

Education, Research, and Methodology: A Transdisciplinary Cybernetic Whole

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ABSTRACT

In this article, we explore the implicit yet foundational cybernetic relationships among three of the most transdisciplinary conceptual constructs: **Education**, **Research**, and **Methodology**. It argues that these three domains are not merely interconnected but form a **Cybernetic Triad** whose interactions generate emergent properties, such as deeper understanding, creativity, and systemic synergy, when made explicit. By using a top-down approach, the article models these relationships through feedback loops and mutual influence, highlighting how each domain serves as both input and output to the others. The discussion incorporates examples from various disciplines, distinguishing between **systematic (closed)** and **systemic (open)** methodologies, and proposing a knowledge framework that includes not just "know-what" and "know-how" but also "know-why", "know-when", and "know-where". It concludes that engaging with this triadic system reflexively enhances individual and collective effectiveness, particularly in transdisciplinary contexts. In this context, a gap is identified in regard to making transdisciplinary communication a practical skill within academia. Consequently, a structured model is proposed to embed it systematically into education, research, and methodology, recommending curricular, project, and institutional integration for greater impact.

Keywords: Education, Research, Methodology, cybernetic relationships, Cybernetic Triad.

1. PURPOSE

The purpose of this article is to make explicit the often-implicit cybernetic relationships among **Education**, **Research**, and **Methodology**, three of the most transdisciplinary concepts, which may significantly influence the **mental design** we hold of each. The word *design* itself comes from the Latin "*designare*", which means not only "to mark" but also "to designate" or "to assign purpose." In this sense, *to redesign our understanding of Education, Research, or Methodology is to reorient their telos*, their intended function or role, within a broader system. By bringing to light the mutual feedback loops that link these domains, we do not merely observe their interconnections; we actively reshape the **purpose-driven mental models** through which we engage with them. Such reflexive awareness can enhance both individual insights and collective effectiveness across disciplinary boundaries.

It seems evident that *Education*, *Research*, and *Methodology* are

transdisciplinary abstract concepts, or linguistic notions or constructs, that are used, explicitly or implicitly, across all fields of Science, Engineering, and the Humanities. Hence, our mentioned purpose may be perceived and/or conceived for any discipline. These three general and transdisciplinary notions are inherently interconnected, though their relationships are often **implicit**. Among these relationships, the most important (which are still frequently) implicit, are the *cybernetic* ones) due to the synergies they can generate. Making these relationships **explicit** would significantly amplify their synergistic effects.

In practice, each of these three notions is commonly represented as a system, more precisely, as a **complex system**. Thus, making their interrelations explicit forms a **complex meta-system**, composed of the mutual interactions among these three complex systems. As a result, this explicit relational structure increases both the potential and the probability of **emergent properties** such as deeper understanding, novel insights, enhanced creativity, and greater systemic synergy.

Furthermore, if we recognize that the relations among Education, Research, and Methodology are understood as fundamentally cybernetic, based on feedback loops and mutual influence, **making them explicit** further increases the likelihood and the intensity of emergent properties such as those previously described. This reflexive awareness also adds complexity to the neural and cognitive systems of those who reflect on these interrelations, thereby contributing to the cybernetic complexity of the entire triadic system.

In this light, the individual who consciously grasps and reflects upon this Cybernetic Triad may be the one who benefits most intellectually. These emergent cognitive and systemic properties may, in turn, lead to pragmatic outcomes, namely, enhanced effectiveness in both internal and external actions.

2. CYBERNETIC RELATIONSHIPS

We will now briefly describe the cybernetic relationships within the mentioned triad. In this case, we have chosen a top-down approach, beginning with a diagram that presents a visual overview of the Cybernetic Triad. This initial synthesis is intended to provide a contextual framework, allowing the detailed descriptions that follow to be more meaningfully understood. As is well known, it is the context that gives meaning to the parts. While beginning with a part-by-part analysis and moving toward synthesis has its own advantages, our subject matter, three of the most transdisciplinary concepts, may benefit

more from an initial synthetic representation before examining the nine interrelated components of the diagram presented in Figure 1.

2.1. Education and Research: A Cybernetic Relationship

The relationship between education and research is neither linear nor unidirectional; it is fundamentally cybernetic in nature, characterized by reciprocal influence and continuous feedback loops. Education equips individuals with foundational knowledge, conceptual frameworks, and cognitive strategies essential for engaging in research. At the same time, research transforms education by enriching its content, challenging its assumptions, and updating its methodologies.

This mutual conditioning fosters a dynamic process in which learning is not merely the passive reception of information, but rather an active, iterative construction of understanding. Educational processes frequently culminate in research projects, theses, capstone projects, or exploratory studies, which serve as both a test and a refinement of what has been learned. Conversely, research continually informs educational practices, curricular development, and epistemological orientations, thereby ensuring that education remains responsive to evolving knowledge and real-world complexity.

This cybernetic interplay generates *emergent intelligence*¹: as learners become researchers, they also become co-producers of knowledge, and as research reshapes educational structures, it also transforms the learning subject. This systemic relationship sets the stage for a more detailed analysis of the inputs each domain provides to the other, an analysis that follows in two interrelated subsections.

Each research project or activity is, by its very nature, an educational process, even if implicitly so. The self-directed learning involved in conducting research is one reason why research effectiveness is a critical factor in academic advancement. Research not only facilitates independent learning but often requires a rethinking or reconfiguration of previously acquired knowledge. Moreover, it demands adaptation to the inherent uncertainty of inquiry, uncertainty that stems, in part, from the classical and still-relevant meta-method of “trial and error.” This source of variability challenges the researcher to engage in self-correction, reflective adaptation, and intellectual diversification.

Such intellectual diversification aligns with Ross Ashby’s (1958) First Law of Cybernetics (Requisite Variety², i.e., “*Only variety can absorb variety*”), which was translated by Ashby from its mathematical formalism to a transdisciplinary principle. In this context, only intellectual variety can effectively respond to the complexity and unpredictability that emerge during research processes, particularly those guided by heuristic, open-ended methodologies like trial and error.

On the other side, most educational systems incorporate explicit research components, particularly at the graduate level. Master’s and PhD programs typically culminate in substantial research projects. In many universities, even five-year undergraduate programs include a final year dedicated to a graduation project or thesis. These requirements often aim to apply theoretical learning to real-world problems, thereby deepening understanding through praxis. When knowledge is applied, it tends to generate its own understanding; the more knowledge is applied across diverse contexts, the deeper and more nuanced that understanding becomes.

It is important to underscore that while knowledge acquisition can be binary (one either possesses specific knowledge or not), understanding is gradational, ranging from shallow familiarity to deep insight. Research provides a privileged pathway for transitioning from knowing to understanding, and education increasingly recognizes this by embedding research activities into its core structure.

In order to continue with Top-Down Presentation, we are trying to do so; let us now have two short subsections separating some details in two opposite cybernetic directions.

2.1.1. Education as Input to Research

Education serves as the foundational input to research by providing not only factual knowledge but also conceptual schemas, methodological principles, and the cognitive dispositions necessary for inquiry. This preparatory role includes both explicit instruction, through curricula, textbooks, and coursework, and implicit habituation to problem-solving, reasoning, and critical thinking. Moreover, educational systems often culminate in research-like activities such as theses or capstone projects, which apply knowledge to real-world problems. These projects not only synthesize prior learning but also generate deeper understanding, since applied knowledge produces insight through experience. In this sense, education sets the stage for research by constructing the cognitive and epistemic infrastructure on which it depends.

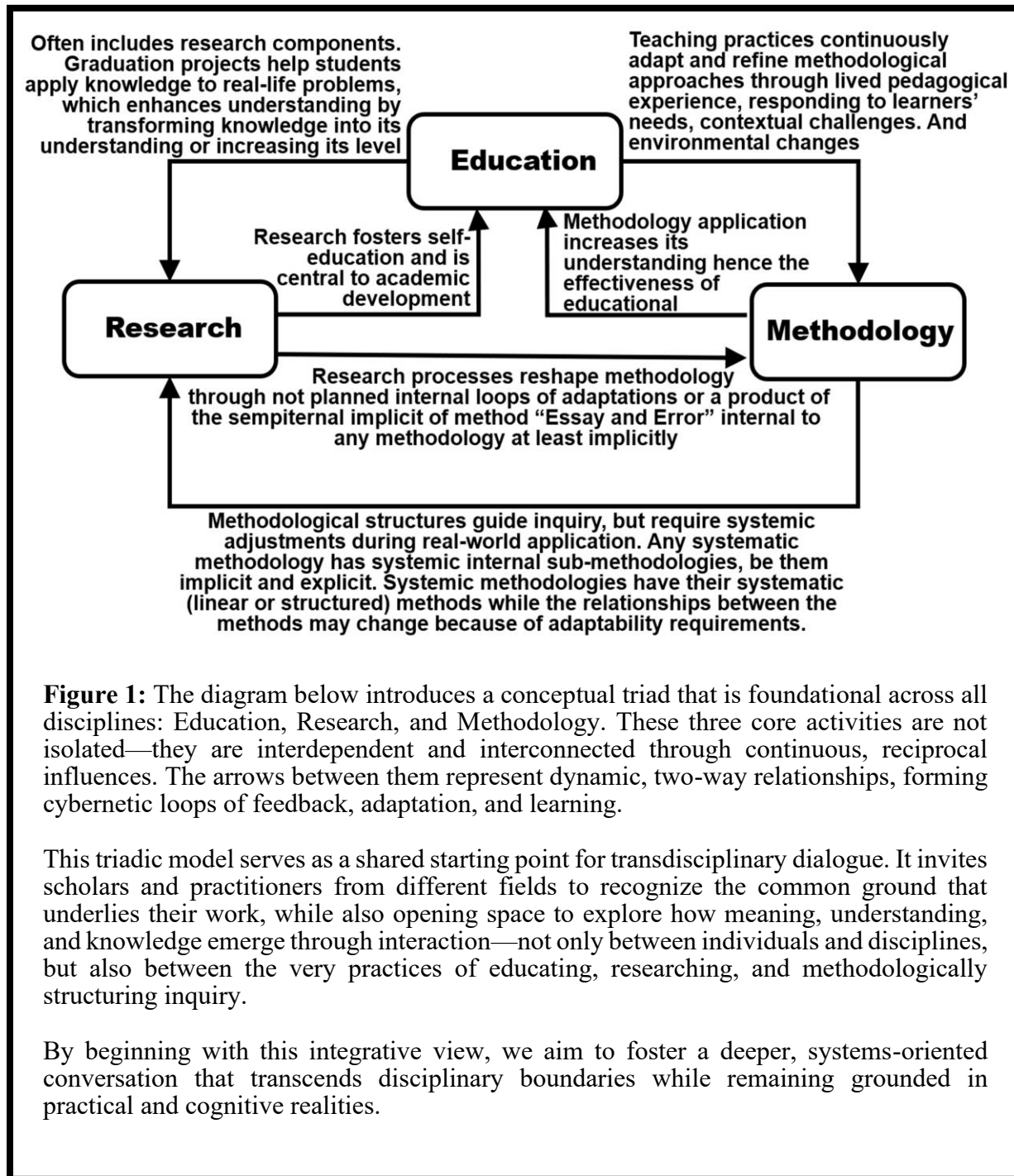
2.1.2. Research as Input to Education

Research reciprocally contributes to education by refining its content, reshaping its assumptions, and updating its methods. It acts as an adaptive feedback mechanism that keeps education aligned with emergent knowledge and evolving realities. Instructors who are active researchers inject current findings into the classroom, while students engaged in research activities internalize the uncertain, iterative, and self-corrective nature of knowledge production. Furthermore, research fosters intellectual resilience, requiring learners to adapt to error, ambiguity, and failure, conditions that mirror real-world complexity.

¹ As is well known, emergent properties characterize complex systems. A classic example is the liquidity of water, a property that is not present in its separate components, hydrogen and oxygen, both of which are gases, but which arises from the interaction between their subatomic particles of H and O, when they form H₂O molecules. The complexity of the resulting system

surpasses that of its individual parts, creating a whole with new and irreducible properties.

² Based on a general law foundational to cybernetics and the systems approach, a system must possess at least as much variety as its environment to maintain adaptability and stability. [Further details in End Note i.]



As such, research does not merely supplement education; it transforms learners into co-creators of knowledge and active participants in its continual evolution, and prepares individuals to engage more effectively with the inherent complexities of everyday life, as it fosters cognitive flexibility, adaptive strategies. The latter also provides a preparation for developing 1) the interdisciplinary potential needed to navigate its unpredictable and problem-solving demands, as well as 2) the skills for transdisciplinary communication, which is important for cross-disciplinary communication as well as for communicating with stakeholders that usually contain professionals from other disciplines and lay persons.

2.2. Education and Methodology: A Cybernetic Relationship

It is widely recognized that education necessarily involves a methodology, either explicitly mandated by institutions or implicitly shaped by the teacher's or faculty member's pedagogical approach. We propose that methodological knowledge and understanding significantly enhance the effectiveness of the educational process. Furthermore, educators who engage in research, whether in education or in other fields, are likely to improve their teaching, as research deepens their understanding of the subject-matter and enriches their pedagogical strategies.

This reciprocal dynamic recalls the quote commonly attributed to Einstein: "*If you can't explain it to your grandmother, you don't understand it yourself.*" Teaching requires not just knowing, but knowing in such a way that it can be communicated clearly—something research and methodological reflection help foster. Conversely, research in any discipline tends to improve the researcher's educational methodology. Engaging in research adds to the complexity of the researcher's knowledge, thereby enriching both their cognitive structures (e.g., neural networks) and their internal knowledge systems. As these complexities grow, they increase the likelihood of emergent properties such as deeper understanding, insightful associations, analogical and metaphorical thinking, all of which enhance educational practice and communication.

2.2.1. Methodology as Input to Education

Methodology contributes to education through both explicit and implicit channels, shaping how educational systems develop and function.

Explicitly, methodology provides structured frameworks for curriculum design, assessment, and instruction. These include formalized procedures, models (such as action research and/or action learning), and best practices encoded in training programs, educational policies, and systemic teaching strategies.

Implicitly, methodology introduces assumptions, values, and worldviews that inform educational culture. Concepts such as iterative improvement, feedback loops, and reflective/reflexive practice, core to first and second-order cybernetic thinking, permeate teaching environments, often without being formally stated. Tacit knowledge, transmitted through mentorship and peer collaboration, also constitutes a critical input, influencing the ethos and micro-decisions of everyday educational activity.

In a cybernetic framework, these inputs, both explicit and implicit, contribute to a dynamic, adaptive system in which negative and positive feedback, as well as feedforward, generate learning loops that are essential for sustaining and improving

educational effectiveness, which depend on adaptability. The latter requires an adequate variety..

2.2.2. Education as Input to Methodology

Education, in turn, feeds back into methodology, offering its own set of explicit and implicit inputs.

Explicitly, educational practice generates empirical data; classroom outcomes, assessments, and system-wide feedback, which prompt methodological refinement. Identified gaps, evolving learner needs, and emerging insights from practice indicate where and how the methodology must adapt. This reflects the already mentioned Ashby's (1958) *First Law of Cybernetics*: "*Only variety can absorb variety.*" That is, the more diverse and complex the educational input, the more systemic, rather than merely systematic, the methodology must be in order to remain adaptive and effective.

Implicitly, education shapes methodology through its cultural, experiential, and contextual realities. Educators' lived experiences, community norms, and evolving practices gradually influence which methods are deemed effective or appropriate. These inputs, often unarticulated, are reflected in changing classroom behaviors, instructional preferences, and learner engagement patterns. Underlying beliefs about knowledge, learning, ethics, and teaching also shape methodological evolution over time. *These latent epistemologies form the invisible architecture* that supports explicit methods. In this way, education ensures that methodology stays relevant, responsive, and grounded in real-world conditions.

Together, these *bidirectional flows between education and methodology* illustrate a core *cybernetic relationship*, embedded not only in their mutual feedback loops but also within the broader *cybernetic triad* introduced in Figure 1.

2.3. Research and Methodology

Both notions and activities have evident and frequent cybernetic loops. Even in the case of the more systematic research methodology ends up having parts of systemic sub-methodologies. This is a consequence of what is being discovered and learned in the research process, because the essence of any inquiry is to discover information, knowledge, etc. All of this happens in both successful and failed instances. Both are learning processes, and both generate learning processes that require methodical or methodological adaptation or micro-adaptation to continue to avoid the already made *failure* or to repeat and, potentially, to enhance the ongoing *success*. So there is no way that a research process does not impact the explicit methodology being followed. No systematic methodology has any implicit internal cybernetic processes when it is applied. So there is no theoretical systematic methodology that, in practice or action, may not have multiple internal adjustments, i.e., systemic and adaptable parts in the context of the systematic whole. In general, we should affirm that there is no pure systematic or systemic methodology in research. This means there is no purely linear methodology without internal unplanned non-linearities. And vice versa, there is no systemic methodology that has no systematic methods, i.e., there is no non-linear methodology that does not have internal linearities. Consequently, research and methodology are inherently related cybernetically. This is because all research or Inquiry is based on the sempiternal known "essay and error"

2.3.1. Research as input to Methodology

The combination of the research's nature and the researcher's objective determines the research methodology, or the type of methodology to be adopted. Typically, work requirements, the researcher's interests, and her/his methodological skills influence the selection or pre-selection of a particular approach. As the research process unfolds, alongside the parallel process of implicit or explicit learning, it is common for additional methods to be introduced, modified, excluded, or reiterated in the context of the methodology, which is a network of related methods.

This dynamic adjustment reflects the evolving understanding that emerges with the potential new information obtained during the research process itself. Methodology. Therefore, the research methodology is not always a pre-fixed one, not even in the starting point, but often a responsive framework that co-evolves with the research. As new insights arise, the methodology may shift in scope or emphasis, guided by both practical and theoretical constraints as well as by epistemological reflection and reflexive thinking. In this sense, *methodology becomes both a means and a mirror*: a structured path for inquiry and a reflexive space for recognizing the complexity, uncertainty, and learning inherent in research processes.

2.3.2. Methodology as input to Research

Systemic or systematic methodological structures provide a guiding framework for inquiry, offering coherence and direction to the research process. However, during real-world applications, these structures often require *systemic adjustments (even in the case of systematic methodological systems)* to respond to contextual variability, complexity, and unpredictability.

Any systematic methodology, that is, a methodologically ordered sequence of steps, contains within it multiple *internal sub-methodologies*, which may be either *explicitly articulated or implicitly embedded in practice*. These sub-methodologies support different phases or dimensions of the inquiry and contribute to the overall coherence of the process.

Meanwhile, *systemic methodologies*, understood as open, adaptive, and dynamic approaches, often include systematic methods as components. Yet, the *relationships between these methods* are not fixed; they may shift or evolve in response to emerging situations or challenges, new information, or evolving objectives. This adaptability reflects the *cybernetic nature of methodological practice*, in which feedback loops and contextual reflexivity guide the selection, combination, or reconfiguration of methods.

In this way, methodology is not a static blueprint but a *living system*, structured yet adaptable, capable of aligning rigor with relevance in complex and changing environments. We will provide more details regarding the notion of methodology in the next section.

3. MEANING OF METHODOLOGY³

Being the notion or concept of “methodology,” one of the Cybernetic Triad (Figure 1), and having so many denotations and connotations, it is sometimes undistinguished from method and other related concepts; let us provide a less ambiguous and imprecise meaning, based on its etymological roots, and then use a metaphor to distinguish the notions or methodology from “method”, “technique”, etc. This metaphor would allow us to be as brief as possible in this article.⁴

The term “method” derives from **Ancient Greek**: μέθοδος (*methodos*), which is composed of μετά (*meta*): “after,” “with,” or “in pursuit or quest of” ὁδός (*hodos*): “way,” “path,” “road.” The suffix “-logy” (from λόγος, “study of”), making it literally “the study of methods”—but in practical and metaphorical terms, it becomes a map or a **network of roads**, offering multiple routes. We are using a physical metaphor to be as brief as possible regarding a more conceptually details description we presented in other writings.

Even, in this article, we are using the word “methodology” in *plural*, applied in different domains, it would be convenient to briefly refer to “Methodology”, in *singular*, (with a capital “M”), defined as the *science or theory of methods*, often aligning with epistemology and traditionally associated with the logic of science or philosophy. In this singular, abstract sense, it refers to a “*science of science*”, focused on knowing, not doing, and without praxiological (practical) considerations.

However, when used in the *plural* (“*methodologies*”), the term takes on a broader and more applied meaning: it becomes **the theory of methods within a specific domain of knowledge and/or action**, thus encompassing both *epistemological and praxiological* orientations.

A *methodology*, in this practical sense, is a **network or system of related (or relatable) methods**, each with its corresponding tools and techniques. Using our metaphor, just as a city is not simply any of its streets, cars, or drivers, a methodology is *not reducible to any single method, tool, or technique*. Frequently, the word “methodology” has been used in the connotation of “method”, “technique”, and “tool use, and this may be misleading and a source of misunderstanding.

For example, **CASE** (Computer-Aided Software Engineering TOOLS) is often misidentified as a methodology, and even as methodologies, but they are actually **tools**, not theories of method, not methods, let alone a related set of methods. Similarly, Structured Analysis is a **method**, while Data Flow Diagrams are **tools**, and the skill to create them is a **technique**.

A true **methodology, in general**, as well as for the specific case (of the examples, we are providing for information systems development), may include multiple and even **opposing methods** (e.g., top-down and bottom-up), integrated to suit a particular situation. Confusing “methodology” with “method” leads to *conceptual errors and false contradictions*, overlooking the

³ More details on this sections are presented at Callaos & Callaos (Toward A Practical General Systems Methodological Theory, 1995) and (Callaos & Callaos, Toward a Systemic Notion of Methodology, 2014)

⁴ Several articles were published regarding this issue: (Callaos & Callaos, 1995); (Callaos & Callaos, Toward a Systemic Notion

of Methodology, 2014), etc. which, in turn, are based on a voluminous and detailed book, of about 850 pages on General Systems Theory. (Callaos, 1995), based on the First General Systems Theory, i.e., Ludwig Von Bertalanffy’s (von Bertalanffy, 1968)

value of the complementarity in using polar opposites methods, especially in complex systems.

3.1. Methodologies as Closed and Open Systems

This section explores the conceptual and practical distinction between the two types of methodologies: **systematic (closed)** and **systemic (open)**. Both types fall under a broader understanding of methodology as a structured set of interrelated or potentially relatable methods, along with their corresponding tools and techniques.

A systematic or closed methodology is defined by its fixed, predetermined relationships among methods. These relationships do not change according to context; instead, they are applied uniformly regardless of the situation. *Among the examples we may cite are administrative and financial procedures that are generally systematic or closed methodologies. There might be exceptions, but in general, they represent well-known and illustrative examples.*

In this model, the specific circumstances of an application are expected to adapt to the structure of the methodology itself. As such, a closed methodology functions like a closed system; it is highly standardized and internally consistent. This characteristic **makes systematic methodologies highly efficient**, especially in stable and predictable environments. Their use demands less effort in decision-making and requires fewer psychological or managerial resources, as the path of application is already charted.

However, the rigidity of systematic methodologies becomes a limitation in more dynamic contexts. Their fixed nature restricts adaptability, which can hinder their overall effectiveness when situations are fluid, complex, or unpredictable. The uniformity that enhances efficiency in stability becomes an obstacle when flexibility is required.

In contrast, a systemic or open methodology is characterized by dynamic and situational relationships among its methods. These relationships are not predetermined but are guided by strategies, rules, and heuristics that take into account the specific context in which the methodology is applied. A systemic methodology allows for the introduction of new methods, tools, and techniques, thereby expanding its adaptability. This openness transforms it into a more responsive framework capable of adjusting to real-world complexities.

The adaptive nature of systemic methodologies **increases their effectiveness in uncertain or evolving environments**, but this comes at a cost. **They are less efficient than their systematic counterparts** because they lack standardized procedures and require greater decision-making efforts, more time, and more intensive psychological and managerial input. Applying a systemic methodology typically involves navigating more complexity and investing more human resources (and frequently more time) in order to shape the methodology around the needs of a particular situation.

⁵ Japanese word a visual system for managing workflow, originally developed at Toyota, that focuses on optimizing the flow of work and reducing waste. It's a method for managing work by visualizing the workflow, limiting work in progress, and maximizing efficiency. Kanban emphasizes continuous improvement and is used in various fields, including software

Neither type of methodology is universally superior; their appropriateness depends on the context in which they are used and on the objectives of their use. In stable environments, where predictability allows for streamlined processes, systematic methodologies are more suitable because their efficiency outweighs the need for flexibility. On the other hand, in dynamic or uncertain environments, systemic methodologies become indispensable. Although they may be less efficient, they offer the necessary flexibility to achieve meaningful and context-sensitive results. In such situations, the decrease in efficiency is a cost that must be accepted in order to ensure efficacy, i.e., an adequate tradeoff between effectiveness and efficiency.

A practical illustration is found in the domain of information systems development. For routine systems, such as payroll or general ledger applications, systematic methodologies are generally sufficient and more efficient. However, when developing systems such as Executive Decision Support Systems (EDSS), which operate in complex and evolving decision-making environments, a systemic approach is required. In these cases, adaptability and responsiveness are essential, and a rigid methodology would fail to meet the demands of the environment.

In conclusion, systematic methodologies emphasize efficiency through structure, while systemic methodologies prioritize effectiveness through adaptability. The choice between them or a tradeoff in combining them should be determined by the stability or dynamism of the context, with each approach offering specific advantages and inherent limitations.

Before providing some examples of systematic and systemic methodologies, let us do it via the Top-Down approach, starting with a table, instead of summarizing them at the end of this section, via a table, which would be a Bottom-Up description.

3.2. Examples of Basically Closed (Systematic) and Open (Systemic) Methodologies

A well well-known example of **systematic** and highly closed methodologies may be found in fields like construction, car manufacturing, and mechanical industries. Several well-known systematic (mainly closed) methodologies are widely used due to their emphasis on standardization, efficiency, and repeatability. For example, the Critical Path Method (CPM) and PERT in construction engineering follow fixed sequences and predefined dependencies to ensure projects are completed on time and within budget. Similarly, the Toyota Production System (TPS) and Lean Manufacturing in automotive production prioritize minimizing waste through rigid workflows like Just-In-Time and Kanban⁵. Additionally, ISO 9001 Quality Management Systems offer standardized procedures to ensure consistent quality across manufacturing sectors. These methodologies are systematic because they operate best in stable environments where tasks can be planned in advance and executed uniformly.

In contrast, well-known **systemic** (open) methodologies such as Design Thinking⁶ or the very old and well-known “trial and error” allows for flexibility, adaptation, and responsiveness to

development, project management, and manufacturing software development, project management, and manufacturing

⁶ Design Thinking is a human-centered, iterative problem-solving approach that emphasizes understanding user needs, generating ideas, prototyping, and testing.

context. Design Thinking, used in product development and innovation, follows iterative stages, via cybernetic iterations (like empathizing, ideating, and prototyping) that can be reordered or repeated depending on user feedback and evolving challenges. Trial and error, one of the oldest methodologies, involves learning through direct experience or experimentation and feedback, making it especially useful in complex or novel situations where solutions can't be fully anticipated. These systemic methodologies prioritize effectiveness in dynamic or uncertain environments, allowing for continuous learning and context-sensitive adaptation. Comparison Table A is a way to summarize the above subsection 3.2.

3.2.1. Examples in Education of Basically Closed (Systematic) and Open (Systemic) Methodologies

The Traditional Behaviorist Instructional Models (e.g., Direct Instruction, programmed instruction) are examples of systematic methodologies, which

- Characteristics are: Predefined objectives, standardized lesson plans, fixed sequences of content delivery, and measurable via exams and behavioral outcomes.
- Context is often used in basic literacy and arithmetic training, especially in large-scale public education systems where efficiency, repetition, and uniformity are prioritized over flexibility.
- Justifications are: efficiency and stability in stable contexts (e.g., national standardized testing environments), where educational goals are clear and tightly controlled by curriculum standards.

Project-Based Learning (PBL) or Problem-Based Learning are examples of *Basically Open (Systemic) Education Methodologies*, which

- Characteristics are Emergent content, student-driven inquiry, flexible grouping, adaptive assessments, and teacher as facilitator rather than instructor.
- Context: is *transdisciplinary or experiential education* settings, particularly in innovation-oriented programs, design thinking courses, or real-world problem-solving.
- Justification is *effectiveness in dynamic, uncertain learning environments* (e.g., cross-cultural teams, rapidly changing technology fields) where learning goals evolve in response to the learner's progress and the complexity of the problem.

3.2.2. Examples of Research, Basically, Via Closed (Systematic) and Open (Systemic) Methodologies

The Classical Experimental Design in Quantitative Research (e.g., Randomized Controlled Trials – RCTs) is, basically, a systematic methodology, which:

- Characteristics are fixed variables, strict control groups, pre-set hypotheses, and statistically measurable outcomes.
- Context: is mostly and frequently in medical and psychological research, or in agriculture and pharmacology, where high internal validity and replicability are essential.
- Justification is its adequate balance between effectiveness and efficiency when the research context must be controlled and isolated from external variability to ensure causal inference.

**Comparison Table A:
Efficiency and Effectiveness of Systematic vs. Systemic Methodologies**

Domain	Example	Type	Efficiency	Effectiveness
Engineering	CPM, PERT, TPS, Lean, ISO 9001	Systematic	High (due to predefined sequence and repeatability)	Moderate (in stable environments)
Innovation	Design Thinking, Trial and Error	Systemic	Low to Moderate	High (due to adaptability and contextual responsiveness)
Education	Direct Instruction	Systematic	High (especially in basic content)	Limited in changing environments
Education	Project-Based / Problem-Based Learning	Systemic	Lower (more resources required)	High in deep and complex learning
Research	Randomized Controlled Trials (RCTs)	Systematic	High in controlled settings	High (when replicable results are needed)
Research	Action Research, Grounded Theory	Systemic	Low to Moderate	High in complex and social contexts

Comparison Table B: Systematic (Closed) vs. Systemic (Open) Methodologies

Domain	Methodology Type	Characteristics	Context	Justification
Education	Systematic (Closed): Traditional Behaviorist Instructional Models (e.g., Direct Instruction, Programmed Instruction)	Predefined objectives, standardized lesson plans, fixed sequences of content delivery, and measurable behavioral outcomes.	Basic literacy or arithmetic, especially in large-scale public education systems where efficiency, repetition, and uniformity are prioritized.	Efficiency and stability in stable contexts (e.g., national standardized testing environments), where educational goals are clear and tightly controlled by curriculum standards.
Education	Systemic (Open): Project-Based Learning (PBL), Problem-Based Learning	Emergent content, student-driven inquiry, flexible grouping, adaptive assessments, teacher as facilitator.	Transdisciplinary or experiential education, innovation programs, design thinking, and real-world problem-solving.	Effectiveness in dynamic, uncertain learning environments where learning goals evolve based on student progress and problem complexity.
Research	Systematic (Closed): Classical Experimental Design in Quantitative Research (e.g., RCTs)	Fixed variables, strict control groups, preset hypotheses, and statistically measurable outcomes.	Medical and psychological research, agriculture, and pharmacology require high internal validity and replicability	Balances effectiveness and efficiency when context must be controlled to ensure causal inference.
Research	Systemic (Open): Action Research, Grounded Theory (Qualitative, Adaptive)	Iterative cybernetic inquiry cycles, reflexive methodology (Second Order Cybernetics), evolving data collection, researcher-context engagement.	Educational research, community development, and organizational change, especially for co-constructing context-relevant knowledge.	Suitable for fluid research contexts, emergent outcomes, and evolving understanding with stakeholder interaction.

Action Research and Grounded Theory (qualitative, adaptive) are examples of cybernetic systemic methodologies, which

- Characteristics are Iterative Cybernetic cycles of inquiry, reflexive methodology according to “Second Order Cybernetics”, data collection shaped by ongoing analysis, and researcher engagement with the research context and own reflections and reflexivity.
- Context is mostly education research, community development, and organizational change, especially when the goal is the co-construction of knowledge and local relevance.
- Justification: Suitable when the *research context is fluid*, outcomes are emergent, and understanding must evolve along with stakeholder interaction and contextual insight.

Table B provides a kind of summary of subsections 3.2.1 and 3.2.1

4. METHODOLOGIES ARE INHERENTLY KNOWLEDGE AND INFORMING SYSTEMS

In any type of methodology, whether systemic, systematic, or hybrid, there must be supporting information systems and informing processes, which may be human-based, computer-based, or hybrid. Hybrid systems are the most common. **Computers process data**, while **human beings process information**. Likewise, methods must be known by at least one person to enable *know-what to do and why*, and tools must be handled by someone with the appropriate *aptitude and attitude*—

that is, tools require not only *know-how*, but also the will to apply that know-how. *Systemic methodologies*, in particular, also require *know-where* and *know-when*.

Gerald Weinberg in (*Rethinking Systems Analysis and Design*, 1982) highlighted the importance of these two types of knowledge even within highly systematic contexts, such as Structured Methods (e.g., Structured Analysis, Structured Design, and Structured Programming). Paraphrasing what he proposed in *Rethinking Systems Analysis and Design*, it is necessary to insert structured, systematic methods into a broader **systemic context**. Within systemic methodologies, it is also essential to incorporate *know-why*.

(Banathy, 1992) emphasized the importance of this kind of knowing as a key component in the design of information systems, no matter if they are computer-supported supported not, as is the case with educational systems and research processes. Similarly, Russell Ackoff, in (*Scientific Method: Optimizing Applied Research Decisions*, 1962), underlined the relevance of *know-why* in real-world consulting, especially in research processes. He advised asking clients or users two levels of “why”: (1) “Why do you want that?” and then, upon receiving a reply, (2) “Why do you want ‘why’ you just gave me?” His experience showed that *clients often express what they think they want, when in reality, they are implicitly asking how to achieve what they truly need*. In these cases, their second *why* (the *meta-why*) often reveals their real *what*.

For this reason, *know-why* is indispensable in systemic methodologies. Both **effectiveness** and even **efficiency** may depend on this deeper understanding, on grasping the **real purpose** behind methodological choices.

While **systematic methodologies generally require two types of knowledge**, *know-what* and *know-how*, **systemic methodologies require five**: *know-what*, *know-how*, *know-where*, *know-when*, and *know-why*. Because these knowledge types must be connected or connectable, it follows that **every methodology requires a knowledge system**, which is often, either explicitly or implicitly, *distributed and systemic*.

To develop any analysis/synthesis, any system, including a human software-based information system, a knowledge system is a prerequisite. More precisely, we need a **Human Knowledge System**, which can be supported by technological systems such as knowledge bases, project control software, or meta-software (e.g., CASE tools). However, no matter how advanced automated support systems become (even when labeled “knowledge systems” or “expert systems”), **they always support human knowledge systems**, especially in the methodological domain.

Some vendors mistakenly *confuse supporting tools with methodologies*, a conceptual, notional, and practical error. Likewise, some managers (including Chief Information Officers) wrongly equate methodologies with a collection of written rules, procedures, or diagramming conventions. This is akin to **confusing the map with the territory**: *a map may describe a territory, but it is not the territory itself*.

In conclusion, a methodology requires, as a human subsystem, an **adequate Human Knowledge System**. For systematic methodologies, this includes *know-that* and *know-how*. For systemic methodologies, it must also encompass *know-where*, *know-when*, and *know-why*. Furthermore, since human beings are a necessary condition for any methodology; hence, it requires addressing the notions of Ethics and Power, especially in the case of systemic methodologies.

The table C summarizes what has been presented in this section.

5. POWER, ETHICS, AND SYSTEMIC METHODOLOGIES⁷

In any methodological practice, be it systemic, systematic, or hybrid, a supporting framework of informing/knowledge processes and information/knowledge systems is indispensable. These systems may be human-centered, machine-assisted, or hybrid. While computers can process data, human beings engage in meaning-making through the processing of lived information, what Goethe^{8,ii} might have called “phenomena as perceived through participation,” i.e., the role of the observer as an active participant. This notion, often referred to as “tender empiricism,”⁹ suggests a deep and intimate engagement with the observed object, transcending the traditional subject-object dichotomy prevalent in conventional scientific inquiry.

This parallels and resonates with C. West Churchman’s “evoked set”, presented in his book (*The Design of Enquiring Systems: Basic Concepts of Systems and Organization*, 1971), which is what sense data “evokes”, elicits from the receiving subject’s memory, and where the combination of both represents the perception of the subject. Consequently, **objective sense data and subjective memory combine to form the perceptions that are input to memory, abstraction, concepts, notions, thinking, etc.** This Churchman’s book is widely recognized as a foundational text in systems theory and systemic epistemology, exploring the nature of inquiry and the role of information and perception in the construction of knowledge.

⁷ More details on the relationships among Systemic Methodologies, Ethics and Power, and well as with Ethos, Pathos, and Logos are included in (Callaos & Callaos, *Toward a Systemic Notion of Methodology*, 2014)

⁸ We are referencing Goethe in this section because Goethe’s thinking was more systemic than systematic, long before the Systems Approach appeared. **Goethe’s thinking was fundamentally systemic rather than systematic**. Goethe’s thinking embraced wholeness, context, and dynamic interrelations. His study of metamorphosis, color, and organic form reflected a deep commitment to understanding phenomena

as living processes embedded in their environments. Long before systems theory emerged, Goethe cultivated a relational, integrative way of knowing, grounded in observation, participation, and the unity of nature and mind, that resonates strongly with contemporary systemic epistemologies

⁹ “**Tender Empiricism**,” is a scientific method inspired by Goethe that emphasizes careful, respectful observation of phenomena without reducing them to abstract analysis

**Comparison Table C:
Systematic vs. Systemic Methodologies in Education and Research**

Domain	Methodology Type	Characteristics	Context	Justification
Education	Systematic (Closed) Traditional Behaviorist Models (e.g., Direct Instruction)	Predefined objectives, standardized lesson plans, fixed content sequences, measurable outcomes	Basic literacy or arithmetic training in large-scale public education systems	Efficiency and stability in standardized testing environments with clear curriculum standards
Education	Systemic (Open) Project-Based or Problem-Based Learning (PBL)	Emergent content, student-driven inquiry, flexible grouping, adaptive assessments, teacher as facilitator	Transdisciplinary or experiential education settings, innovation programs, and real-world problem-solving	Effectiveness in dynamic, uncertain environments with evolving learning goals
Research	Systematic (Closed) Classical Experimental Design (e.g., RCTs)	Fixed variables, strict control groups, predefined hypotheses, and statistically measurable outcomes	Medical, psychological, agricultural, and pharmacological research requires high internal validity	Balanced efficiency and effectiveness for causal inference in controlled settings
Research	Systemic (Open) Action Research and Grounded Theory	Iterative cybernetic inquiry cycles, reflexive methodology, adaptive data collection, researcher engagement	Educational research, community development, and organizational change are focused on local relevance	Suitable for fluid contexts with emergent outcomes and evolving understanding

Just as a finely crafted tool, like a well-engineered car, remains inert without a skilled driver, so too do methodologies demand not only technical knowledge (*know-what*) and skill (*know-how*), but also attunement in time (*know-when*), in place (*know-where*), and with the purpose (*know-why*).

Systemic methodologies, in particular, echo Goethe's holistic view: they require not merely the structure of method(s), but the spirit of inquiry, context-awareness, and moral intention. Gerald Weinberg's (1975) insights on *know-where* and *know-when* align with Goethe's *delicate empiricism*, which calls for a cultivated awareness of how phenomena unfold in their living context. Similarly, Russell Ackoff's (1962) layered "why" questions, which we have distilled to their essence in Section 4, are used to identify the true *what for*, beyond what the user or client believes or expresses. This inquiry, culminating in a "meta-what for", that is, asking again what the user wants that *for*, parallels Goethe's method of observing the metamorphosis of forms: *in both cases, the aim is to penetrate beyond immediate appearances to uncover*

the internal telos that gives meaning and direction to what is being observed.

In practical terms, knowledge and will alone are not sufficient for the successful implementation of systems, including methodological systems. Power, the capacity to align action with intention within organizational dynamics, is often necessary. A project manager may possess clarity and competence, yet lack the institutional influence to align users' time and attention with training and implementation. Thus, even a well-conceived information methodological system research and educational processes may fail due to organizational inertia or conflicting work demands. Goethe would recognize in such disjunctions a failure to see and act upon the whole: a fragmentation of parts without their living context.

Power (to do) and, hence, Ethics cannot be detached from methodological application. Decisions, especially within systemic methodologies, are not neutral; they shape not only

outcomes but relationships. Goethe maintained that true knowing arises from inner participation with the object; in parallel, systemic action must engage ethically with its context. When one's or a group's "local interest or good" compromises the greater whole, we enter into ethically problematic territory. In Goethean terms, the harmony of the whole has been disrupted by a misalignment of becoming.

Systemic methodologies, as ways of thinking and acting, require more than logic or procedural rigor; they require the presence of moral insight. While a scientific method may pause at the threshold of the "what is," ethical methodology demands attention to the "what ought to be." This ethical dimension is not an accessory but an essence, embedded in the very becoming of the system. Ignoring the moral implications of methodological decisions is not ethically neutral, but it is ethically negligent.

We thus propose a framework akin to what could be termed **ethical methodologies**, i.e., a view in which ethical knowledge is inseparable from technical and organizational knowledge. Six interwoven dimensions of human knowing are essential: **know-what, know-how, know-who, know-where, know-when, and know-what-ought-to**. These are not merely cognitive attributes but relational ones, forming a dynamic human knowledge system capable of responding to complexity with wisdom.

It is worth noting that wisdom, like understanding, is a matter of degrees and not a "yes or no" issue, as is the case with knowledge. Something is either known or not known, but understanding grows gradually, as does wisdom. This is because both understanding and wisdom are emergent properties inherent to any complex system. In the case of human beings, the complexity of the brain and its neural networks tends to increase with the knowledge and experience acquired, which raises the level of comprehension of knowledge — both in its epistemological and experiential senses — and strengthens the integration between knowledge and judgment, including ethical judgment, which is essential for knowing and wisdom.

Moreover, this ethical structure must be supported by enforceable legal frameworks. Systemic methodologies must include legal instruments that safeguard the integrity of ethical intentions and actions. Just as Goethe insisted that the laws of nature emerge through attentive perception of unfolding form, so too should organizational ethics emerge through coherent legal and procedural grounding.

Consequently, A systemic methodology must include (1) a set of methods, tools, and techniques; (2) a flexible structure of inter-method relations responsive to context; (3) diverse kinds of knowledge—*know-where, know-when, know-why*—in addition to *know-what* and *know-how*; and (4) ethical and legal methods and tools. The goal is to assemble an *ad hoc* system of human knowledge and action capable of generating a methodological system, as well as educational and research processes that are not only efficient and effective, but also ethically sound or, at least, acceptable.

In a few words, implementing systemic methodologies is not merely a technical or managerial one, but it is also a Goethean one because it asks for *delicate empiricism*, participatory insight, ethical discernment, and above all, a minimum of *wisdom*, or a *synthesis of knowing, doing, and becoming*. For in Goethe's own words: "*Knowing is not enough; we must apply. Willing is not enough; we must do.*"

6. OPERATIONALIZING TRANSDISCIPLINARY COMMUNICATION IN THE CYBERNETIC TRIAD

Transdisciplinary communication (TDC) is recognized as essential for connecting education, research, and methodology, yet its effective operationalization remains lacking in academia. This gap causes communication delays, fragmented curricula, and ineffective knowledge transfer, limiting societal impact. While initiatives like Future Earth's co-design models and transdisciplinary graduate programs address some aspects, they often fail to sustain TDC or provide domain-specific communication frameworks. To address this, this section proposes the Transdisciplinary Communication Integration Model (TCIM), featuring Meta-Reflective Protocols, Contextual Translation Maps, and Feedback Loops Codification to make TDC explicit, assessable, and adaptable. Recommended actions include embedding TDC in curricula, integrating TCIM into funded research, and establishing institutional support units. Operationalizing TDC is vital for maximizing the Education–Research–Methodology triad's intellectual and societal potential.

6.1. The Gap in Operationalizing Transdisciplinary Communication

Despite the increasing recognition of the value of transdisciplinary approaches in linking education, research, and methodology, there remains a persistent gap in operationalizing transdisciplinary communication (TDC) within academic practice. Existing frameworks often acknowledge TDC as a desirable skill but stop short of providing actionable, systemic strategies to integrate it into the feedback loops between education, research, and methodology. Without operational clarity, TDC risks remaining a rhetorical ideal rather than a functional competency embedded in institutional and methodological design.

This omission undermines the potential of the Cybernetic Triad described in this paper, as the absence of an explicit TDC framework limits the capacity for mutual enrichment across domains (Pohl, Krütli, & Stauffacher, 2017)

6.2. Consequences of the Gap

Leaving TDC underdeveloped has measurable consequences. Empirical studies indicate that interdisciplinary and transdisciplinary research projects face higher rates of communication-related delays and scope misalignment compared to disciplinary projects (Golde & Gallagher, 1999); (Ho, et al., 2021); (Lyall, Meagher, & Bruce, 2015)

In educational contexts, the absence of structured TDC training leads to fragmented curricula, where students can complete advanced degrees without mastering the ability to communicate research across disciplinary and stakeholder boundaries. This fragmentation not only limits intellectual integration but also reduces the societal relevance and policy impact of academic outputs. When methodologies are applied without TDC competence, knowledge transfer to non-specialist audiences, policymakers, community partners, or industry stakeholders often fails, constraining the systemic adaptability that is essential in dynamic environments.

6.3. A Limited Attempt at Integration

An illustrative example can be found in the European Union's Horizon 2020 program, which funded numerous cross-sectoral research projects between 2014 and 2020. Many of these projects aimed to integrate education, research, and methodology within sustainability science. However, evaluations revealed that while technical outputs met disciplinary standards, many projects underperformed in stakeholder engagement and broader societal uptake (Defila & Di Giulio, 2018). The reports cited the absence of a shared communication framework across disciplinary teams as a key factor. In effect, methodological innovation and research excellence were present, but the lack of explicit TDC scaffolding prevented these outputs from achieving their intended systemic impact. This case underscores the argument that without operational TDC, even well-funded, methodologically robust initiatives can stall in real-world application.

6.4. Analysis of Related Efforts

Several initiatives have attempted to address communication challenges at the intersection of education, research, and methodology. For example, the Future Earth Knowledge–Action Networks have implemented co-design and co-production models that explicitly integrate multiple knowledge systems (Mausser, et al., 2013). These models excel at fostering early-stage collaboration and aligning research questions with stakeholder needs. However, they often lack continuity mechanisms to sustain TDC beyond initial project phases. Similarly, transdisciplinary graduate programs, such as those at ETH Zurich and Arizona State University, embed collaborative project work into curricula, providing students with structured opportunities to practice TDC in real-world contexts (Jahn, Bergmann, & Keil, 2012). Yet, evaluations suggest that these programs sometimes conflate interpersonal skills training with TDC, overlooking the need for domain-specific communication protocols that bridge epistemological and methodological divides.

From a methodological standpoint, systemic approaches like Action Research inherently require iterative communication loops between academic and non-academic actors (Reason & Bradbury-Huang, 2001). These approaches succeed in maintaining engagement but can become resource-intensive, limiting scalability. Across these examples, what is done well is the emphasis on participatory processes and the recognition of communication as a systemic function. What remains incomplete is the development of codified, adaptable TDC frameworks that can be embedded into the very structure of educational and research methodologies, ensuring durability and transferability.

6.5. A Structured Contribution

Building on the Cybernetic Triad framework presented in this paper, this contribution proposes a **Transdisciplinary Communication Integration Model (TCIM)** designed to operationalize TDC within the feedback loops between education, research, and methodology. TCIM consists of three interlocking components:

1. **Meta-Reflective Protocols:** Structured reflexivity checkpoints embedded in methodological design phases, requiring participants to articulate disciplinary assumptions,

terminologies, and epistemologies before, during, and after collaborative work.

2. **Contextual Translation Maps:** Visual and textual tools that link specialized concepts to stakeholder-relevant language, ensuring that outputs remain comprehensible without loss of conceptual integrity.
3. **Feedback Loop Codification:** Formalized channels for bidirectional knowledge flow between research outputs and educational inputs, ensuring that methodological innovations are rapidly integrated into teaching, and that pedagogical insights inform ongoing research adaptation.

The TCIM approach directly addresses the identified gap by making TDC an explicit, assessable, and repeatable process rather than an incidental byproduct of collaboration. By embedding these components within both systematic and systemic methodologies, TCIM ensures adaptability to stable and dynamic environments alike. Furthermore, the model aligns with Ashby's (1958). Law of Requisite Variety, increasing the communicative capacity of the triadic system to match the complexity of its operational contexts.

6.6. Recommended Actions and Future Directions

To realize the potential of TCIM and fully leverage the cybernetic interrelations of education, research, and methodology, three strategic actions are recommended:

1. **Curricular Embedding:** Integrate TDC competencies into formal learning outcomes at undergraduate and graduate levels, ensuring early and sustained exposure. This includes assessment rubrics that evaluate students' ability to translate disciplinary content for diverse audiences.
2. **Methodological Integration:** Require the inclusion of TCIM components in the design phase of funded research projects, with progress on TDC outcomes reported alongside technical milestones.
3. **Institutional Support Structures** – Establish TDC facilitation units within universities and research centers, staffed by professionals trained in both communication science and the relevant disciplinary domains. These units would function analogously to statistical consulting centers, providing targeted TDC expertise.

Future research should focus on empirically validating the impact of TCIM on both project outcomes and systemic knowledge integration. This includes comparative studies across disciplines, longitudinal assessments of student and researcher TDC competencies, and cost-benefit analyses of institutional TDC support. The “so what” is clear: without operational TDC, the emergent properties of the Education–Research–Methodology triad cannot be fully realized. With it, academic systems can achieve not only intellectual integration but also societal relevance, resilience, and adaptability in addressing complex global challenges.

7. CONCLUSIONS

It has been shown in this article that **Education, Research, and Methodology** are not independent fields or static constructs but dynamically interrelated systems forming a **cybernetic meta-system or Triad**. Their reciprocal feedback loops are, implicit or

explicitly, essential for adaptive learning, intellectual development, and pragmatic problem-solving across disciplines.

By treating each as a complex system and exploring their *bidirectional influences*, the article reveals that their synergy gives rise to emergent properties such as novel insights and effective cross-disciplinary communication. This systemic framework becomes even more powerful when we consider their *methodological expressions*, especially the difference between *systematic methodologies*, structured, efficient, and closed, and *systemic methodologies*, adaptive, flexible, and open to real-world complexity.

Emphasis was made on the fact that *systemic methodologies*, though less efficient, are more effective in uncertain and evolving environments, especially where ethical considerations, tacit knowledge, and human insight are required. In this light, ***methodologies must be understood as human knowledge systems***, integrating multiple ways of knowing: not just technical skills (*know-how*), but also contextual awareness (*know-where*, *know-when*) and moral discernment (*know-why* and *know-what-ought-to*).

Drawing from thinkers like Ashby, Ackoff, Churchman, and Goethe, the article also posits that ***true methodological practice is inherently ethical and participatory***, demanding attention to purpose (telos), not just performance. The closing assertion is *that a systemic methodology is not only epistemological and praxiological, but it must also be ethical and even existential*.

An important operational gap has also been identified: the ability to effectively translate from the language of disciplinary or interdisciplinary fields into a transdisciplinary language. To address this issue, a Transdisciplinary Communication Integration Model (TCIM) was proposed, that would designed to operationalize and transform Transdisciplinary Communication (TDC) into an explicit, assessable, and repeatable process, as well as one that can be integrated into systematic, systemic, or hybrid methodologies to adapt to stable or dynamic environments, that is, to different degrees of adaptability and uncertainty, in accordance with Ashby's Law of Requisite Variety (An Introduction to Cybernetics, 1958)- This strengthens the communicative capacity of the triadic system and may even be necessary for addressing the dynamic complexities and uncertainty of its contexts.

In sum, engaging reflexively with the *Cybernetic Triad* of Education, Research, and Methodology, and including reflexivity, offers a path toward wiser, more integrative forms of knowing and acting, especially vital in today's transdisciplinary and fast-changing world. It is a Goethean, cybernetic, systemic, and deeply human approach to learning and inquiry. It has also been proposed a model (TCIM) to address the key gap of translating disciplinary or interdisciplinary language into transdisciplinary terms, making TDC an explicit, assessable, repeatable process adaptable to varied contexts, thereby enhancing the triadic system's capacity to handle complexity and uncertainty.

8. ACKNOWLEDGEMENTS

We are grateful to Maximus Rafla, a student at New Jersey Institute of Technology, Computer Science, who participated in the non-anonymous reviewing.

Editing and tabling support has been done via Generative AIs, mostly with ChatGPT, but all the outcomes were re-edited by at least one of the authors. So, the authors are responsible for all the content of this article.

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End Notes

ⁱ Ross Ashby's Law of Requisite Variety, originally formulated in mathematical terms, was translated by Ashby himself into the more accessible and transdisciplinary expression: **"only variety can absorb variety."** This foundational cybernetic principle asserts that for any system to maintain stability, achieve regulation, or successfully adapt, it must possess internal complexity (or *variety*) that is at least equal to the complexity of the environment it is trying to regulate or respond to. In other words, a system can only deal effectively with the challenges posed by a complex or variable environment if it has sufficient internal flexibility, options, or degrees of freedom. This is why this law is also basic one in the System Approach especially in Social and biological systems, as well as in Complexity Science and Systems Engineering. It is as well a cornerstone in *cybernetics and systems theory and has profound implications when applied to educational and research contexts*. In education, it suggests that teaching methods, pedagogical strategies, and institutional models must be diverse and adaptive enough to address the wide range of learners' needs, disciplinary differences, and ever-changing societal demands.

Methodologies that are overly rigid or narrowly systematic may struggle to cope in dynamic, interdisciplinary, or culturally diverse environments. By contrast, systemic methodologies, those that include feedback and/or feedforward relationships, reflexivity, and openness to emergence—are more likely to remain effective in the face of complexity and uncertainty.

This principle extends beyond education to research and its corresponding methodologies. Research conducted in complex, open systems (whether scientific, technological, social, or educational) must likewise employ methodological approaches that reflect the variety and uncertainty inherent in those domains.

A methodology that is too narrow in scope or too focused on linear procedures may fail to capture emergent phenomena or interdisciplinary interactions. Therefore, in both research and education, there is a need to strike an adequate balance between the efficiency of systematic methods (which emphasize structure and control) and the effectiveness of systemic methods (which prioritize adaptability and responsiveness).

Ashby's Law thus reveals *a deeper cybernetic truth*: that sustainable, intelligent action, whether in teaching, learning, researching, or governing, requires a form of internal complexity or variety that mirrors or exceeds the external complexity or variety being addressed. In this sense, the law supports the rationale for intellectual and skills diversification, transdisciplinary inquiry, and iterative methodologies, all of which are central to the adaptive capacity of both individual actors and institutional systems as well as methodological systems. *While widely known among cyberneticians and systems theorists, its implications remain underappreciated in many applied domains, where oversimplified solutions are often pursued in the face of growing complexity.*

Given the foundational role of this principle, one could argue for its inclusion in the body of this article or even as an appendix. However, it has been placed here as an extended endnote to avoid digression for readers already familiar with it, while still offering a sufficiently detailed account for those who may wish to revisit or deepen their understanding of its relevance

ⁱⁱ *Goethe's thinking was inherently systemic*, even though it predated the emergence and formalization of systems theory by more than a century. Unlike the mechanistic and reductionist approaches of Enlightenment science, Goethe cultivated a way of knowing rooted in *wholeness, context, and process*. His work exemplifies a participatory epistemology, grounded in what has been called *"delicate empiricism"*, where the observer enters

into a relationship with the phenomenon rather than imposing abstract models onto it.

Goethe viewed phenomena as living, interconnected wholes, not as isolated or static objects. In his botanical studies, for example, he explored *metamorphosis*, not as a linear change, but as an unfolding of inherent potential guided by both internal form and external conditions. Likewise, in his *Theory of Colours*, (von Goethe, Theory of Colours, 1970) he rejected Newton's analytic treatment and instead emphasized the role of perception, polarity, and harmony, demonstrating a form of ***dynamic relationality*** that *closely parallels later systemic frameworks*.

Goethe ***systemic thinking*** may be very summarized as follows:

- He sought ***unity in diversity***, observing how individual manifestations point to underlying archetypes.
- He attended to the ***interplay of parts within evolving wholes***, such as in organic growth or cultural transformation.
- He recognized that ***truth emerges through dialogue and relationship***, not through control or rigid formalism.

Goethe's method resonates strongly with *contemporary systemic paradigms*. Specially with ***second-order cybernetics***, which acknowledges the observer as part of the system; *holism*, which sees systems as more than the sum of their parts (hence the potential respectively emergent properties) ; and *living systems theory*, which studies form as a dynamic, evolving process. Goethe intuited, through a *fusion of science, art, and philosophy*, many of the core principles that systems theorists like von Bertalanffy (General System Theory: Foundations, Development, Applications, 1968), Bateson (Mind and Nature: A Necessary Unity, 1979), and Maturana & Varela (Autopoiesis and Cognition: The Realization of the Living, 1979) would later articulate in the context of the system approach

In this sense, *Goethe did not merely anticipate systemic thought—he embodied it*, offering a model of inquiry in which perception, participation, ethics, and aesthetics are fully integrated. His work remains a profound and underrecognized foundation for ***the development of systemic methodologies in both science and the humanities***.