

TOWARDS A UNIFYING FRAMEWORK FOR SYSTEM KNOWLEDGE

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ABSTRACT

The premise of System Science is that there are concepts, theories, principles, and practices that are universally transversal and a basis for transdisciplinary wisdom. This paper explores System Science and its organization, emphasizing the necessity of a shared orientation for effective conceptualisation, research, development, education, and application. Drawing from Information Physics and General Systems Theory, particularly Relational Theory, Holarchy, and AIC, it employs an inductive approach to extract essential concepts and integrate them into a cohesive framework. By incorporating philosophical concepts, Principles of Science, Systems Engineering, and Systems Thinking heuristics, the paper presents System Science as a conceptual whole. Once integrated, System Science would provide the theoretical foundations for Systems Engineering, Project Management, Business Management and Governance, helping to foster transdisciplinary integration, equity, effectiveness and efficiency. Humanity would be better equipped to tackle existential challenges like climate change, ecosystem collapse, sustainability goals, digitalization, and the positive integration of artificial intelligence.

INTRODUCTION

Significant progress has been made in the development of System Science (Hammond, 2010), General System Processes (Friendshuh & Troncale, 2012) and Systems Practice (Ison, 2010). We have a rich heritage of established wisdom, such as Soft Systems Methodology (Checkland, 1989), System Dynamics (Forrester, 1993), the Viable System Model (Beer, 1984), Architectural Frameworks (Armour et al., 1999) and others, in fields like Systems Engineering (INCOSE, 2015), Operations Research (Churchman et al., 1957), Project Management (Burke, 2013), Cybernetics (Ashby, 1961), Complexity Science (LARSEN-FREEMAN, 1997) and Organisational Management (Mullins, 2007). The goal of this paper is to propose a unifying reference framework that would enhance our capability to understand, communicate, teach, develop, and coherently practice system science through a shared orientation much like the periodic table provides for chemistry and the standard model for physics. Work has already been performed in explaining how Systems Engineering and Project Management processes and principles can be framed as such through invited talks by these disciplines, and the detail of this analysis will be the subject of future papers that build upon this one.

In 2017, the International Federation for System Research (IFSR) conversation "What is System Science?" (Metcalf et al., 2019) aimed to determine if these diverse threads could somehow be woven together. Questions were posed and requirements for the reference framework were specified as part of the conversation. These are addressed, in part or in full, in this paper which represents a work of qualitative research (Khan, 2014) in the context of twenty years of engagement with INCOSE and ten years of engagement with the International Society for

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System Science. Starting in the centre of the diagram, the narrative of the paper follows this structure from the more conceptual to the more practical. The logic of the overall structure becoming apparent as the framework itself emerges.

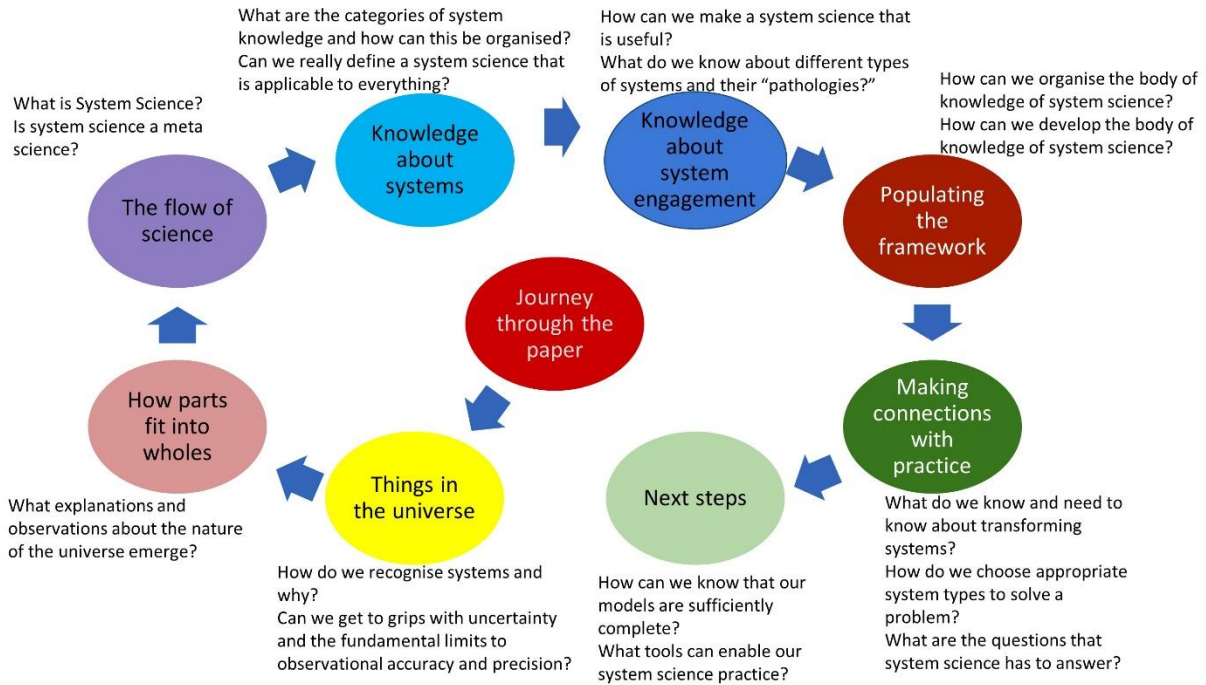


Fig. 1. Journey through the paper

The broader and even more fundamental question of “What is the scientific basis for systems practice?” has led to a continuous and iterative content analysis to make some overall sense of the deeply rich information available. Inductive reasoning has been applied in the approach to understand how diverse transversal knowledge about systems can be generally organised and then intimately connected to equally transversal knowledge of how to engage systemically with systems. The inductive work of this synthesis draws on an authoritative work 'A guide to systems research' (Edson et al., 2017) because it provides a philosophical basis for this paper (Hammond, 2017). The proposed structure and attribution of content within this paper draws on (Kineman, 2017b) because it provides a meta-theoretical orientation of systems and an orientation for systems research. The universality of this meta-theoretical model is justified in relation to fundamental physics within the first part of this paper, ‘Foundations for the framework’. In keeping with this guide, the relational holon is used as central organising theory where specific integrative structures for a) system knowledge and b) knowledge of engagement with systems is proposed with candidate content. With systemic structures for knowledge about systems and knowledge about engaging with systems, we begin to see how all system science knowledge is related and can be organised coherently as an integrated system (Metcalf et al., 2019). As an aid to orientation throughout this paper, figure 2 is provided as a simplified abstraction of these two structures. The colour coding is significant as it indicates a tracing to the quadrants in the relational holon described in figure 3.

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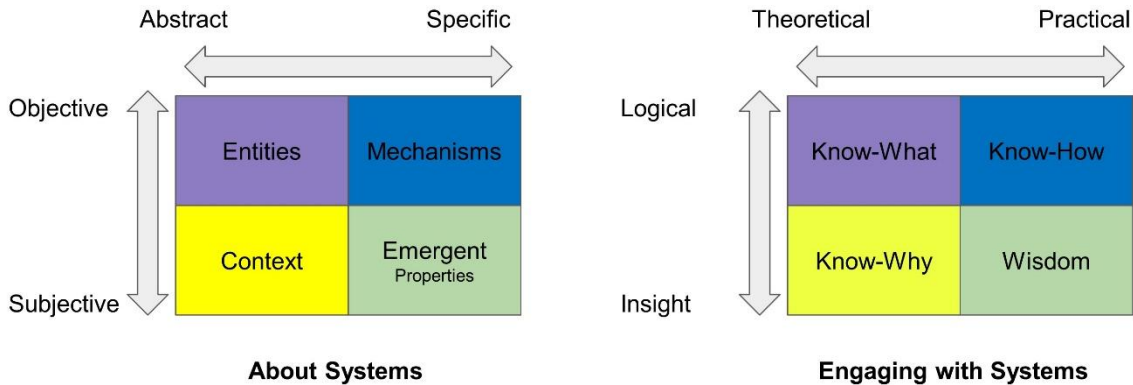


Fig. 2. In essence, the overall framework

The yellow segments align with observation, purple with reflection (or orientation), blue with planning (deciding) and green with acting. Within figure 2, the knowledge of engaging with systems can be directly related and supported by the knowledge about systems:

- Observation, information appreciation of context providing a basis for ‘know-why’.
- Reflection, and appreciation of entities (things) providing a basis for ‘knowing-what’.
- Planning, deciding, understanding mechanisms as a basis for ‘knowing-how’.
- Acting, experience, lessons learnt of living in systems may result in ‘Wisdom’.

These structures are deepened in expression and expanded upon in the second part of this paper, ‘A candidate framework’. The form and content of these structures being the result of continuous iterative gathering (observing), synthesis (reflection), review (planning), and validation (acts of presenting and provision) of information across the diverse systems community using this context. Whilst it is impossible to be truly exhaustive, it is proposed that the resultant combined and connected structure provides a sufficient baseline for the organisation of the knowledge of system science and for further research, communication and testing.

Foundations for the framework

The core of this paper is realised through three main parts. ‘Foundations for the framework’, ‘A Candidate Framework’ and ‘Using the Framework’. In this first part we propose a structure for knowledge development in keeping with the relational holon. We draw upon the physics of systems in terms of informational events, knowledge, forces, energy and mass. We consider the concept of holarchy whereby everything in the universe is both an organised whole and a part of something greater. Science is itself described in this context of the relational holon and the consideration of its discrete parts as a system of stages that bridge theory and practice. Towards a system science of generic, truly transversal, concepts, theories, principles and practices we express the requirement that everything must thereby be a system, an organised whole either conceptually or physically (including system science). Finally, there is an examination and validation of the structure for knowledge development by comparison with a well-established heuristic of systems engineering.

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THINGS IN THE UNIVERSE: RELATIONS, INFORMATION, KNOWLEDGE AND ORGANISATION

The observable universe is a system that contains systems (Mobus & Kalton, 2014). Things interact with other things through forces (Melott, 2015). Every physical and conceptual thing that we know about is made from other things and contributes to one another. For example, the Earth is made of things, the human body is made of things, the universe is made of things, and this paper is made of conceptual things (words and pictures). Things have an identity and a behaviour. Everything is also a part of something else, we call this phenomena ‘holarchy’ (Koestler, 1968). At the limits of our knowledge for the most fundamentally small things in our universe, we have built up the Standard Model of physics. Some of these things have mass (or convey mass) and some of them don't. Some of them convey the electromagnetic force or the strong and weak forces (Wells, 2020).

Things convey forces which interact with other things, but they also convey contextual organisation. According to relational theory (Kineman, 2011), this conveyance can start as a signal from the originating thing, it is a source of data. When this data enters a context, it becomes information (Vedral, 2018), and the informational content of an event is proportional to the log of its inverse probability of occurrence (Vedral, 2018). Information is the impact on the receiver by the data and the consequence depends on the nature of the receiver and the context. In fact, we could say that if information does not have an impact, a ‘relation’, then it's just data and zero information (Mingers, 1995). Organised information, the net result of impactful experience, is knowledge. We use ‘knowledge’ in a universally general way in this paper where it is a property of all things. Knowledge is tangible in the physicality of the universe. The knowledge of a thing is inherent in the relation of a thing to some context, and this kind of logical structure determines what it can do (its behaviour) when it is stimulated by an interaction.

The way that we are using knowledge is in keeping with a measure of knowledge by James Simms - “*an individual's knowledge is directly proportional to its capacity to direct energy*” p. 217 (Simms, 1971). Simms further expresses ‘*everything has knowledge and that all substances can be categorised by the amount of knowledge that they possess and that they can be further classified by type of knowledge*’ p. 220 (Simms, 1971). Therefore, a thing may be defined as structured information, all things, potentially, can be defined as such (Stonier, 2012). Stonier, consistent with Simms, states three theorems pp. 25-26 (Stonier, 2012).

- All organised structures contain information and as a corollary: No organised structure can exist without containing some form of information.
- The addition of information to a system manifests itself by causing a system to become more organised or reorganised.
- An organised system has the capacity to release or convey information.

Stonier further states three axioms of a general theory of information p. 114 (Stonier, 2012):

- Information is a basic property of the universe.
- The information contained by a system is a function of the linkages binding simpler, into more complex units.
- The universe is organised into a hierarchy of information levels.

At the lowest level of our knowledge, quantum mechanics explains that the things in the Standard Model (the basis of all things in the universe that we know about) are themselves formed from structured quantum information and that these things come about because of field

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interactions (Schwartz, 2014; Weinberg et al., 1995). According to quantum field theory, the whole physical universe is derived from quantum information (Vedral, 2018; Zurek, 2018) “It from Bit”. Information comes from data, data comes from signals, and signals come from field interactions. However, it is the more hidden contexts in and of these things that translates the data into meaningful action towards the whole. From data to knowledge, and from knowledge to action, the system is in essence experiencing and expanding its world or indeed the universe (Kineman, 2019; Kineman, 2017a). To give a simple example, an atom is a thing that has a structure consisting of a nucleus and one or more electrons (parts in the context of the atom). The structure also has ‘orbits’ in which these electrons spend their time. These orbitals, inherent in the nature of the atom, have different energy levels. When a photon of light at the right frequency (conveying the right data) interacts with the atom, an electron moves up into a higher energy level (a different internal context) and the photon is absorbed (Whelan, 2018). The resultant information is integrated into the structure of the atom and new knowledge is formed. The form of the atom has now changed. It is at a higher, yet less stable, energy state. It is the structure of the atom that defines its knowledge, it is a characteristic of its organisation. Physical organisation structure is therefore a form of knowledge. When the electron drops back to its original orbital, a photon of light is released, and the atom reverts to its original organisation. The atom has had an experience (the process of doing and responding to things), it has gained knowledge and lost it when the photon is released. Overall, its knowledge is essentially unchanged from this experience. It does not have the capability in its nature (it’s essential structure) to learn from the experience and change how it would behave if the process were repeated. Thus, and consistent with Brown (Brown, 2019), things are aware of their environment based on their ability to absorb information when the right data interacts with their form. To summarise some essentials; things have a form (Joad, 1933), they are made up of parts, which are themselves things, everything has a structure, an identity, characteristics and displays behaviours. Things, because of their form, convey and receive signals that provide data. The structure of things provides a capability to act on information, resulting in a power to create new structures, new knowledge, and new forms (Kineman, 2011). So far, we have mostly focused on the form of things and how they interact in a cycle of relational interactions that is explained by Relational Theory (Kineman, 2017b).

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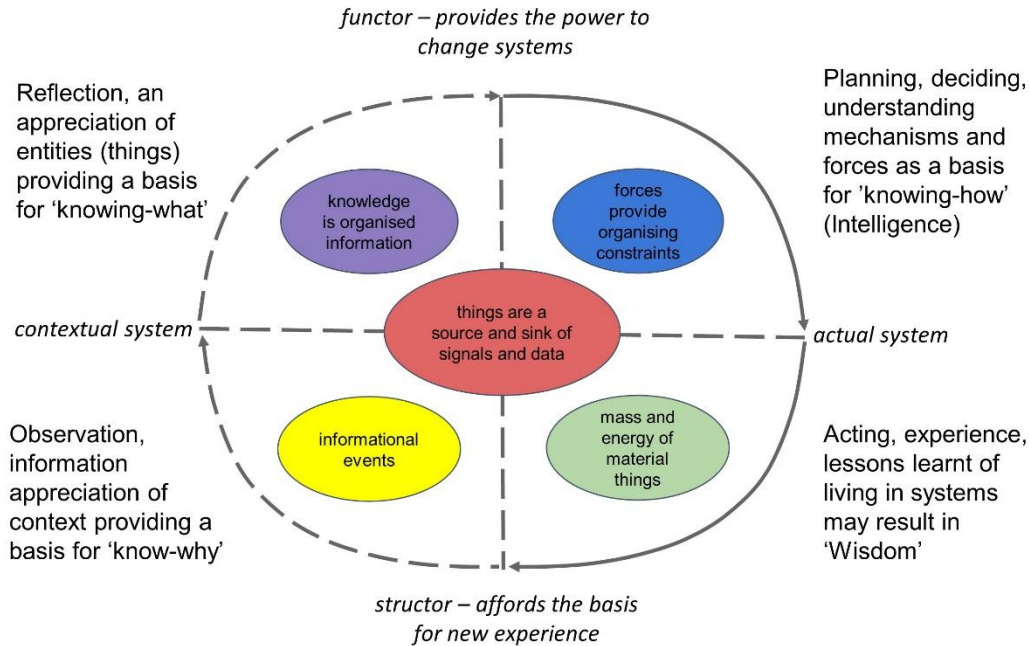


Fig. 3. The universal physics of the relational holon

Figure 3 provides an adapted illustration of the relational model and makes explicit the connection of universal physics to the system research framework (Kineman, 2017b).

HOW PARTS FIT INTO WHOLE: STRUCTURES, COMPOSITIONS AND ENABLING CONSTRAINTS

As mentioned previously, everything is also a part. Parts play a function in the context of the whole thing that they contribute to. A part receives inputs from its environment (the sum of the systems in which it plays a part), processes those inputs and then exhibits outputs which influences the complexity of the whole, thus playing a particular influence within context states. Parts, as systems in their own right, also have a structure, an identity, characteristics, and display behaviours. Regarding the whole, parts have a place that they occupy in the structure of the whole. They have a purpose in terms of what behaviour they exemplify, they have their own lifecycle which is strongly influenced by the whole and they provide capabilities towards the whole. The whole provides constraints on the parts and affordances for relationships with other parts, of other wholes; they provide an environment within which the parts occupy and provide a means of engagement and stability to the wider context.

The International Council On Systems Engineering provides a definition of system p. 2 (Dori et al., 2019), “*A system is an arrangement of parts or elements that together exhibit behaviour or meaning that the individual constituents do not*”. However, when taking into account the relational perspective, Alexander Bogdanov provides perhaps the richer description as expressed by Dudley p. 18 (Bogdanov, 1996)

"Bogdanov's system (or complex) is not simply a collection, aggregate (or vector) of components and their relationships. A system is a process, or continuous flux of

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independent component producing processes, concatenated in self-triggering circles of build-up and degradation. Bogdanov's system cannot be separated from its environment, because it does not simply exist or interact with its environment: it is structurally coupled with its environment and thus evolves its own environment while co-evolving with it”.

To recap, in systems science, a part is an entity that performs a function within the context of a whole. This function involves receiving inputs from its environment, processing these inputs, and producing outputs that influence the whole. The environment of a part comprises the systems in which it plays a role, highlighting the interconnectedness and interdependence of parts within larger systems.

Key Characteristics of Parts:

- **Structure:** Parts have a specific arrangement and organization that define their identity and functionality.
- **Identity:** Each part has unique characteristics that distinguish it from other parts.
- **Behaviour:** Parts exhibit behaviours based on their structure and interactions with the environment.
- **Lifecycle:** Parts have a lifecycle influenced by the whole, including phases of formation, operation, and termination.

Key Characteristics of Wholes:

- **Composition:** Wholes are composed of interconnected parts that collectively exhibit behaviours or meanings not present in the individual parts.
- **Constraints and Affordances:** Wholes impose constraints on parts and provide affordances for relationships with other parts, contributing to the stability and functionality of the system.
- **Environment:** Wholes create environments within which parts operate, influencing their behaviour and interactions.

In this work we work on the premise the everything is both a part and a system. Everything in the universe being subject to universal laws (its organising constraints) and everything (conceptual or physical) being a part of the universe.

SCIENCE AS A SYSTEM: PURPOSE, PARTS AND RELATIONAL DYNAMICS

Science, originating from the Latin word *Scientia*, which means "knowledge", is the systematic enterprise that builds and organises information in the form of testable explanations and predictions about the universe. Science takes into account heuristics and through the application of the experimental method over time the fidelity of the knowledge increases (Wilson, 1999). “The fundamental principles of the scientific method are essential for enhancing perspective, increasing productivity, and stimulating innovation.” (Gauch, 2012) Thus, usefulness is important for science, and this is equally true towards the utility and purpose of a science of systems. System science is a science of general knowledge about things and human engagement with things (Hieronymi, 2013; Metcalf et al., 2019).

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“System science provides a somewhat unique mode of inquiry in revealing not just how one kind of system works but rather how all kinds of systems work” p. 3 (Mobus & Kalton, 2014).

The purpose of system science is to expand our knowledge about systems and the processes of engaging with and transforming systems. The feedforward and feedback relationships in the development of knowledge include “seven witnesses” p. 63 (Gauch, 2012) to science’s success (i..vii). The incorporation of this serves to provide an explanation how science achieves its purpose based on the function, interaction and development of the parts towards and within the whole.

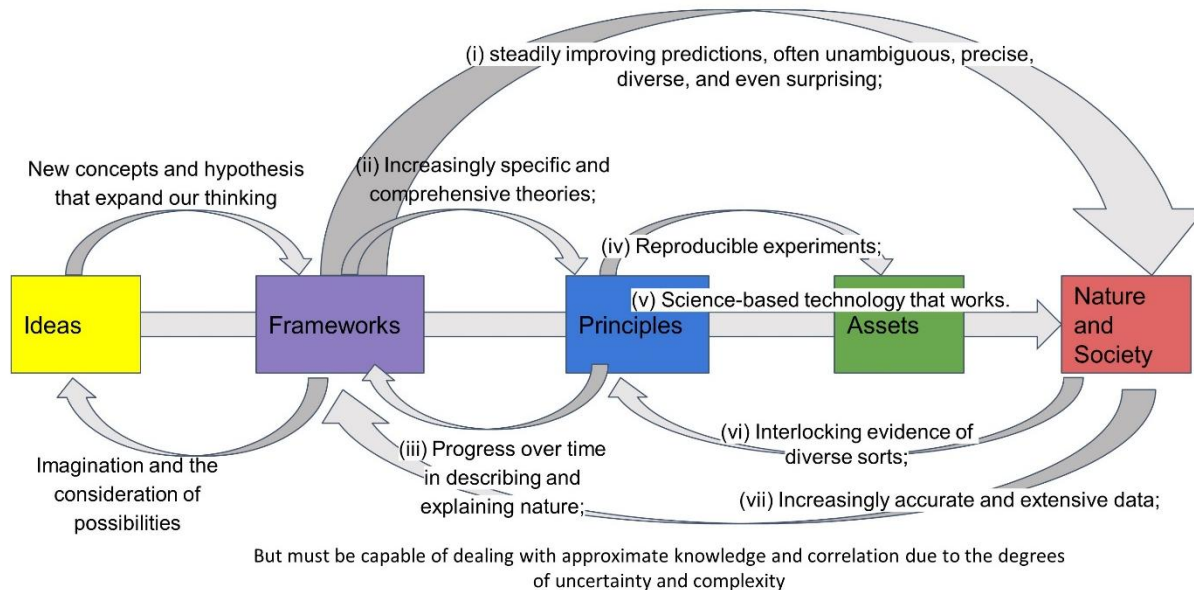


Fig. 4. Science as a system

In the context of relational theory, the five main parts of science are illustrated in figure 4, thereby making it explicit how this instantiates figure 2 and 3. In doing so, science can be understood as a system and in keeping to the nature of systems. The relational framework represented in figure 3 as a theory of natural causation and its application connected with our engagement with systems has been previously expressed (Blockley et al., 2023). The colour coding reflects the correspondence and instantiation of the relational holon in this system of system science. In making this connection we make explicit the purpose of the parts and their interactions towards the whole: ideas, concepts for meaning and observation (informational events); frameworks for orientation built from reflection (knowledge formation, general theories in a context of system science); principles used for planning and decision making (the application of enabling constraints/forces); assets with action on substance (energy/mass realisations) for engagement with nature and society (the greater and emergent whole). The functional sequence provided by the parts, provides a vital structuring element for understanding how concepts contribute to theories, how theories provide the basis for principles and how principles form the basis for action.

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Ideas. This is the part of science where new things, conceptual or physical, are distinguished (Informational events). Information with semantic meaning, based on **observation**, experiencing or imagination, new needs, insights and concepts are brought to light (Gelman, 2009). Simply put these are represented by the key words we use when we communicate or those things we visualise in our minds (Hampton & Winter, 2017).

Frameworks. This is the place of conceptual systems. We connect concepts together, **reflecting** on these connections and build models, big pictures that convey joined up understanding. General frameworks for organising relationships and understanding why they occur in the universe (Wallis, 2021). Conceptual frameworks are built up from theories about relationships (Collins & Stockton, 2018).

Principles. This is the place for expressing the result of conceptual or physical component interactions within a framework. A kind of knowledge that expresses rules of nature (or those defined within our human activity systems) and provides guidance, **plans**, for action (Rousseau, 2018). Verifiable facts.

Assets. Assets in the flow of science would be the part that holds the enablers for **action**. The methods, tools, technologies, resources, wisdom that has been acquired through the application of principles, experimentation, and experience.

Nature and Society. Nature and society are the subject of our engagement, being life, the universe and everything which are all sources of data and affordances for new relations, new informational events.

In general guidance to students on writing a literature review, a prominent university provides the following statement: *“In order to take this argument further, the picture below is important to visualise. It portrays the symbiotic existence of the domains of theory and practice, which are in constant dialogue with each other. In the science of theory-making, these domains are often referred to as the conceptual and the operational domains. Hence, you will see the two important verbs that capture the essence of this dialogue, namely operationalise and conceptualise.”*(Stellenbosch)

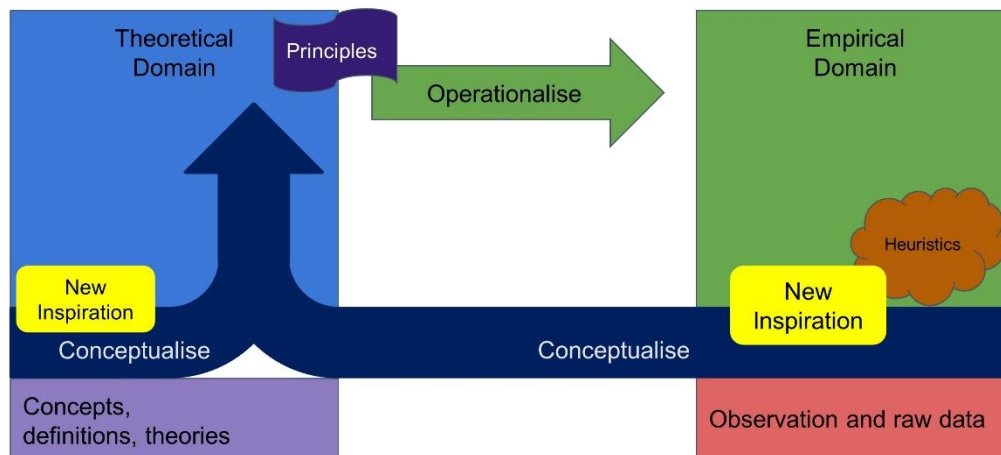


Fig. 5. Dialogue between theory and practice (Stellenbosch)

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Figure 5, adapted with colour coding (Stellenbosch) expresses the integrated dialogue between theory and practice in relation to the system of science proposed in figure 4. We can observe in the diagram that inspiration for new ideas, explanations of ‘why’ may be generated through the process of conceptualisation inspired by analogy with existing concepts and theories or from observation and wondering why (the apple falls - Newton). The result of this integral connection and feedback in the flow of science is a growing fidelity between theory and practice. This coherence is sometimes surprising, two threads, one of theory and one of practice unexpectedly coming together and found to be mutually supporting. For example, the concepts of Fit, Form and Function provides a well-established heuristic model in engineering that is of utility when parts in existing products need to be replaced by a suitable substitute (Cloud & Cloud, 1997). The replacement part must fulfil all three criteria to be acceptable.

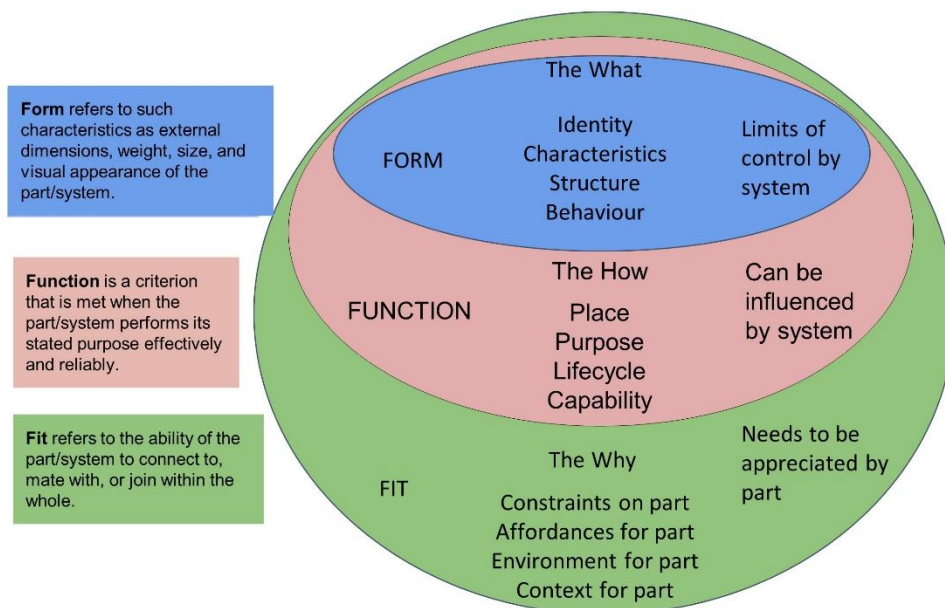


Fig. 6. Fit, form, function, and some related concepts

This heuristic model can now be seen to fit with the concept of holarchy that is a universal characteristic of all things. When grounded in underpinning theory this heuristic can be seen to be scientifically based (Frigg & Hartmann, 2006; Winther, 2015). Interestingly, in keeping with the model of Fit, Form and Function, Ring’s Problem Solution System (Ring, 1998) includes within it a “Focus on System”, “Focus on Purpose” and “Focus on Value”. In engineering there is also the concept of a system breakdown structure (Tonnelier & Terrien, 2012), which is an integrated holarchy of all the parts and subparts that make up the system-of-interest.

Interest in consciousness as a general concept to all things (Young, 1973) remains controversial, but this is an important feature of holarchy. There is a growing opinion that all things have a degree of consciousness, and the simplest definition is merely awareness of surroundings. To further explain, we refer to the experience of an atom. Since all things are a part of a greater whole, all things must have some awareness of how they fit, otherwise they would not (Bennett, 2004). Without awareness they would have no attraction/binding force to be part of a whole.

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This relates to another important general system concept – auto-organisation p. 493 (Mobus & Kalton, 2014) “*not as a magic process but as the result of components interacting and forming structures*”.

A CANDIDATE FRAMEWORK

We have so far in this paper referred to the universal physics of systems and described the stages and context of science using the relational holon as a meta-theoretical orientation. In this second section of the paper, we build upon the foundations expressed in the first. A candidate framework for organising the knowledge of system science is gradually constructed in two inter-related parts:

- In ‘Structuring knowledge about systems’, we introduce and make use of knowledge categories as one axis of a matrix in relation to the phases and context of science as a system on the other axis. This provides the left-hand side of the overall framework that is presented in figure 1.
- Before commencing with a structure for ‘engaging with systems’ we reflect on the problems and general pathologies we observe in our projects, programmes, social structures and in our everyday lives. We note the great diversity of heuristics that is available and how this potential wealth is disordered, competing, not collaborative and to the need and challenge of organising this as a more effective coherent whole.
- In ‘Structuring knowledge about system engagement’, ‘Appreciation, Influence, Control’ (AIC) as a general model for social systems is introduced and utilised. This provides a means of structuring knowledge of engaging with systems and makes connections with the ‘structure of knowledge about systems’. Within this structure of engagement (another instantiation of the relational holon), pathways that work to resolve or promote pathologies are proposed. This structure provides the right-hand side of the overall framework that is presented in figure 1.

STRUCTURING KNOWLEDGE ABOUT SYSTEMS

Tables have been effective for helping to organise knowledge in other sciences. They provide enabling constraints to segment and focus on individual parts while working within the context of a whole. A framework for system knowledge has been proposed (Rousseau et al., 2018). It is a matrix using two dimensions of classical philosophy and types of knowledge. Considering the key concepts and frameworks explained in the first section, we now propose the following categories of knowledge within a framing of holarchy (form, fit and function) which elaborates and extends this previous work:

- Form is associated with our knowledge of:
 - Identity and the existence of things (within the concept of ontology)
 - Behaviour and the expressed nature of things (within the concept of metaphysics)
- Function is associated with our knowledge of:
 - Cycle of origins, evolution, and end of things (within the concept of cosmology)
 - Capability, purposes, the pursuit of meanings of things (within the concept of praxeology)
- Fit is associated with our knowledge of:

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- Values of things and about why and how things have qualities, worthiness (within the concept of axiology)
- Consciousness, about the nature of and routes to knowledge of things, this includes awareness, experience, learning (within the associated concept of epistemology)

We use the philosophical terms ('-ologies') in the context of form, fit and function very generally here. This abstraction provides insight, and which is informative. Generalising the term, we use it for human thinking about knowledge in a way that is relatable to the characteristics of systems. A table for framing knowledge about systems can now be formed. The parts, derived from figure 4 plus its associated description and grounded in the relational model, provides columns, the categories as rows. In the resultant matrix, every segment in the framework would then be a place to collate, integrate and relate segments of knowledge as an organised whole. As we progress with the content of this paper, the logic of these categories and their connections will become more apparent.

		Ideas - Concepts (for meaning and observation)	General Theories - Frameworks (for orientation)	Big Ideas - Principles (for deciding)	Enablers - Assets (for acting on)	The whole-Context (to realise)
C a t e g o r i e s	FORM					
	Identity of wholes (togetherness of things)					
	FUNCTION					
	Behaviour of wholes (processes of things)					
	FIT					
	Cycles of wholes (phases of things)					
	Capability of wholes (purpose of things)					
	Value of wholes (qualities of things)					
	Consciousness of wholes (experience of things)					

Table 1. Candidate framework for organising knowledge about systems.

Problems and Pathologies - A wealth and disorder in system practice

THE NEED FOR A SHARED ORIENTATION

The Fourth Wave of Systems Thinking (Cabrera et al., 2021), is a work of which we see many parallels. This work describes four waves as a continuum. 1st 'Hard Systems', 2nd 'Soft Systems', 3rd 'Critical Systems' and 4th 'Universality and diversity' *"The fourth wave has been brought on by a renewed search for universal structures of systems thinking... a search for universality (that there are underlying 'universal' patterns of mind and nature) across the systems thinking field, as well all forms of knowledge"*. We concur that an enterprise for system science, one

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where we have a shared language and shared orientation, will have the capability to foster ‘unity and diversity.’

A practical example of the problems that result from a lack of shared orientation can be seen in complex programmes; the Project Management and System Engineering disciplines both recognize that the other is essential for the successful delivery of complex programmes. Yet, most complex programmes fall well short of their expectations or outright fail and are cancelled due to poor organisation, poorly defined or missing objectives, ineffective planning, and insufficient resources (Boehm, 2000; Decker et al., 2012; Whitney & Daniels, 2013). Despite common interests between these disciplines, these issues can be traced to insufficient cooperation and unproductive tension as a result of a lack of shared orientation (Conforto et al., 2013). Once again, a reminder previously mentioned, “Dis-organized wholes are practically less than the sum of their parts” p.75 (Bogdanov, 1996). In the experience of the author, we observe that competition outweighs collaboration in the space of our system practice knowledge and that this is ultimately detrimental in our attempts to promote system science - ‘my theory, my concept, my method... is better than yours’ is often heard or evident, we have no generally shared orientation yet and this contributes to the pathologies we see in our organisations.

General system pathologies

In 2019, at the annual conference of the International Society for the Systems Sciences (ISSS), a half day workshop was held on system literacy (Wilby, 2020) inspired by the Ocean Literacy programme (Santoro et al., 2017). The purpose of the workshop was to generate ideas on how to take system literacy forward. As part of the workshop the forty-five participants were asked the question, “Can you identify features that you would associate with being ‘non-systemic’?”. The following twelve clusters were identified, arranged, and refined (Tuddenham, 2019).

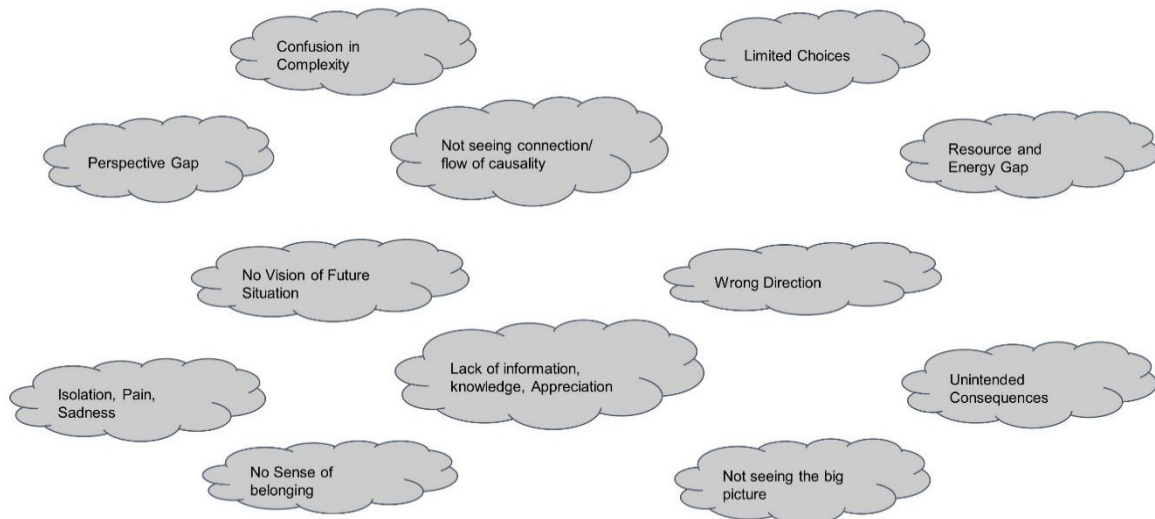


Fig. 7. Twelve clustered systemic pathologies

We experience these “Systemic Pathologies” in our daily lives, in our businesses, our organisations, our programmes and in the challenges of the Anthropocene (Schill et al., 2019). There are many kinds of frameworks for engaging with systems to address these pathologies, to

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promote systemic practice and here below we list just a few, not intended to be exclusive but merely illustrative of the diversity that somehow needs to be integrated.

System Thinking

Systems thinking is used very broadly to express heuristics of how to engage more effectively with systems and to address pathologies (Schaveling & Bryan, 2018). There are some seminal works and frameworks on systems thinking of which ‘DSRP’ is one (Cabrera et al., 2015; Cabrera & Colosi, 2008). ‘DSRP’ is a useful entry point into Systems Thinking due to its simplicity, it is made up of four essential building blocks - Distinctions, Systems, Relationships and Perspectives. There are however many other systems thinking frameworks from diverse sources that should be considered complementary (and not positioned as competing). For instance, the ‘habits of the system thinker’ (Benson, 2015) provides accompanying graphical cards that illustrate heuristics in easily understandable context. They also provide associated questions that can help pinpoint increased situational understanding and appreciation. Predating all these though is the ‘Tao Te Ching’ (Laozi & Wing, 1986), a construct of eighty-one poems, that offers wisdom for living in harmony with the flow of the universe.

Business Standards

There are numerous complete collections of international standards for business and organisation management (Marimon et al., 2009), project management (Shepherd et al., 2023) and system engineering (INCOSE, 2015) all of which can be considered largely heuristic in nature.

Situation appreciation and management

There are frameworks for sense making, situational awareness and situational management such as Cynefin (Snowden et al., 2020), OODA (Rousseau & Breton, 2004) (extended here to incorporate command, control and teamwork), Panarchy (Allen et al., 2014), Cybernetics (Birnbaum & Edelson, 1989; Lent, 2012) and Agile (Tallon et al., 2019).

Intervention methodologies

There are system intervention methodologies – “Soft Systems” (Checkland, 1989), Lean (Oehmen et al., 2012), Six Sigma (Brady & Allen, 2006).

Frameworks for understanding teams

There are frameworks for understanding the personality traits (McCrae & Costa, 1989), and team roles (Belbin, 2012), that combine synergistically to form effective teams (Higgs, 1996).

What if all this diversity and more could be organised and better yet grounded and explicitly connected with our knowledge about systems (Troncale, 1988)? Could it be that this human activity knowledge might be unified as a whole (Troncale, 2013; Wilson, 1999)? We now propose a candidate that would foster a shared orientation that could be used to explicitly connect this wealth of system practice knowledge as a system.

STRUCTURING KNOWLEDGE ABOUT SYSTEM ENGAGEMENT

A key challenge in creating an organisational structure for system engagement is how to ground and connect this structure with knowledge about systems. In doing so we would not only verify the structure as systemic, but we would also be able to connect knowledge as informative across

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the two. For instance, providing context for the practices in relation to which aspects of the system of interest are most relevant to the act of practice. Bridging between the two construction has been found to be enabled through the Appreciation, Influence and Control (AIC) Model (Smith, 2008). AIC in its one-dimensional form maps to holarchy: Appreciation to the greater whole; Influence being the consideration of the interdependence between the whole and the part; Control of the part (a maintenance of self). This alignment of AIC with holarchy was noted in figure 6 and is worth the reflection of the reader at this point.

In the two-dimensional form of AIC, a matrix arises, and this is shown in Table 2. It too is an instantiation of the relational holon and can thus be used as an overlay onto the 'knowledge about systems structure'. Nine transformational powers are made evident (Smith & Tuddenham, 2019) within this matrix and can be considered the motivations for system change when we engage with systems. The AIC matrix provides a general model for understanding power, purpose and practice in social systems.

	POWER			
PURPOSE	Global Fit Appreciation Coherence	Regional Function Influence Coordination	Local Form Control Organization	
One's Form control Objective	Theory Orientation Know-What	Technical Expertise	Action Potential Means Know-How	
One's Function influence Relational	Philosophy Vision	Political Governance Balance	Decisions Management	
One's Fit appreciation Subjective	Spirit Life Values Know-Why	Social Stakeholder Needs	Design Aesthetics Wisdom	
	Information Resonance Legitimacy	Energy Transformation Effectiveness	Matter Formation Efficiency	Substance Process Criterion
	Order of process			
	PRACTICE			

Table 2. AIC Theory - Purpose and practice of transformational powers

By way of an example to explain the meaning of this table. As individuals we have some control over our own behaviour, our form. Our fitness is judged in the context of all the systems in which we choose, or by necessity must belong, since we are all a part of nature. We have some influence on these systems, but it pays us to be appreciative of these systems, the part we play and the functions we provide in service to the whole. Our orientation (**Theory**, know-what in our world), expertise (**Technical**, know-how in the systems in which we interact) and means (**Action Potential**, what we could act upon if we choose to do so) are all aspects that we have control over. We all have within us the potential to develop our knowledge and expertise. Our vision (**Philosophy**, for our place and purpose, balanced reasoning) is influenced by our life values

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(**Spirit**, connectedness, feelings of resonance). Our governance (**Politics** of self, equality, negotiation) is influenced by those around us (**Social**, caring, norms of behaviour) Our management (**Decisions**, commitments, responsibility) is influenced by how we perceive (the **Design** aesthetics, appeal, pride) in the systems in which we play a part. The AIC matrix maps to figure 3 and to the right-hand side of figure 2.

AIC as a matrix represents the generic social system for engaging with systems. The transformational powers are connected to the pathologies from figure 7 as they promote overall system coherence or alternatively disorder. Although the allocation in figure 8 is candidate, it has proved meaningful and useful through demonstration in various professional contexts.

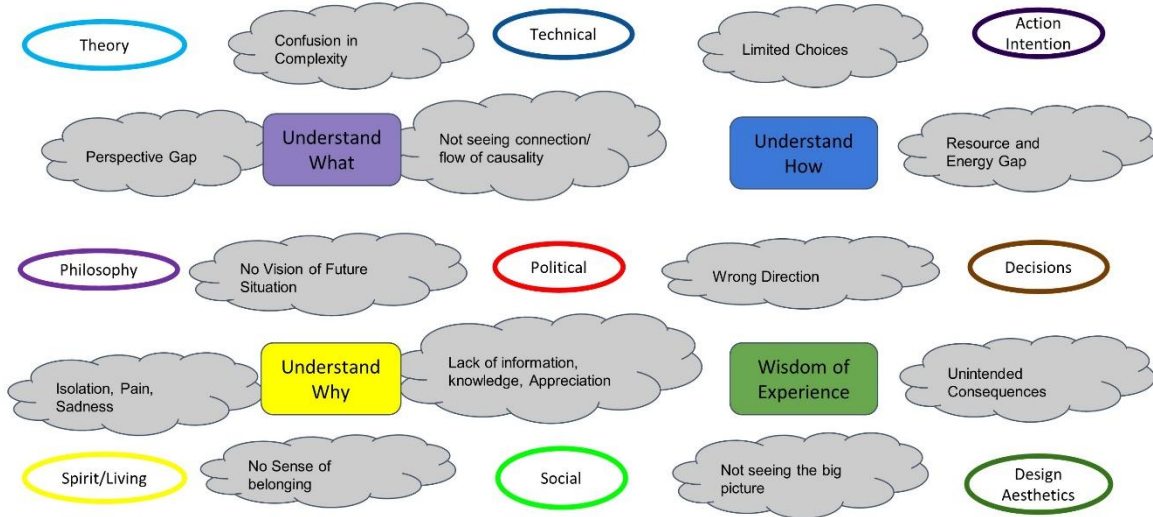


Fig. 8. Pathologies and transformation powers

Note that for further traceability we have included mapping in context for Observing, Reflection, Planning and Acting in the holon of system research. We can overlay figure 8 onto the system of knowledge about systems given that both systems are an instantiation of the relational holon model. The transformational powers are “drivers for change” and provide a logical bridge between the two dimensions of system knowledge.

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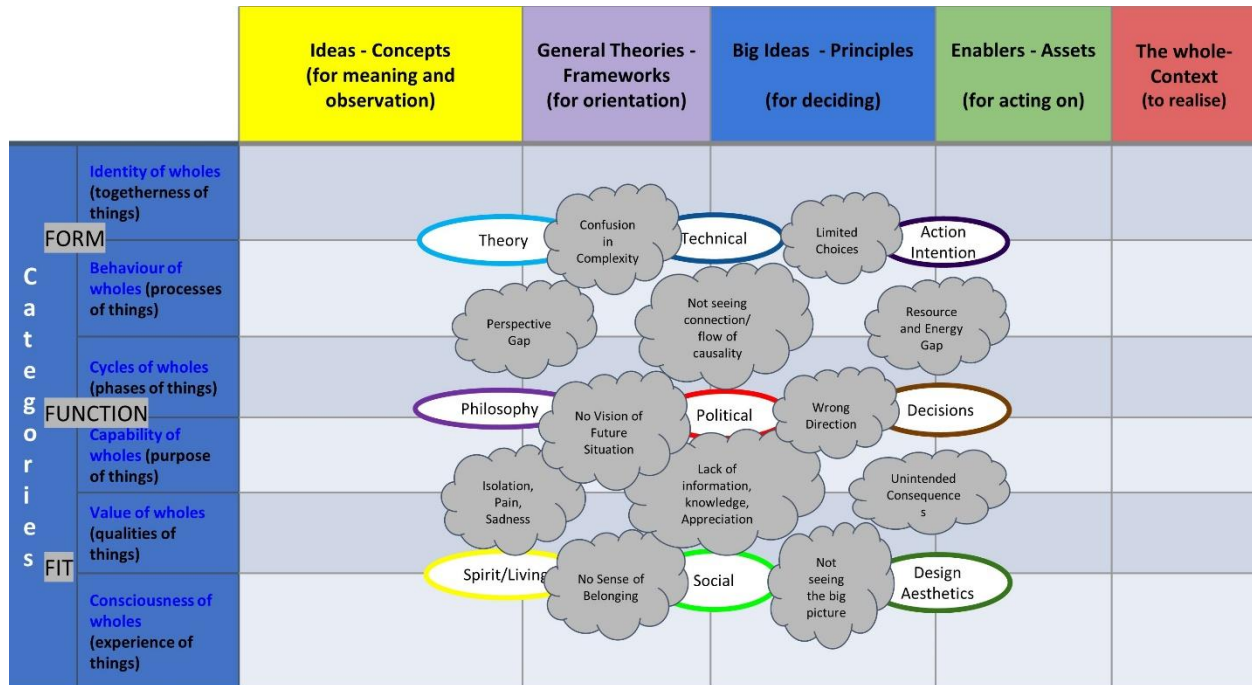


Fig. 9. Overlay of pathologies and transformation powers

The reader will note that each transformational power spans four surrounding segments in the ‘knowledge about systems’ structure. The power of theory as an example operates on concepts and theories in the space of identities/togetherness and behaviour/processes. The power of spirit/living operates on concepts and theories in the space of value/qualities and consciousness/experience. What becomes noticeable is that the more conceptual or intuitive aspects are towards the left, and the more tangible, sensing, to the right. Objective oriented thinking is towards the top, and the more subjective feeling is towards the bottom. Introverted motivation bottom left, extraverted motivation top right, perceptive towards top left and judgmental towards bottom right. In the resultant framing the segments of the matrix would be expected to provide ‘about system’ knowledge context in the support of transformational power as demonstrated in table 3.

Using this framework about systems as a structure, we then progress to map again the heuristics on the pathways between the pathologies and the powers (Smith, 2021b). Analysing the overall purpose of the allocated heuristics, we give voice to the pathways and provide a suitable name to communicate their function.

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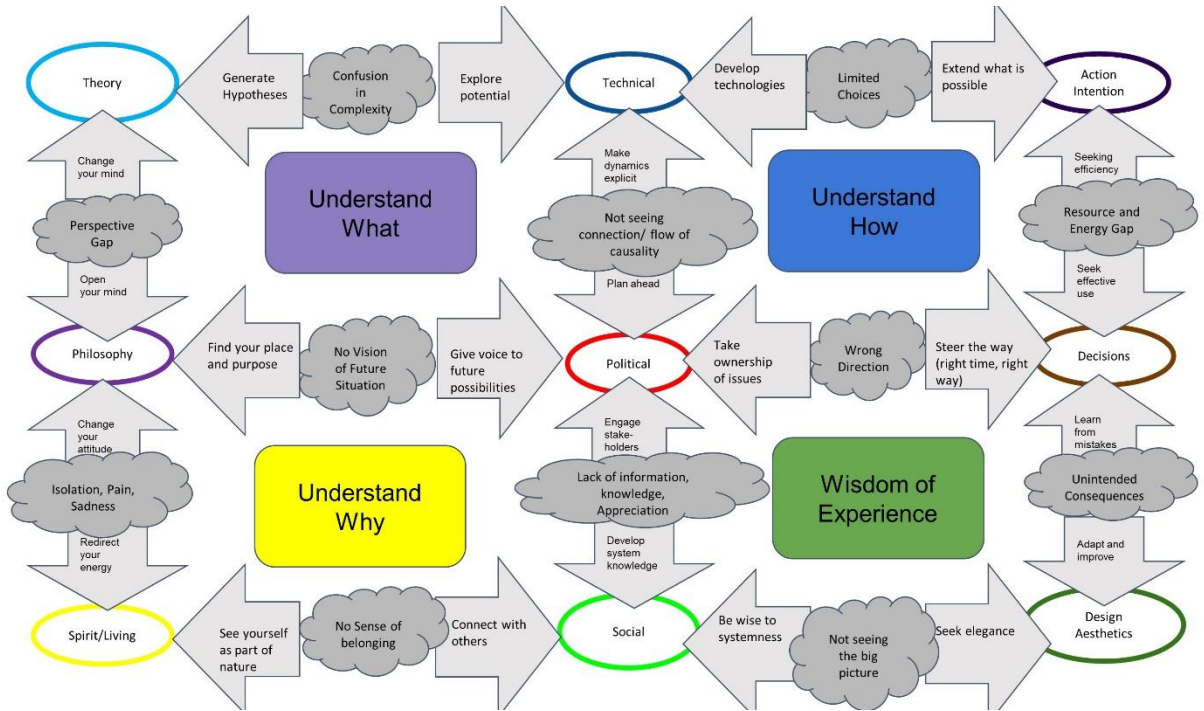


Fig. 10. Pathways that enact powers systemically

Belbin team roles (Belbin, 2012) can be overlaid (30:40) (Smith, 2021a), giving context of the pathologies and pathways that these roles pursue, e.g. Innovator/Plant with theory and generate hypothesis, Implementor with action potential and “extend what is possible”.

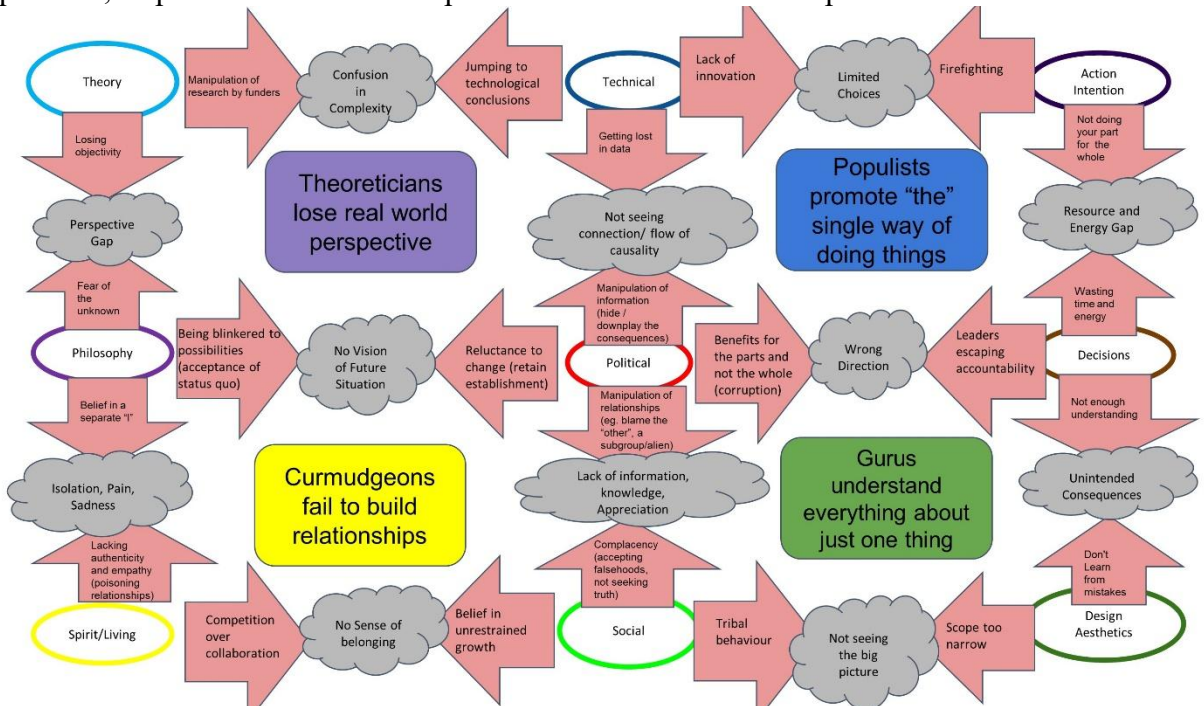


Fig. 11. Pathways that enact power non-systemically

Figures 10 and 11 should also be considered work in progress. However, this provides a means whereby we are now able to appreciate the positive and negative paths in the context of the

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human activity system. Inclusive in figure 11 are four ego traps (Curmudgeons, Theoreticians, Populists and Gurus), by Taylor, that lie in wait as you enter any powerful field of knowledge, *“Each of the types will poison the field and put others off, if you’re not careful.”* (Taylor)

USING THE CANDIDATE FRAMEWORK

Populating the framework

To help with understanding, the idea is to populate the framework with our knowledge about systems. The concepts, the frameworks, the principles, assets, and context that relate to the categories of knowledge about systems. The text below provides examples for the category of identity and togetherness.

Concepts of identity and togetherness. These would be the key words that we use when we discuss and share ideas related to things such as structure, organisation, arrangement, shape, and content.

Theories of identity and togetherness help to comprise general frameworks for organising and classifying the different types of things. There are theories that provide explanations for ‘grand leaps’ or levels of emerging complexity of systems (Kleineberg, 2017) such as those expressed in ‘Quarks to Culture’ (Volk, 2017). We can identify that there are two other distinct kinds of emergence. Within levels there is ‘scaled emergence’; add more protons, neutrons, and electrons within the level of atoms and all the elements emerge. Within established systems, subsystem emergence can take place; specialisation of cells and the development of organs in multicellular organisms, or specialists, experts, leaders emerging within social systems. We anticipate that an organising structure of system types, based on the three dimensions of emergence (levels, scaled and subsystem), would be attainable and illustrative of the system landscape.

Principles, or ‘Big ideas’, about identity and togetherness, here again just one simple example (simpler identities combine into more complex identities) of a kind of knowledge that is useful for facts about how things work. Without doubt, there will be many such big ideas and it would be very useful to organise them for educational purposes and for system literacy (in the style of Ocean literacy (Santoro et al., 2017) for instance).

Assets, what kind of resources (identifiable things) are there in the context of creating, transforming, and maintaining systems? What do we know about togetherness generally? As evidenced in the scaled application of protons, neutrons and electrons coming together under the same togetherness ruleset this is not without limits to growth (increasingly radioactive and short-lived elements occur beyond Uranium) and this is most likely seen in higher orders of systems in the biological and social contexts (Meadows & Randers, 2012) (‘Limits to Growth’). This would be the place for describing such knowledge. In ‘Quarks to Culture’ (Volk, 2017) provides a well thought through set of mechanisms for togetherness and motivations for binding that could be expressed as a taxonomy. The work of Boulding and others could provide the basis for a taxonomy of system types (Mingers, 1997).

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The table below is the result with some content for illustrative purposes. In this paper we will not attempt to justify the accuracy of the content but provide the illustration to resonate and convey the overall potential of the framework for exploration and orientation.

		Ideas - Concepts (for meaning and observation)	General Theories - Frameworks (for orientation)	Big Ideas - Principles (for deciding)	Enablers - Assets (for acting on)	The whole-Context (to realise)	
C a t e g o r i e s	FORM	Identity of wholes (togetherness of things)	Structure, Components, Boundary, Boundedness, Hierarchy, Topology, Wholeness, Integrity, Network,	Theories of Identity and Togetherness	Simpler things combine into more complex things #1 have systemness #3 are networks	Taxonomy of togetherness (eg Volk)	Taxonomy of system types (eg Boulding)
	FUNCTION	Behaviour of wholes (processes of things)	Activity, Dynamic, Influence, Interaction, Dependency, Feedback, Source, Sink, Stock, Flow, Effect	Theories of Behaviour and Processes	Very different things do many things in the same fashion #2 are processes #4 are dynamic	Taxonomy of processes (eg Troncale)	Taxonomy of behaviours (eg. Troncale)
		Cycles of wholes (phases of things)	State, Phase, Transition, Event, Tipping point	Theories of Cycles and Phases	Everything follows a lifecycle, even the universe #11 can be understood #12 can be improved	Taxonomy of phases (eg Troncale)	Taxonomy of cycles (eg. Troncale)
		Capability of wholes (purpose of things)	Stakeholder, Responsibility, Role, Hierarchy, Autonomy, Environment	Theories of Capability and Purpose	Emergent Properties when things combine #5 are complex #8 have regulatory subsystems	Taxonomies of purposeful subsystems (eg Miller)	Taxonomy of capabilities (eg. Mobus/Beer)
		Value of wholes (qualities of things)	Perspective, Use, Judgement, Condition, Circumstances, Benefit, Selection	Theories of Value and Qualities	Value increases when stakeholders are engaged #9 models of others #10 models of themselves	Taxonomies of qualities (eg Virtues - Rousseau et al)	Taxonomy of values (eg. Swartz)
	FIT	Consciousness of wholes (experience of things)	Awareness, Understanding, Empathy, Comprehension, Learning, History, Memory, Evolution, Adaptation, Anticipation	Theories of Consciousness and Experience	The more complex something is, the richer is its experience #6 are evolving #7 encode knowledge and exchange information	Taxonomies of experiences (eg Bloom)	Taxonomy of Consciousness (eg Jonkisz)

Table 3. Candidate examples of knowledge about systems

In table 3, the principles of system science (Mobus & Kalton, 2014) (e.g. #1 ‘systems have systemness’) have been mapped. The taxonomies for assets and for the whole have been illustrated with examples from (Volk, 2017), (Troncale, 2013; Troncale, 1978), (Miller, 1995), (Rousseau et al., 2019), (Bloom et al., 1984), (Boulding, 1985), and (Jonkisz, 2021). The concept of ‘degrees of’ is applicable to all these taxonomies. The greater the integrated information, the level of complexity (as we rise from quarks to culture), and the greater the emergent ‘degree of or richness of’ identity, behaviour, lifecycle, capability, values, and consciousness.

MAKING CONNECTIONS TO PRACTICE

“The chemist uses their understanding of chemical elements when they interact with chemical substances. Likewise, in the future the systemist will use their understanding of systemics when they manipulate and transform systems” (Allegro & Smith, 2016). Le Chatelier's principle is most associated with chemistry and is used to predict the effect of a change in conditions on chemical equilibria. However, we can treat the principle as a more general application (Griffin, 1990; Norwich, 2010) of systemics, such as when a settled system is disturbed, it will adjust to diminish the change that has been made to it or, "roughly stated", any change in status quo prompts an opposing reaction in the responding system. This manifests as an enactment of the political power (in AIC) to resist change. In Gaul’s ‘The System Bible’ it is stated that ‘the system always kicks back’ p. 25 (Gall, 2002). For each of the twenty four forward and backward pathways, “systemical” reactions (analogous to chemical) that we see in the human activity system, we have provided an analysis and allocated the heuristics that are most associated with

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these (39:20) (Smith, 2021a). Below we visualise one; the interplay between the political power (AIC) and the pathology of “no vision of the future situation” as an example.

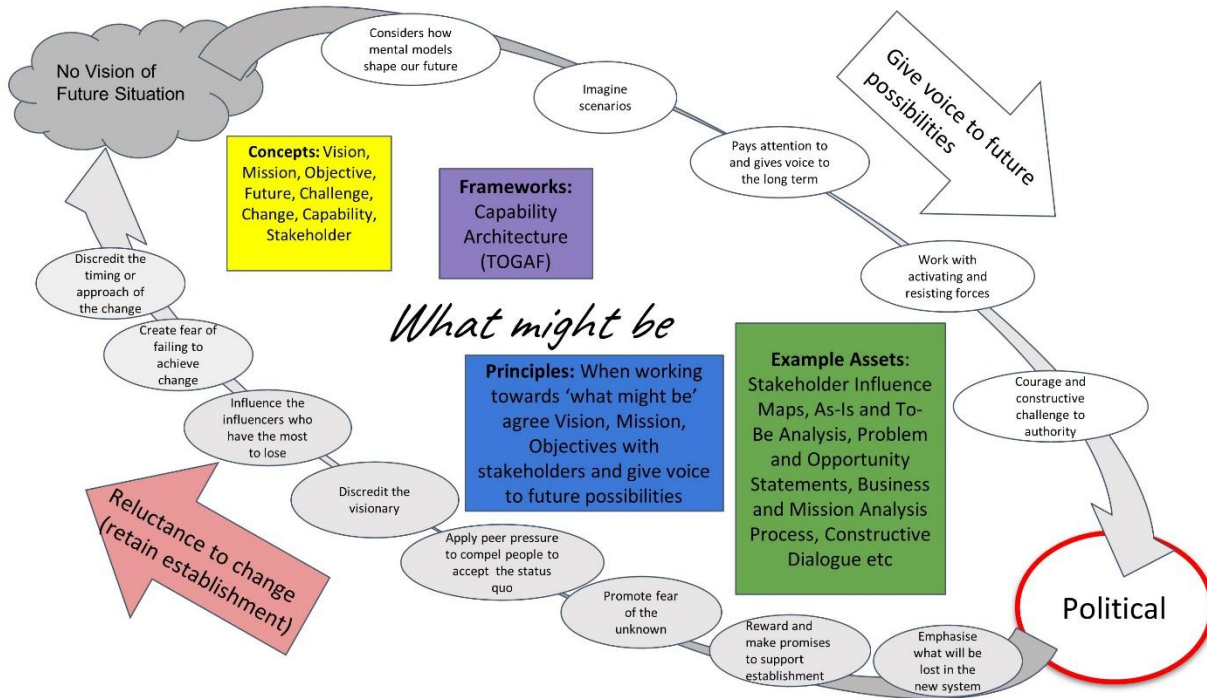


Fig. 12. Spotlight on the “What might be” reversible reaction

In figure 12, a sample of ‘negative’ heuristics (Tanner, 2009) associated with resistance to change have been added. It is envisaged that in comprehending the situation in which they are confronted, the individual or team can draw on system concept, frameworks, principles, and assets (methods, tools etc.) within the system science knowledge base, utilising them to better influence and act on the balance in these systemical reactions. Illustrative content has been provided as an example.

CONCLUSIONS / NEXT STEPS

The framework should facilitate integration, pulling together all the knowledge into a coherent, consistent discipline with known gaps. It makes visible where each knowledge item is in the knowledge formation process, thereby fuelling further research in the field to progress them towards accepted concepts, theories, principles, assets, and applicable context. If there are phenomena for which there is no explanation, or conjectures and theories with no corresponding empirical data and validation, it makes that visible. If there are inconsistencies, such as explanations for different phenomena being based on incompatible concepts or assumptions, this will become evident as well. In the overall presentation of the framework, we have taken many viewpoints into consideration of a single topic. The single topic in this case is the relational holon that has been used as a meta-theory for orientation. It is this that is the central theme that is presented in several different contexts to suit the needs of audiences and purposes. By bringing these diverse viewpoints together we accommodate the complexity necessary of a candidate

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solution for organising our rich heritage of system knowledge. From the perspective of the author, being both a systems engineer and project manager, it offers the potential to better integrate disciplines more successfully in the delivery of complex programmes with approaches based not just on heuristics but grounded in science.

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CONFLICT OF INTEREST

No conflict of interest.s

REFERENCES

- Allegro, B. D., & Smith, G. R. (2016). *Exploring the Branches of the Systems Landscape*. les Éditions Allegro Brigitte D. <https://books.google.co.uk/books?id=t1QlnQAACAAJ>
- Allen, C. R., Angeler, D. G., Garmestani, A. S., Gunderson, L. H., & Holling, C. S. (2014). Panarchy: theory and application. *Ecosystems*, 17(4), 578-589.
- Armour, F. J., Kaisler, S. H., & Liu, S. Y. (1999). A big-picture look at enterprise architectures. *IT professional*, 1(1), 35-42.
- Ashby, W. R. (1961). *An introduction to cybernetics*. Chapman & Hall Ltd.
- Beer, S. (1984). The viable system model: Its provenance, development, methodology and pathology. *Journal of the operational research society*, 35(1), 7-25.
- Belbin, R. M. (2012). *Team roles at work*. Routledge.
- Bennett, J. (2004). The force of things: Steps toward an ecology of matter. *Political theory*, 32(3), 347-372.
- Benson, T. (2015). *The habit-forming guide to becoming a systems thinker*. Pittsburgh, P.A. : Systems Thinking Group, Inc.
- Birnbaum, R., & Edelson, P. J. (1989). How colleges work: The cybernetics of academic organization and leadership. In: Taylor & Francis.
- Blockley, D., Smith, G., Godfrey, P., & Kineman, J. J. (2023). Relational holon science and Popper's 3 worlds in engineering practice. *Systems Research and Behavioral Science*, 40(6), 955-967. <https://doi.org/https://doi.org/10.1002/sres.2906>
- Bloom, B. S., Krathwohl, D. R., & Masia, B. B. (1984). Bloom taxonomy of educational objectives. In *Allyn and Bacon*. Pearson Education.
- Boehm, B. (2000). Project termination doesn't equal project failure. *Computer*, 33(9), 94-96.
- Bogdanov, A. A. (1996). *Bogdanov's tektology. Book 1*. Centre for Systems Studies, University of Hull.
- Boulding, K. E. (1985). The world as a total system.

Towards a Unified Framework for System Knowledge

- Brady, J. E., & Allen, T. T. (2006). Six Sigma literature: a review and agenda for future research. *Quality and reliability engineering International*, 22(3), 335-367.
- Brown, W. (2019). Unified Physics and the Entanglement Nexus of Awareness. *NeuroQuantology*, 17(07), 40-52.
- Burke, R. (2013). *Project management: planning and control techniques*. John Wiley & Sons.
- Cabrera, D., Cabrera, L., & Midgley, G. (2021). *The Four Waves of Systems Thinking*.
<https://doi.org/10.13140/RG.2.2.32099.68649>
- Cabrera, D., Cabrera, L., & Powers, E. (2015). A Unifying Theory of Systems Thinking with Psychosocial Applications. *Systems Research and Behavioral Science*, 32.
<https://doi.org/10.1002/sres.2351>
- Cabrera, D., & Colosi, L. (2008). Distinctions, systems, relationships, and perspectives (DSRP): A theory of thinking and of things. *Evaluation and Program Planning*, 31(3), 311-316.
- Checkland, P. B. (1989). Soft Systems Methodology. *Human Systems Management*, 8, 273-289.
<https://doi.org/10.3233/HSM-1989-8405>
- Churchman, C. W., Ackoff, R. L., & Arnoff, E. L. (1957). Introduction to operations research.
- Cloud, P. A., & Cloud, P. A. (1997). *Engineering Procedures Handbook*. Elsevier Science.
<https://books.google.co.uk/books?id=YG84ob2Sde0C>
- Collins, C. S., & Stockton, C. M. (2018). The Central Role of Theory in Qualitative Research. *International Journal of Qualitative Methods*, 17(1), 1609406918797475.
<https://doi.org/10.1177/1609406918797475>
- Conforto, E., Rossi, M., Rebentisch, E., Oehmen, J., & Pacenza, M. (2013). *Survey report: Improving integration of program management and systems engineering*.
- Decker, P., Durand, R., Mayfield, C. O., McCormack, C., Skinner, D., & Perdue, G. (2012). Predicting implementation failure in organization change. *Journal of Organizational Culture, Communications and Conflict*, 16(2), 29.
- Dori, D., Sillitto, H., Griego, R., McKinney, D., Arnold, E., Godfrey, P., Martin, J., Jackson, S., & Krob, D. (2019). System Definition, System Worldviews, and Systemness Characteristics. *IEEE Systems Journal*, PP, 1-11.
<https://doi.org/10.1109/JSYST.2019.2904116>
- Edson, M. C., Henning, P. B., & Sankaran, S. (2017). *A Guide to Systems Research: Philosophy, Processes and Practice*. Springer Singapore.
<https://books.google.co.uk/books?id=m7kFvwEACAAJ>
- Forrester, J. W. (1993). System dynamics and the lessons of 35 years. In *A systems-based approach to policymaking* (pp. 199-240). Springer.
- Friendshuh, L., & Troncale, L. (2012). Identifying fundamental systems processes for a general theory of systems. Proceedings of the 56th Annual Conference, International Society for the Systems Sciences (ISSS), San Jose State University, San Jose, CA, USA,
- Frigg, R., & Hartmann, S. (2006). Models in science.
- Gall, J. (2002). *The systems bible: the beginner's guide to systems large and small*. General Systemantics Press.
- Gauch, H. G. (2012). *Scientific Method in Brief*. Cambridge University Press.
- Gelman, S. A. (2009). Learning from others: children's construction of concepts. *Annual review of psychology*, 60, 115-140. <https://doi.org/10.1146/annurev.psych.59.103006.093659>
- Griffin, P. B. (1990). *The impact of affirmative action on labor demand: A test of some implications of the Le Chatelier principle* University of California, Santa Barbara].

Towards a Unified Framework for System Knowledge

- Hammond, D. (2010). *The science of synthesis: Exploring the social implications of general systems theory*. University Press of Colorado.
- Hammond, D. (2017). Philosophical Foundations of Systems Research. In M. C. Edson, P. Buckle Henning, & S. Sankaran (Eds.), *A Guide to Systems Research: Philosophy, Processes and Practice* (pp. 1-19). Springer Singapore. https://doi.org/10.1007/978-981-10-0263-2_1
- Hampton, J., & Winter, Y. (2017). *Compositionality and Concepts in Linguistics and Psychology*. <https://doi.org/10.1007/978-3-319-45977-6>
- Hieronymi, A. (2013). Understanding Systems Science: A Visual and Integrative Approach. *Systems Research and Behavioral Science*, 30(5), 580-595. <https://doi.org/https://doi.org/10.1002/sres.2215>
- Higgs, M. (1996). A comparison of Myers Briggs type indicator profiles and Belbin team roles. *WORKING PAPER SERIES-HENLEY MANAGEMENT COLLEGE HWP*.
- INCOSE. (2015). *INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities*. Wiley. <https://books.google.co.uk/books?id=8-cbBgAAQBAJ>
- Ison, R. (2010). *Systems practice: how to act in a climate change world*. Springer Science & Business Media.
- Joad, C. E. M. (1933). Plato's Theory of Forms and Modern Physics. *Philosophy*, 8(30), 142-154. <http://www.jstor.org/stable/3746463>
- Jonkisz, J. (2021). Consciousness, Subjectivity, and Gradedness. *Semiotic Studies*, 35(1).
- Khan, S. N. (2014). Qualitative research method: Grounded theory. *International journal of business and management*, 9(11), 224-233.
- Kineman, J. (2019). Four Kinds of Anticipatory (M-R) Life and a Definition of Sustainability.
- Kineman, J. J. (2011). Relational Science: A Synthesis. *Axiomathes*, 21(3), 393-437. <https://doi.org/10.1007/s10516-011-9154-z>
- Kineman, J. J. (2017a). A causal framework for integrating contemporary and Vedic holism. *Progress in Biophysics and Molecular Biology*, 131, 402-423. <https://doi.org/https://doi.org/10.1016/j.pbiomolbio.2017.09.011>
- Kineman, J. J. (2017b). Systems Research Framework. In M. C. Edson, P. Buckle Henning, & S. Sankaran (Eds.), *A Guide to Systems Research: Philosophy, Processes and Practice* (pp. 21-57). Springer Singapore. https://doi.org/10.1007/978-981-10-0263-2_2
- Kleineberg, M. (2017). Integrative Levels. *Knowledge Organization*, 44, 349-379. <https://doi.org/10.5771/0943-7444-2017-5-349>
- Koestler, A. (1968). *The ghost in the machine*. Macmillan.
- Laozi, & Wing, R. (1986). *The Tao of power: a translation of the Tao Te Ching by Lao Tzu*. Doubleday.
- LARSEN-FREEMAN, D. (1997). Chaos/Complexity Science and Second Language Acquisition. *Applied Linguistics*, 18(2), 141-165. <https://doi.org/10.1093/applin/18.2.141>
- Lent, B. (2012). Cybernetic approach to project management: where sense making intelligence is needed. In *Autonomous Systems: Developments and Trends* (pp. 97-108). Springer.
- Marimon, F., Heras, I., & Casadesús, M. (2009). ISO 9000 and ISO 14000 standards: A projection model for the decline phase. *Total Quality Management*, 20(1), 1-21.
- McCrae, R., & Costa, P. (1989). Reinterpreting the Myers-Briggs Type Indicator From the Perspective of the Five-Factor Model of Personality. *Journal of personality*, 57, 17-40. <https://doi.org/10.1111/j.1467-6494.1989.tb00759.x>
- Meadows, D., & Randers, J. (2012). *The limits to growth: the 30-year update*. Routledge.

Towards a Unified Framework for System Knowledge

- Melott, A. L. (2015). Views: 'The Theory of Everything' is missing something. *Astronomy & Geophysics*, 56(2), 2.9-2.9. <https://doi.org/10.1093/astrogeo/atv057>
- Metcalf, G. S., Edson, M. C., & Chroust, G. (2019). *Systems: from science to practice: Proceedings of the Nineteenth IFSR Conversation 2018, St. Magdalena, Linz, Austria*. Books on Demand. <https://books.google.co.uk/books?id=puKZDwAAQBAJ>
- Miller, J. G. (1995). *Living Systems*. University Press of Colorado. <https://books.google.co.uk/books?id=wftEAQAAIAAJ>
- Mingers, J. (1997). Systems typologies in the light of autopoiesis: a reconceptualization of Boulding's hierarchy, and a typology of self-referential systems. *Systems Research and Behavioral Science*, 14(5), 303-313. [https://doi.org/https://doi.org/10.1002/\(SICI\)1099-1743\(199709/10\)14:5<303::AID-SRES161>3.0.CO;2-A](https://doi.org/https://doi.org/10.1002/(SICI)1099-1743(199709/10)14:5<303::AID-SRES161>3.0.CO;2-A)
- Mingers, J. C. (1995). Information and meaning: foundations for an intersubjective account. *Information Systems Journal*, 5(4), 285-306.
- Mobus, G. E., & Kalton, M. C. (2014). *Principles of Systems Science*. Springer New York. <https://books.google.co.uk/books?id=twBNBQAAQBAJ>
- Mullins, L. J. (2007). *Management and organisational behaviour*. Pearson education.
- Norwich, K. (2010). Le Chatelier's principle in sensation and perception: fractal-like enfolding at different scales [Original Research]. *Frontiers in Physiology*, 1(17). <https://doi.org/10.3389/fphys.2010.00017>
- Oehmen, J., Oppenheim, B. W., Secor, D., Norman, E., Rebentisch, E., Sopko, J. A., Steuber, M., Dove, R., Moghaddam, K., & McNeal, S. (2012). *The guide to lean enablers for managing engineering programs*. Joint MIT-PMI-INCOSE Community of Practice on Lean in Program Management.
- Ring, J. (1998, 14-14 Oct. 1998). A value-seeking approach to the engineering of systems. SMC'98 Conference Proceedings. 1998 IEEE International Conference on Systems, Man, and Cybernetics (Cat. No.98CH36218),
- Rousseau, D. (2018). On the Architecture of Systemology and the Typology of Its Principles. *Systems*, 6(1), 7. <https://www.mdpi.com/2079-8954/6/1/7>
- Rousseau, D., Billingham, J., & Calvo-Amodio, J. (2018). Systemic Semantics: A Systems Approach to Building Ontologies and Concept Maps. *Systems*, 6(3), 32. <https://www.mdpi.com/2079-8954/6/3/32>
- Rousseau, D., Billingham, J., & Calvo-Amodio, J. (2019). Systemic virtues as a foundation for a general theory of design elegance. *Systems Research and Behavioral Science*, 36(5), 656-667. <https://doi.org/https://doi.org/10.1002/sres.2627>
- Rousseau, R., & Breton, R. (2004). The M-OODA: A model incorporating control functions and teamwork in the OODA loop. Proc. Command and Control Res, & Tech. Symp,
- Santoro, F., Selvaggia, S., Scowcroft, G., Fauville, G., & Tuddenham, P. (2017). *Ocean literacy for all: A toolkit* (Vol. 80). UNESCO Publishing.
- Schaveling, J., & Bryan, B. (2018). Making Better Decisions Using Systems Thinking. In J. Schaveling & B. Bryan (Eds.), *Making Better Decisions Using Systems Thinking: How to stop firefighting, deal with root causes and deliver permanent solutions* (pp. 1-3). Springer International Publishing. https://doi.org/10.1007/978-3-319-63880-5_1
- Schill, C., Anderies, J. M., Lindahl, T., Folke, C., Polasky, S., Cárdenas, J. C., Crépin, A.-S., Janssen, M. A., Norberg, J., & Schlüter, M. (2019). A more dynamic understanding of human behaviour for the Anthropocene. *Nature Sustainability*, 2(12), 1075-1082.

Towards a Unified Framework for System Knowledge

- Schwartz, M. D. (2014). *Quantum Field Theory and the Standard Model*. Cambridge University Press. <https://books.google.co.uk/books?id=HbdEAgAAQBAJ>
- Shepherd, M., Blampied, N., Buttrick, R., Jucan, G., Piney, C., Stevens, C., Violette, D., & Wideman, R. M. (2023). In Search of Project Management Principles. *Project Management Journal*, 54(6).
- Simms, J. R. (1971). *A Measure of Knowledge*. Philosophical Library. <https://books.google.co.uk/books?id=YRk8vwEACAAJ>
- Smith, G. (2021a, 20/02/21). *An approach to an architecture for systems science*. <https://vimeo.com/519125085>
- Smith, G. (2021b). *Pathways to systemicity*. Retrieved August 17, 2021 from <https://embed.kumu.io/505cc936bffb9c5f1b2807ebcf8c1e1>
- Smith, W. E. (2008). *The creative power: Transforming ourselves, our organizations, and our world*. Routledge.
- Smith, W. E., & Tuddenham, P. D. (2019). SYSTEMS LITERACY Evolving our Power to Address the Issues of Our Time. Proceedings of the 63rd Annual Meeting of the ISSS-2019 Corvallis, OR, USA,
- Snowden, D., Greenberg, R., Bertsch, B., Borchardt, S., Blignaut, S., & Goh, Z. (2020). *Cynefin - Weaving Sense-Making Into the Fabric of Our World*. Cognitive Edge - The Cynefin Company. <https://books.google.co.uk/books?id=bv75zQEACAAJ>
- Stellenbosch, U. o. *Planning and designing your literature review*. University of Stellenbosch.
- Stonier, T. (2012). *Information and the internal structure of the universe: An exploration into information physics*. Springer Science & Business Media.
- Tallon, P. P., Queiroz, M., Coltman, T., & Sharma, R. (2019). Information technology and the search for organizational agility: A systematic review with future research possibilities. *The Journal of Strategic Information Systems*, 28(2), 218-237.
- Tanner, R. (2009). *Organizational change: 8 reasons why people resist change*. . Business Consulting Solutions LLC. Retrieved 23 August 2012 from <https://managementisajourney.com/organizational-change-8-reasons-why-people-resist-change/>
- Taylor, B. P. *Are you a naive enthusiast, an oversimplifying populariser, a gooroo, or a curmudgeon?* Retrieved 18 January 2021 from <https://chosen-path.org/2021/01/18/are-you-a-naive-enthusiast-an-oversimplifying-populariser-a-gooroo-or-a-curmudgeon/>
- Tonnellier, E., & Terrien, O. (2012). PBS: A Major Enabler for Systems Engineering. CSDM,
- Troncale, L. (1988). The systems sciences: What are they? are they one, or many? *European Journal of Operational Research*, 37(1), 8-33. [https://doi.org/https://doi.org/10.1016/0377-2217\(88\)90277-9](https://doi.org/https://doi.org/10.1016/0377-2217(88)90277-9)
- Troncale, L. (2013). Systems processes and pathologies: Creating an integrated framework for systems science. INCOSE International Symposium,
- Troncale, L. R. (1978). Linkage propositions between fifty principal systems concepts. In *Applied general systems research* (pp. 29-52). Springer.
- Tuddenham, P. (2019). *Systems Literacy Update*. College of Exploration. Retrieved August 17, 2021 from <https://vimeo.com/357886110>
- Vedral, V. (2018). *Decoding Reality: The Universe as Quantum Information*. Oxford University Press. <https://doi.org/10.1093/oso/9780198815433.001.0001>
- Volk, T. (2017). *Quarks to Culture: How We Came to Be*. Columbia University Press. <https://books.google.co.uk/books?id=2xuSDgAAQBAJ>

Towards a Unified Framework for System Knowledge

- Wallis, S. E. (2021). Understanding and improving the usefulness of conceptual systems: An Integrative Propositional Analysis-based perspective on levels of structure and emergence. *Systems Research and Behavioral Science*, 38(4), 426-447.
<https://doi.org/https://doi.org/10.1002/sres.2680>
- Weinberg, S., S. W., & de campos, T. (1995). *The Quantum Theory of Fields*. Cambridge University Press. https://books.google.co.uk/books?id=doeDB3_WLvwC
- Wells, J. D. (2020). *Discovery Beyond the Standard Model of Elementary Particle Physics*. Springer International Publishing.
<https://books.google.co.uk/books?id=8tHHDwAAQBAJ>
- Whelan, C. T. (2018). *Atomic Structure*. Morgan & Claypool Publishers.
<https://books.google.co.uk/books?id=tlZaDwAAQBAJ>
- Whitney, K. M., & Daniels, C. B. (2013). The Root Cause of Failure in Complex IT Projects: Complexity Itself. *Procedia Computer Science*, 20, 325-330.
<https://doi.org/https://doi.org/10.1016/j.procs.2013.09.280>
- Wilby, J. (2020). ISSS2019: Program and Abstract Book. *Proceedings of the 63rd Annual Meeting of the ISSS - 2019 Corvallis, OR, USA*, 63(1).
<https://journals.issis.org/index.php/proceedings63rd/article/view/3651>
- Wilson, E. O. (1999). *Consilience: The unity of knowledge* (Vol. 31). Vintage.
- Winther, R. G. (2015). The structure of scientific theories.
- Young, A. M. (1973). *The Reflexive Universe: Evolution of Consciousness*. [N.P.]Big Sur Recordings.
- Zurek, W. H. (2018). *Complexity, Entropy And The Physics Of Information*. CRC Press.
<https://books.google.co.uk/books?id=RQpQDwAAQBAJ>