUCATION

2.1. Etymological Approach:

The word *education* originates from Latin, primarily from two terms: (1) *educare*, meaning "to nourish" or "bring up," and (2) *educere*, meaning "to lead out" or "bring forth."[2] The term entered the English language in the 1530s, initially referring to child-rearing, later evolving by the 1580s to encompass academic teaching (Online Etymological Dictionary). Today, education is understood as both the transmission of knowledge and the cultivation of understanding and judgment. Our experience-based opinion is that the transmission of knowledge is more effectively and adequately addressed than the other two.

We already mentioned above that the word's etymology provides the foundation of a *Semantic Structure* based on predicate or categorial Logic providing general predicates while also providing support for additional predicates of the different specific uses in the word by adding emergent specific predicate via the grammatical use of adjectives.

For example, specific disciplines contribute unique meanings to the notion of education, adding specialized predicates to the general predicates derived from the genus. These specific predicates emerge from the disciplinary contexts in which education is conceptualized and applied.

General and Specific Meanings of Education: As discussed, a general meaning of education serves as a necessary condition for defining the notion or concept. However, education within disciplinary and interdisciplinary fields requires additional specific predicates (or adjectives) to address the specificness of each field. While the general meaning provides a foundational baseline, it may not be sufficient to encompass the complexities of education tailored to specific disciplines. In general, we may provide the following examples.

- *Scientific Education* emphasizes empirical methods, experimental design, and hypothesis testing, fostering critical thinking and problem-solving skills within the natural or social sciences.
- *Arts Education* prioritizes creativity, aesthetic interpretation, and self-expression, aligning with the unique values of artistic disciplines.
- *Interdisciplinary Education*, such as environmental studies, integrates ecological, economic, and sociocultural perspectives, encouraging knowledge synthesis to address complex global challenges.
- *Technical Education,* including engineering and information technology, emphasizes applied skills, precision, and adherence to industry standards, bridging theoretical knowledge with professional practice.

Thus, while education is broadly defined as the process of acquiring knowledge, understanding, skills, and values, ensuring its relevance and effectiveness requires complementing this general meaning with discipline-specific predicates

2.2. A Systemic Perspective of Education

Based on what has been termed Singer/Churchman's "pragmatic Teleological Truth" (Churchman, 1971), the Systems Approach can be interpreted from two perspectives: (1) a pragmatic philosophical framework and (2) the inherent nature of any system to have goals, objectives, or purposes. Within this framework, a system's truth is determined by its *effectiveness* in achieving its goals, objectives, or purpose—its *telos*.

Consequently, education, whether as a process, a formal structure (for explicit formal education), and/or an informal organizational or cultural (for implicit informal education), can be defined by its *telos*. Its truth, in turn, is measured by its pragmatic effectiveness in achieving that *telos*.

In this context, I propose a teleological *description* (not necessarily a prescriptive *definition*) of education as "*preparation for life."* This description aligns with:

1. ***A pragmatic teleological framework***, where education's value and truth lie in its capacity to prepare individuals for life effectively, i.e. fulfilling its purpose.
2. ***An evolutionary perspective***, where education can be seen as a means for equipping individuals with knowledge, understanding, skills, judgment, and the necessary adaptability for survival, reflects the principle of "survival of the fittest," where "fittest" may be interpreted in various ways, such as physical strength, intelligence, empathy, or an optimal combination of these and other traits necessary for adaptation and success in different life contexts.

This teleological description situates education as a dynamic, purpose-driven system that evolves to meet the needs of individuals and societies, emphasizing its role in fostering resilience and adaptability in an ever-changing world.

Education's Telos is Associated with a Dynamic System in Evolution*:* Education, as a purposeful system and/or process, evolves to meet the changing needs of society and individuals. This evolution aligns with the concept of *telos*, where education's purpose adapts to cultural, environmental, and societal demands. Its definition, whether prescriptive or descriptive, must remain flexible to address evolving goals such as preparing individuals for global citizenship and supporting sustainable development.

[1] A **fuzzy set** extends the concept of a classical (crisp) set by allowing elements to have varying degrees of membership rather than a strict binary classification (belonging or not belonging). In a **non-fuzzy (crisp) set**, an element either fully belongs (membership = 1) or does not belong (membership = 0). In contrast, a fuzzy set assigns each element a membership value between 0 and 1, reflecting gradual or partial inclusion, which is particularly useful for modeling concepts with vague or overlapping boundaries.

[2] The second etymological root is the basis of the well-known Socratic method, also called the "midwifery method," whose function is to bring out the baby—in Socrates' case, to bring out the truth from the student.

From an evolutionary perspective, education's *telos* is to equip individuals with the tools to adapt to an interconnected, technologically advanced, and still advancing, diverse world, fostering resilience and adaptability. Education, as a teleological system and/or process, plays a vital role in shaping individuals and societies. Its truth lies in its effectiveness in achieving its *telos*, which evolves to meet individual and collective needs, ensuring its continued relevance in a dynamic world.

3. THE NOTION OF RESEARCH

3.1. Etymological Approach:

Research, *as a noun,* is from the "1570s, "act of searching closely" for a specific person or thing, from French recerche (1530s, Modern French recherche), back-formation[3] from Old French recercher "seek out, search closely" (Online Etymological Dictionary).

As a verb, two terms were used:

- Research, since 1590s, to mean "investigate or study (a matter) closely, search or examine with continued care," from French recercher, from Old French recercher "seek out, search closely," from re-, here perhaps an intensive prefix (…re-), + cercher "to seek for," from Latin circare "go about, wander, traverse," in Late Latin "to wander hither and thither," from circus "circle"." (Online Etymological Dictionary)
- *"Re-search",* in 1768, meant "to search again, examine repeatedly or anew" " (Online Etymological Dictionary). It was hyphenated to distinguish it from "research" as a noun and emphasize the prefix RE which means *repetition and reiteration.*
- In the 19th century, the differentiation between the noun and verb forms of "research" became less necessary, as context typically clarified its meaning. The noun form was understood through the use of articles ("a research," "the research"), while the verb form appeared in phrases like "to research." By this time, the singular form "research" had become fully established, and the hyphenated "re-search" had fallen out of use, reflecting broader trends in English towards simplification.

We extended this etymological description to emphasize the importance of the prefix "RE" because it represented the essence of the notion of research, i.e. reiteration, a cybernetic process with loops of negative (regulative) and positive (reinforcing) feedback.

This aligns with the idea of research not just as a static search for answers but as an ongoing process of refinement, adjustment, and discovery. It also aligns with the very well-known and old "*essay and error"* which characterizes both: scientific and non-scientific activities via explicit or implicit decision-making, as well as with inter- and transdisciplinary communication where iterations for improvements have, as a consequence, an increase of the knowledge we are trying to communicate. As with scientific research, each "iteration" of the research process of transdisciplinary communication brings new insights, which then loop back into the exploration, refining the question, the answer, or the transdisciplinary communication. This also explains the well-known effectiveness of the Feynman technique that proved to be effective in explaining quantum physics to freshmen.

The implicit and/or explicit cybernetic loop in a research process (research as a verb) is a self-educational process, especially because it provides understanding and not just knowledge. It increases the understanding of the knowledge being applied in the process as well as the new knowledge that the research process may create. This is because applying knowledge is one effective way to understand it. The implicit or explicit cybernetic loops in a research process are a necessary condition for self-education and, hence, for effective research because they provide a more or deeper understanding of the previous knowledge being applied, as well as of the new one that may be generated from the research process.

3.2. A Systemic Perspective of Research:

Research as a process (verb) or as a product (noun) is a temporal or atemporal system. i.e. a related set of parts with an intrinsic telos related to the objective(s) of the researcher(s).

1. Research, as a verb, is typically a complex system, especially when considered as a process that interacts with other highly intricate systems, such as the brain's neural networks and the meta-networks related to a researcher team, in which case the collective interplay of individual neural networks forms an even more complex system, particularly when mediated by complex semiotic systems, such as disciplinary frameworks and natural language.

   In this context, team-based research functions as a highly complex meta-system, whose components—already complex in themselves—interact dynamically. This complexity increases the likelihood of emergent properties, such as solving previously unsolved problems, generating new knowledge, understanding this new knowledge, and uncovering facts or potential truths.

2. While the *telos* of research as a *verb* is tied to the intentions of the researcher(s), the *telos* of research as a *noun* can be seen as an inherent orientation toward producing reliable, structured, and meaningful contributions to knowledge.

The general telos of research, as a noun, can be framed as the product of a reiterated systematic (structured) process. Since the reiteration of a systematic (structured) process generates implicit and/or explicit cybernetic loops, the reiterative process is, as a whole, a systemic one, making the systematic process self-regulating, self-reinforcing, and evolving. Research is not merely a linear accumulation of knowledge but a dynamic and adaptive system that refines itself through feedback loops.

Since research, as a noun, refers to a reiterated structured process rather than a linearly achieved intentional act, its *telos* can be understood as an emergent property of its reiterative methodology where reiteration adds complexity to the methodology while inserting the huge complexity of the neurological networks of the researcher(s) brain(s). Among these

[3] In this context "back-formation", the term "formation" is used to describe how the word "research" (in its modern English form) was created by taking the Old French *recercher* (which meant "to seek out or search closely") and altering it, often by dropping a suffix like "-er." The word "research" is an example of a back-formation from the original verb *recercher*.

emergent properties, we may have the following, via creativity and insights, which themselves are emergent properties as well. :

- *Advances knowledge*—whether by discovering new facts or theories, refining existing theories, or challenging assumptions or axioms used as foundations of other theories.
- *Generates and/or deepens understanding*—i.e., not just accumulating information and knowledge, but making sense of it in a coherent and meaningful way.
- *Solves problems*—that may be theoretical, practical, scientific, philosophical, humanistic, etc.
- *Improves communication*—as research contributes to shared knowledge, enabling inter- and transdisciplinary dialogues and cross-disciplinary knowledge sharing.
- *Supports analysis and synthesis*—and relating them via. Mathematical analysis, for example, discovers mathematical proofs, while mathematical synthesis generates the proofs that are used in education. This is due to the method of mathematical analysis going from potential theorems to their proof in the sense that they can be derived from the respective. Mathematical synthesis has the opposite method that goes from the axioms to the derivable theorems. Mathematical Analysis is a heuristic and creative process while synthesis is descriptive, demonstrative, and communicational process
- *Discovery and Explanation*—these are the product of analysis and synthesis, in general. Discovery is related to unveiling new facts, principles, or relationships; while explanation is related to providing a coherent and structured presentation of phenomena, which may support understanding and/or comprehending[4] it.

Consequently, any of the above or a combination of two or more of them may be the telos of research.

Because research functions within complex systems (cognitive, social, epistemic, linguistic, etc.) that interact through cybernetic reiteration, its "telos" remains open-ended. This open-ended nature enables the emergence of (1) new purposes and applications beyond the initial intentions of the individual researcher(s) and (2) serendipitous events where emergent phenomena lead to valuable and unforeseen discoveries or insights within scientific research.

4. THE CYBERNETIC RELATIONSHIPS BETWEEN THE RESEARCHER SUBJECT AND THE OBJECT BEING RESEARCHED

This cybernetic relationship happens, at least, at two levels: at the biological and the intellectual levels: the biological level is based on a bottom-up process while at the intellectual level, the process is mostly a top-down one. Both processes interact cybernetically with each other. Bottom-up processing relies solely on raw sensory data, building perception from external stimuli (sense data) without preconceived influence. While bottom-up processing ensures accurate responses to new information, top-down processing is an intellectual process involving the three components of the intellect: Cognition, Conation (Motivation), and Affect (emotion), where prior knowledge, experiences, expectations, beliefs, etc. shape the interpretation of sensory input. It helps resolve ambiguity by filling in missing or non-perceived sense data and is essential for tasks like reading and focused attention. The cybernetic process that relates both of them enables a balanced and adaptive comprehension of the environment. (Main, 2023)[5]

At the macro level the cybernetic relationship between research and the self-education of the researcher is fundamentally rooted in the dynamic interactions between subject and object and these interactions are based on cybernetic relationships between sense data and perception as noted above. In this case, the interaction is initiated by t*he researcher's objective*[6] *determines the object of observation or inquiry. In turn, the observed object, once perceived, is processed through the researcher's perceptual system, which integrates empirical sense data with corresponding neural patterns evoked within the brain,* via a cybernetic process as highly summarized in the above paragraph.

This apprehended perception provides input to a broader neural network, where it is processed through cognition, affect (emotion), and conation (motivation)—the three components of the intellect. As a result, the researcher's neural network adapts to assimilate this new information, forming the basis of learning and, consequently, self-education. This self-education can, in turn, refine or modify the researcher's objective, thereby altering the research focus itself and, hence, *closing the cybernetic loop between the processes of research and the self-education of the researcher.*

These cybernetic loops exhibit both *regulative* (negative feedback) and *reinforcing* (positive feedback) dynamics, ensuring continuous adaptation and refinement of both the research process and the researcher's intellectual development. This interplay sustains an ongoing, self-referential process of inquiry, where each iteration contributes to the evolution of knowledge and understanding of the researcher.

[4] While often used interchangeably, *understanding* and *comprehension* have slight differences. *Comprehension* refers to grasping the meaning of information, often through recognition and recall (e.g., reading a text and knowing what it states). *Understanding*, however, implies a deeper cognitive integration, where one not only comprehends but also connects, interprets, and applies the information meaningfully (e.g., explaining a concept in one's own words or using it in a novel context). Understanding is thus a more holistic and dynamic process, often requiring reflection, synthesis, and insight beyond mere comprehension.

[5] Paul Main´s work often focuses on educational innovation, metacognition, and the science of learning. His article on top-down and bottom-up processing aligns with his expertise in cognitive processes and their applications in education.

[6] This is supported by the intellect as a whole, i.e. cybernetically related Cognition, Conation (motivation), and Affect (emotion)

After the summary, we made above, based on biological processes, let us now make a summary of the cybernetic processes at the conceptual or notional level.

4.1. *A Systemic/Cybernetic Perspective of the Notions of Subject and Object*[7]

Edgar Morin (On Complexity, 2008) affirms clearly and emphatically that "Subject and object are *indissociable*…Our path is cleared on one side by micro-physics where **subject and objects become *relation***…and in the other by *cybernetics* [especially Second Order Cybernetics] and the concept of self-organization." (p. 25) [Italic and emphasis added]

This evolution of epistemological paradigms has increasingly emphasized the inseparability of subject and object, observer and observed. This shift, as Edgar Morin (2008) argues, is driven by advancements in Quantum Mechanics[8] and cybernetics—particularly Second-Order Cybernetics[9]—which reconceptualize knowledge as a relational and self-organizing process, via reflexive practice. Building on these insights, our long-term research (Callaos, 1976) (Callaos, 1995) has sought to develop a systemic epistemology that integrates subject-based rationalistic epistemologies (Descartes, Leibniz, Spinoza), object-based empiricist epistemologies (Locke, Hume), and pragmatic-teleological truth (Singer-Churchman).

Through extensive studies and approximately 100 action-research, action-design, and/or action-learning projects, we proposed a ***plural epistemology*** based on ***distributed truth***—an approach that reconciles multiple epistemological perspectives through systemic interrelations, feedback loops, and reflexive adaptation. This section summarizes the theoretical foundations and practical implications of such an epistemology, particularly in the context of transdisciplinary communication.

Given the interdisciplinary nature of the event, we hope the following text may also provide information to readers from diverse backgrounds in navigating the material more effectively.

4.1.1. The Cybernetic Inseparability of Observer and Observed: Morin's assertion that *"subject and object are indissociable"* reflects a paradigm shift in epistemology. This perspective aligns with second-order cybernetics, where the observer is always embedded in the observing system.

The consequences of this shift include:

- *Knowledge as Relational*: Rather than being purely objective or subjective, knowledge emerges through interactions between the observer and the observed.
- *Self-Organization of Epistemic Systems*: Knowledge processes are adaptive, self-regulating, and subject to positive and negative feedback loops.
- *Reflexivity as a Fundamental Epistemic Criterion**:*** Knowledge production requires an awareness of the observer's role, biases, and transformations within the process.

4.1.2. Towards a Plural Epistemology: Distributed Truth: Traditionally, epistemology has oscillated between rationalist, empiricist, and pragmatic paradigms. Our research suggests that a *plural epistemology*—one that integrates subject-object relations and action-oriented transformations—provides a more comprehensive framework. This approach involves three notions of truth mentioned by (Churchman, 1971):

- *Consensual Truth*: Knowledge that is validated through collective agreement and discourse within intellectual communities.
- *Analytical Truth**:*** Formalized, logical structures that provide coherence and internal consistency.
- *Pragmatic-Teleological Truth*: Knowledge that proves its validity through practical application and goal-oriented transformation. And we should add
- *Perception-Transformation Duality*: Observers not only perceive but are also transformed by their engagement with knowledge processes.

4.1.3. Reflexivity, Cybernetics, and "Transdisciplinary Research, Education, and Communication": One of the key implications of this plural epistemology is its relevance to transdisciplinary research, education, and communication, because they may involve multiple epistemic frameworks. For example, a ***cybernetic approach*** can facilitate the integration of diverse knowledge domains by:

- *Enhancing Reflexivity**:*** Researchers must be aware of their epistemological positioning and how it affects cross-disciplinary dialogue.
- *Creating Meta-Communication Mechanisms*: Shared conceptual tools, such as systemic methodologies and cybernetic models, can help bridge disciplinary boundaries.
- *Facilitating Knowledge Co-Evolution*: Through feedback loops and iterative learning, transdisciplinary collaboration fosters emergent knowledge structures that surpass individual disciplinary limitations.

The cybernetic interplay between education and research is central to this epistemological framework. Research, as a process, is inherently *self-regulating, self-reinforcing, and evolving**, generating both new knowledge and new modes of learning***. The implications for education include:

- *Embedding Reflexivity in Curricula*: Encouraging students and researchers to critically examine their epistemological assumptions.

[7] This sub-section is based on (Callaos, 1995, pp. 389-416)

[8] There are two reasons in Quantum Mechanics: 1) the observer Effect: measurement affects the system being observed, reinforcing the inseparability of subject and object, and 2) Quantum Entanglement that demonstrates nonlocal relationships, suggesting that knowledge and systems cannot be understood in isolation but as interrelated wholes.

[9] Second-order cybernetic reflexivity refers to the self-referential process in which the observer is an integral part of the system being observed. Unlike first-order cybernetics, which focuses on controlling observed systems, second-order cybernetics recognizes that observation itself influences the system. This perspective, advanced by Heinz von Foerster and others, emphasizes that knowledge production is inherently recursive, involving feedback loops that shape both the observer and the observed (Von Foerster, 1981)

- *Promoting Action-Research as a Learning Model:* Integrating iterative cycles of observation, reflection, and adaptation into academic training.
- *Leveraging Cybernetic Feedback for Institutional Learning*: Universities and research institutions can adopt self-organizing principles to continuously refine their knowledge-production processes.
- *Cybernetic Complementarity Between Analogical and Logical Thinking*:
  It is important to make explicit—and perhaps repeatedly—that analogical thinking provides the entry point for logical thinking in the creative process. Consequently, logical thinking would be sterile without analogical thinking, and analogical thinking would be intellectually risky without logical thinking. Both types of thinking are cybernetically related, almost always implicitly. Therefore, *making their relationship explicit* would enhance their efficacy, understanding *efficacy* as an appropriate tradeoff between efficiency and effectiveness within their cybernetic loop.

We may conclude in this section that by integrating first- and second-order cybernetics, systemic methodologies, and a plural epistemology, we may be suggesting a framework where knowledge is *not an isolated product but an emergent, self-organizing process*. This perspective challenges traditional epistemological dichotomies and fosters a more dynamic, reflexive approach to ***integrating research and education***.

Figure 1 schematizes the main object-subject relationships that supported the perspective with which we developed (and still developing in an evolutionary-incremental way *Systemic Systems Methodology.* Details are provided in (Callaos N. , 1995, pp. 369-416), which provides the conceptual foundations for ***making explicit the implicit relations between object and subject and, hence education and research***. We may conclude that research is always educational and education is, or should be, always based on inquiry. Developing inquiry motivation (Conation) and cognition is, or should be essential, in educational processes, especially at a young age because of its respective high level of neural plasticity.

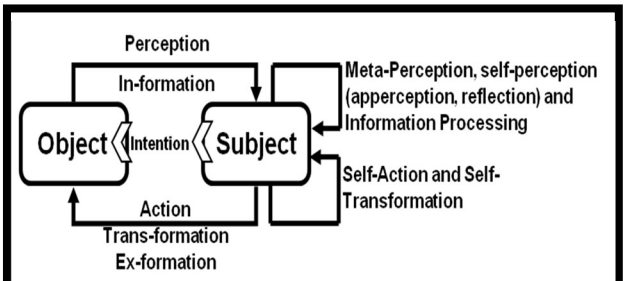

Figure 1. Cybernetic-systemic relationships integrating subject and object into a whole. It is based in 1) an expansion of Singer-Churchman's (Churchman, 1971) teleological-pragmatic conception of the truth, and 2) 2nd Order Cybernetics by means of which we added subject's self-perception and self-action

In Figure 1 we contrasted the words 'in-formation' and 'ex-formation'[10] [i] [ii] to refer reciprocal transformation of internal with external "words and worlds"[11].[iii] That respectively refers to:

1. the 'forms' originating from the object (and other subjects) and are **in**stilled **into** the subject, i.e. in-formation', and
2. the 'forms' originating in the subject's mind (or neural networks), who **trans**-forms them into physical signals (language, for example) in order to communicate them to his/her **ex**ternal environments, or to **ex**press, **ex**teriorize them via **ex**ternal objects or to other subjects, i.e. ex-formation. The subject may exteriorize his/her mental forms via: 1) communicational signals, or verbal action, 2) technological action processes ending in technological innovations or products, or 3) direct physical action. In any case, forms that are internal to a subject's mind are exteriorized into physical forms and/or into mental forms of other subjects. In the way we are using the term 'subject', we are including the minds of observers (philosophers and scientists, for example), as well as doers and creators (e.g., engineers and artists). On the other side of the coin, the term "object" will also include technological and aesthetic objects, and not just what is observed by the observer and what is known by the knower.

Although some authors refer to 'subjective' and 'objective' in the Cartesian sense of these terms, i.e., as Cartesian dichotomies, by no means we are using, in this section 'subject' and 'object' in their Cartesian sense. Object and subject are being used here, from a *systemic perspective*, i.e. as highly interrelated notions via cybernetic loops. The object is what is related to the objective of the subject, so it is what the subject observes and/or mentally or physically structures or construes. We are not using the term "subject" in its sense of "mental substance", but in its sense of

[10] We need to alert that the reader ***we are not using the term "ex-formation" in the sense of*** "explicitly excluded information" as it was used by Danish physicist Tor Nørretranders (The User Illusion: Cutting Consciousness Down to Size, 1999) who used the Danish word *eksformation* (translated as ex-formation by J. Sydenham (1998) to English as 'exformation'. Hugh Fox III (Science Fiction Dictionary) affirms that Tor Nørretranders used the word Exformation to mean "the information which has been abstracted away, and now is implicitly included in the message." (see End Note i). Likewise, we ***are not using the term either in the sense that Stanislaw Lem*** (Exformation: Die explosive Information, 1997) used it to designate "information explosion," (See End Note ii)

[11] In the meaning of the phrase *Internal and external "words and worlds***"**, internal words refer to thought, inner dialogue, and/or mental representation, while external words are expressed language oriented to the exterior in communication processes. Internal worlds encompass subjective cognition and perception, whereas external worlds refer to symbols shared with others and objective reality. *Their interplay shapes understanding and communication (see End Note* iii)

'substratum', substructure', or 'infrastructure', i.e. what underlies and supports our thoughts, what relates our perceptions and ideas and, potentially, integrate them in a whole; what structures and construes our mental constructs; what forms, get informed, and ex-forms, via speech or writing.

We are using the terms "object" and "subject" in their general meaning, not in the many specific or technical senses they have had in different thinkers and philosophers. With the terms "object" and "subject" we are trying to distinguish between knowers and knowns; As Jaquette (1995) did. This author affirmed:

> "[B]etween thinkers and what they think about. The distinction is not an *exclusionary* one, since subjects can also be objects, as it is the case in reflexive self-conscience thought, which takes the subject as its intended object. The dichotomy also needs not to be an *exhaustive* distinction in the strong sense that everything is either a subject or an object, since in a logically possible world in which there are no thinkers [or knowers], there may yet be mind-independent things that are neither subjects nor objects…The dichotomy is ***an inter-implicative distinction*** between thinkers [knowers] and what they think about [known], in which each presupposes the other. If there are no subjects, then neither are there objects in the true sense; and conversely" (Jaquette, 1995, pp. 885-6) [Italics and emphasis added]

5. CYBERNETIC RELATIONSHIPS BETWEEN RESEARCH AND EDUCATION

From the above, we easily may conclude that there is no genuine research activity that does not generate implicit or explicit learning, which is education because it is active learning in the context of a contextual process and product.

Research is itself an educational journey, shaped by both the researcher's objective and the object of study[12]. Explicit research inherently involves implicit or informal education, as it fosters both unconscious and guided informal learning shaped by the researcher's objectives and the nature of the object being investigated. This means that research generates:

1. Explicit Learning: because of the intentional acquisition of knowledge and skills directly related to the research objectives; as well as
2. Implicit Learning: because of the non-intentional absorption of information, patterns, and insights that occur naturally during the research process.

The cybernetic relationships between subject and object are mainly based on

1. The researcher is not separate from the object being studied because it was determined by the researcher's objective and the interaction may change the object or add sub-objectives
2. Hence, there are explicit and implicit continuous feedback loops between objectives, methods, and findings.

This means that the objectives define the research focus, yet interaction with the object can lead to a shift in objectives through *reflection and metacognitive, reflexive practice*. This process, whether unconscious or highly deliberate, aligns with the principles of Second-Order Cybernetics, mentioned several times above, which emphasizes metacognitive self-reference and adaptation in all forms of research.

As we mentioned in section 3, research is, implicitly or explicitly, an iterative process; an ongoing process of refinement and discovery, rather than a static search for answers. This approach aligns with the very old and well-known ***"trial and error"*** notion used in all, or most, fields. Iterative improvements include new insights that refine previous questions, answers, or methods. This cyclical process explains the effectiveness of techniques like Richard Feynman's method based on cybernetically reiterating an explanation in order to increase the understanding of what is already known knowledge. This increase in understanding increases in turn the increase of the skills for explaining and communicating complex issues in understandable terms. Since the Feynman technique has shown once and again its high educational effectiveness, then the iterations in research have also implicitly or explicitly an educational aspect for both: those who are making the reiteration (self-education) and for those to whom the educational processes are oriented to. This is because of the increased understanding the educator has of what s/he already knows. *So,* ***research activities generate self-education which, in turn, may increase the educational effectiveness of the researcher.*** This supports, though in part, the diagram in Figure 2

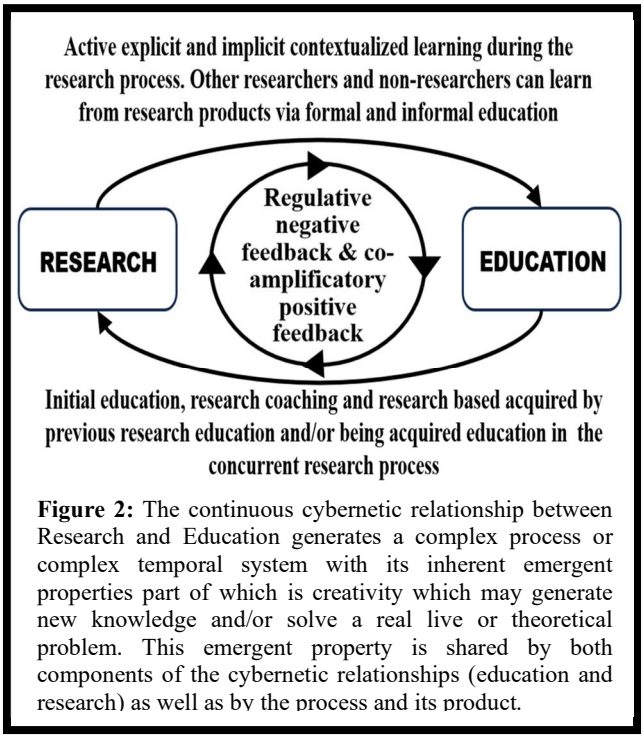

Figure 2: The continuous cybernetic relationship between Research and Education generates a complex process or complex temporal system with its inherent emergent properties part of which is creativity which may generate new knowledge and/or solve a real live or theoretical problem. This emergent property is shared by both components of the cybernetic relationships (education and research) as well as by the process and its product.

[12] This notion aligns with constructivist learning theories, which posit that knowledge is actively constructed through experiences and interactions with the environment. In the context of research, this environment includes both the subject matter and the research process itself.

The transhistorical and transdisciplinary nature of 'trial and error,' whether implicit or explicit, establishes it as the foundational genre of research. As a process, this genre encompasses variations arising from (1) the historical evolution of research and (2) the diversity of disciplinary, interdisciplinary, and transdisciplinary fields of knowledge. These variations introduce specific predicates that supplement the general predicate of the research genre (cybernetic reiteration, essay, and error). This structure formally relates research in general to research in specific fields, which can be modeled using *Predicate Logic, Categorial Logic, or more, precisely*, ***Natural Language Predicate Logic.***

Effective research requires a foundational level of general education and/or in the specific research field, as well as education in and for research processes. Let us reiterate that the specific requirements may vary depending on the disciplinary or interdisciplinary field, as previously mentioned, ***Natural Language Predicate Logic***. And, Conversely, research generates educational content as a direct outcome, besides the already mentioned researcher education. This is because even if someone is not a researcher, they can still benefit from the research process by learning how to engage with new ideas, make informed choices, and contribute to discussions that shape society.

Practical applications are among the most immediate benefits, such as when medical research informs individuals about vaccine safety, agricultural studies help farmers improve yields, or cognitive psychology enhances learning strategies in education. Beyond direct applications, research also expands conceptual understanding. Discoveries in physics and cosmology reshape how people think about the universe, while historical and archaeological findings offer new perspectives on human civilization.

Research also strengthens critical thinking skills. Studies on misinformation and cognitive biases help individuals navigate media more effectively, while insights from behavioral economics make people more aware of how marketing tactics influence their choices. Ethical and social awareness is another key outcome. Understanding AI ethics fosters discussions about algorithmic bias and digital privacy, while environmental science research informs personal and policy decisions regarding climate change and sustainability.

Researchers in other fields and non-researchers benefit from research in learning and education by gaining practical knowledge, expanding their understanding of the world, and developing critical thinking skills. For example, research in cognitive psychology improves learning strategies, helping students and educators optimize study techniques. Historical and scientific discoveries reshape how individuals perceive the past and the universe, fostering intellectual curiosity. Studies on misinformation and biases enhance media literacy, equipping learners with tools to assess information critically. Additionally, interdisciplinary research introduces diverse cultural and epistemological perspectives, enriching education beyond traditional disciplines. Ultimately, research empowers lifelong learning by providing accessible knowledge and analytical skills that help individuals navigate an increasingly complex world.

From a cybernetic and epistemological perspective, the processes of research and education form a dynamic feedback system in which each regulates and transforms the other (Figure 2). They are not merely two sides of the same coin but rather interdependent components within a complex knowledge ecosystem. In this sense, research not only enriches education with new findings, but education also structures the interpretative and methodological frameworks of research. Depending on the context, one may function as a means or criterion for the other, as seen in 'educational research' and 'investigative education' or 'education for research,' where the emphasis is either on studying educational processes or on developing investigative competencies within education itself. This process is not linear but adaptive and recursive, reflecting the emergent nature of knowledge in complex systems.

“Educational Research” and “Research Education” 1) may also be related cybernetically and 2) may support the “cybernetic relationships between education and research”, because both “Educational Research” and “Research Education” function as self-regulating, mutually reinforcing systems within the broader cybernetic framework of knowledge production. This perspective aligns well with second-order cybernetics, where systems reflect on and adapt their own processes, making education and research not just interconnected but ***co-evolving systems***.

Findings from educational research can be incorporated into the curriculum for research education methods, creating a feedback loop where research about education informs how research education may be handled, coached, or taught. Conversely, as potential researchers learn advanced research methodologies, they become better equipped to conduct high-quality educational research, thereby improving the overall quality of the field. The cybernetic relationship between these domains is characterized by self-regulation, self-reinforcements, and adaptation.

Educational Research and Education for Research are linked within a cybernetic framework in which both, mutually, reinforce each other as self-regulating and mutually reinforcing systems within a broader network of knowledge production. This perspective aligns with second-order cybernetics, where systems not only interact but also reflect on, are reflexive (i.e., its human components may make reflexive practice) and adapt their own processes. Thus, education and research are not only interconnected but also co-evolve.

Findings from educational research can be incorporated into research methodology curricula, creating a feedback loop where the study of education informs how the education of future researchers can be designed, taught, and improved. In turn, as these researchers learn advanced methodologies, they become better equipped to conduct high-quality educational research, thereby strengthening the field. The cybernetic relationship between these domains is characterized by self-regulation, co-evolution, and dynamic adaptation.

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END NOTES

[i] Regarding of how the word ex-formation was used by the Danish physicist Tor Nørretranders (The User Illusion, 1991/1999), Michael Quinion (Exformation, 1998) affirms:

> "This word [ex-formation] is used by Tor Nørretranders in his book (1999) *The User Illusion*, published in Danish in 1991 and in English in 1998. He argues that effective communication depends on a shared body of knowledge between the persons communicating. If someone is talking about cows, for example, what is said will be unintelligible unless the person listening has some idea what a cow is, what it is good for, and in what contexts one might encounter one. In using the word "cow", Nørretranders says, the speaker has deliberately thrown away a huge body of information, though it remains implied. He illustrates the point with a story of Victor Hugo writing to his publisher to ask how his most recent book, *Les Miserables*, was getting on. Hugo just wrote "?", to which his publisher replied "!", to indicate it was selling well. The exchange would have no meaning to a third party because the shared context is unique to those taking part in it. This shared context Tor Nørretranders calls *exformation*. He coined the word as a abbreviated form of *explicitly discarded information*, originally in Danish as *eksformation*; the word first appeared in English in an article he wrote in 1992. He says "exformation is everything we do not actually say but have in our heads when or before we say anything at all. Information is the measurable, demonstrable utterance we actually come out with".

[ii] Stanislaw Lem's meaning of *exformation* in *Exformation: Die explosive Information* (1997), referenced by (Swirski, 1997) appears to diverge, in an important way, from the previous two referred in End Note i [Tor Nørretranders (The User Illusion, 1991/1999) and Michael Quinion (Exformation, 1998). Stanislaw Lem's perspective on exformation in "Exformation: Die explosive Information" (1997) [referenced by (Swirski, 1997)] indeed diverges from the views of Nørretranders and Quinion in significant ways. While the latter two conceptualize exformation as a process of information reduction or filtering, Lem explores it within the context of the modern information explosion and its unintended consequences [Jerzy Jarzębski (Stanislaw Lem, Rationalist and Visionay, 1977)

Lem's use of "EX-" in exformation goes beyond the idea of discarding information. Instead, it connects to the concept of an EXPLOSION of information, where the sheer volume of data overwhelms our ability to understand and process it effectively [Ezra Glinter, (Los Angeles Review of Books, 2016)]

This aligns with Lem's broader philosophical concerns about the challenges of knowledge and understanding in an increasingly complex world (Godhe, 2021). In his critique of information overload in the digital age, Lem argues that the vast amounts of available data do not necessarily translate into greater knowledge or wisdom.. He suggest that crucial information can be lost in the noise of excessive data, echoing his long-standing interest in the limits of human cognition and the challenges of communication (Jarzębski, 1977)

Lem's exploration of exformation reflects his broader philosophical approach, which often involved examining the unintended consequences of technological and scientific progress (Godhe, 2021) His perspective on information overload anticipates many of the challenges we face in today's digital landscape, where the abundance of information can paradoxically lead to a loss of meaningful understanding (Delta Psychology, 2025)

This means that:

- While Nørretranders and Quinion see exformation as **a reduction or filtering of information**, Lem explores it in the context of **the modern explosion of information** and its unintended effects.
- Lem's use of "EX-" does not just imply **discarding** (as in Nørretranders' sense) but also connects to the idea of an *EXPLOSION* of information, where the sheer volume of data overwhelms understanding.
- He critiques the **information overload of the digital age**, arguing that vast amounts of data do not necessarily lead to greater knowledge or wisdom. Instead, crucial information can be lost in the noise.

[iii] The highly used notion of "internal words and world" is deeply rooted in philosophical and cognitive traditions, though it seems not to have a clear attribution to any single thinker, in spite of its frequent use. This idea supporting this notion has been shaped by various influential figures across different disciplines. In philosophy, thinkers like:

- *Plato* explored the notion of thought as an inner dialogue or inner speech [Gregory & Langland-Hassan (Inner Speech, 2023)], while
- Augustine delved into the distinction between internal understanding and external signs; he uses the "notion of signification to relate the external to the internal" (Gregory & Langland-Hassan, 2023) .
- *Descartes* further developed the concept of mental representation. Whose notion of ideas are presented as "as modes of thinking that represent (or present or exhibit) objects to the mind" [Kurt Smith (Descartes' Theory of Ideas, 2024)],
- The field of linguistics and psychology saw contributions from scholars such as *Humboldt,* who proposed *that language shapes thought*, i.e. "Humboldt catches sight of a more profound function of language, where it is no longer understood primarily as communication, but rather as itself an originary and formative "organ of thought" not in any sense limited to representation, but which on the contrary is instrumental in the genesis of (new) concepts themselves" [Joseph Weisman (Language is not a Signal: Notes on Wilhelm von Humboldt, 2008)
- *Vygotsky,* who explored the concept of *inner speech*. (Alderson-Day & Fernyhough, 2015) affirm that his "theory of cognitive development, *inner speech* is the outcome of a developmental process". Vygotsky assumed that understanding how such a phenomenon emerges over the life span is necessary for full comprehension of its subjective qualities and functional characteristics. Via a mechanism of internalization, linguistically mediated social exchanges (such as those between the child and a caregiver) are transformed, in Vygotsky's model, into an *internalized "conversation" with the self.* The development of verbal

mediation is envisaged as the process through which children become able to use language and other sign systems to regulate their own behavior. *Prelinguistic intelligence* is thus reshaped by language to create what Vygotsky and his student Luria termed a "functional system," a key concept in their antimodularist view of functional localization in the brain" [Italics added]