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The Substrate-Independence Theory: Advancing Constructor Theory to Scaffold Substrate Attributes for the Recursive Interaction between Knowledge and Information

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Abstract: The substrate-independence theory utilizes sensemaking techniques to provide cognitively based scaffolds that guide and structure learning. Scaffolds are cognitive abstractions of constraints that relate to information within a system. The substrate-independence theory concentrates on the flow of information as the underlying property of the host system. The substrate-independence theory views social systems as complex adaptive systems capable of repurposing their structure to combat external threats by utilizing constructors and substrates. Constructor theory is used to identify potential construction tasks, the legitimate input and output states that are possible, to map the desired change in the substrate's attributes. Construction tasks can be mapped in advance for ordered and known environments. Construction tasks may also be mapped in either real-time or post hoc for unordered and complex environments using current sensemaking techniques. Mapping of the construction tasks in real-time becomes part of the landscape, and scaffolds are implemented to aid in achieving the desired state or move to a more manageable environment (e.g., from complex to complicated).

Keywords: constructor; substrate; construction task; substrate-independence theory; constructor theory; complexity; scaffolding; information; knowledge; hierarchy; origins of life

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1. Introduction

Scaffolding is a metaphor for how information and knowledge are absorbed, how learning can be structured. In education, scaffolding is viewed as a means of closing the gap between the learners' current knowledge to their desired knowledge, allowing them to perform a particular task or activity independently, one which they could not have done previously. Scaffolding is defined as "a temporary structure for supporting something until that something is able to stand on its own" [1] (p. 273). Scaffolding is dependent on the context and environment. In many instances scaffolding is temporary, it is present until the learner can perform a new task without additional support; then, it is removed. These types of scaffolding are called robust scaffolds. In other instances, scaffolding can be more permeable, embedded into our identity or landscape. These types of scaffolds are called resilient scaffolds.

As scaffolding guides learning in education, scaffolding guides sense-making in complex and unordered environments. Scaffolding in sense-making focuses on the flow of information and provides enabling constraints for knowledge generation. This article pulls from the naturalized sense-making (NSM) body of knowledge. Sense-making is defined as how do we make sense of the world so we can act in it, using (naturalizing) natural sciences as a constraint to determine not only what is possible, but what is impossible coupled with the idea of taking action, or executing tasks, to creating meaning. This focus on what is and is not possible introduces the concept of couterfactuals into the NSM field and draws from constructor theory to expand on this concept.

Counterfactuals provide a means of constantly pursuing coherent pathways while also dismissing incoherent ones. The theory of coherence, from the natural philosophy, avoids naïve empiricism and dogmatism by presenting a plausible assessment of both facts and values [2]. Defined as "the quality or state of things 'sticking together'" [1] (p. 28), how elements, events, agents, and our environment fit together. Coherence is achieved through the process of developing counterfactuals and is a critical component to naturalized sense-making because it functions as a method for making sense in complex environments. This concept of coherence through counterfactuals is captured through constructor theory that is being introduced to the field of NSM in the current article. Constructor theory utilizes couterfactuals to identify alternative explanations to a phenomenon. In the social sciences, because there are multiple explanations to any phenomenon under investigation at any one time, understanding can only be achieved from capturing potential alternative explanations, counterfactuals, that are contextually dependent to the environment. Explanations must achieve a level of coherence. The current article will incorporate constructor theory to the field of NSM as a means of obtaining better understanding through coherence.

In non-mechanistic systems, more importantly, when participating in and managing human systems (social systems), participants must utilize sense-making techniques to interpret and understand the conditions of their environment. While some physical constraints (e.g., office, building, conference/meeting room) may be necessary and part of the environment, understanding the requirements of the environment is cognitive, requiring scaffolding techniques to guide and structure learning to a level of coherence. We go beyond the suggestion that scaffolding is a metaphor for how information and learning are absorbed [3], making it an emergent factor promoting sense-making activities. Because scaffolding is associated with learning, it deals with information and knowledge. Rather than viewing constraints or barriers as in mechanistic systems, this article will address scaffolding that focuses on the flow of information through a system rather than concentrating on perceived goals or outcomes. Scaffolding, in this respect, is the cognitive version of a constraint or lack of control. Scaffolding also provides an enabling constraint, a counterfactual to limit the range of possible interactions which allows consistent applications of information and provides evolutionary capability to the substrate.

Incorporating the concept of scaffolding with NSM adds to the literature that has been identified as lacking, calling to extend current theories beyond that of being just a cognitive and discursive process [4] to one that takes a broader approach to applying sense-making [5]. Approaches for extending sense-making techniques to the broader institutional and macro-social structures are also called for [5]. Integrating these methods to improve the flow of information through the larger systemic system, such as information flow across organizational silos, is one advantage that the substrate-independence theory offers. It also provides a new method of facilitating change in complex environments that leaders can utilize to co-create a shared understanding [5] of their new environment when addressing external threats.

2. Constraints vs. Constructors

The distinction between organisms and mechanisms extends to the concept of constraints and constructors. Often associated with mechanical systems, constraints are frequently found in industrial applications through the theory of constraints [6–8]. In contrast, constructors have been associated with more abstract 'physical' systems, not necessarily mechanical systems. Some examples include abstractions of systems in physics [9], cognition [10], and even when viewing knowledge as a physical property [11].

For our theory, we are concerned with social systems capable of learning, self-organizing, and adapting to their environment. These social systems are complex adaptive systems and can adapt through emergent processes resulting in the system repurposing itself into a new coherent structure to sustain its fitness.

3. Fitness

An organization or system remains fit if it can sustain its existence while also adapting to environmental threats. A model of this is the human immune system that is composed of antibodies and antigens. The immune system protects the host organism (sustaining life) through antibodies continually working to combat an ongoing threat of antigens (environmental threats). The immune system changes and adapts to these environmental threats as a means of the host organism's fitness. This fitness operates through infinite interactions among components of the immune system, the host organism, and the environment. Without these interactions, the antibodies would not be capable of identifying and combating any antigens.

Existence is not of itself always the same thing. For example, resilience in a system is the ability to survive with continuity of identity over time, changing as needed (this concept includes anti-fragile) while robustness is the ability to withstand perpetrations.

Fitness is a component of the interactions among its parts. These interactions and the factors that interact are dependent on the context as these activities constantly vary to adapt. Because fitness is contextual and continuously adapting, it is not a fixed value. We determine the fitness of a system or organism by the number of interactions "rather than from some predetermined fitness function" [12] (p. 97). Fitness is similar to assemblages that view the arrangement of heterogeneous elements [13] that emerge from the data of inquiry [14].

As it relates to social systems, fitness can be described using an analogy between social and organic life. In describing the function of a social institution, Durkheim provided the following: "The correspondence between the social institution and the necessary conditions of existence of the social organism" (as cited in [15], p. 97). Here, fitness results in interactions among the components within the system (internally or intrinsically). These interactions take place for the system to sustain within its environment (externally or extrinsically). This coexistence between the social institution and the social organism (e.g., ecosystem) is an integrated whole [15]. This integrated whole aligns with Gibson's (affordances theory) concept of complimentarity in which the organism (agent) and the environment make "an inseparable pair" [16] (p. 950). Fitness represents an organism or an individual's ability to be an integrated whole within its environment.

4. Cynefin Framework

The Cynefin (kuh-nev-in) framework originated in the field of knowledge management as a sense-making framework that has since emerged into a model for naturalizing sense-making that aids agents in their ability to make sense of the world so that they can act in it [17,18]. The framework was the basis for the recently published field guide for decision makers titled "Managing complexity (and chaos) in times of crises", a joint publication of the Cynefin Centre and the EU Commissions Joint Research Centre [19]. Figure 1 provides a preview of the Cynefin framework and its components.

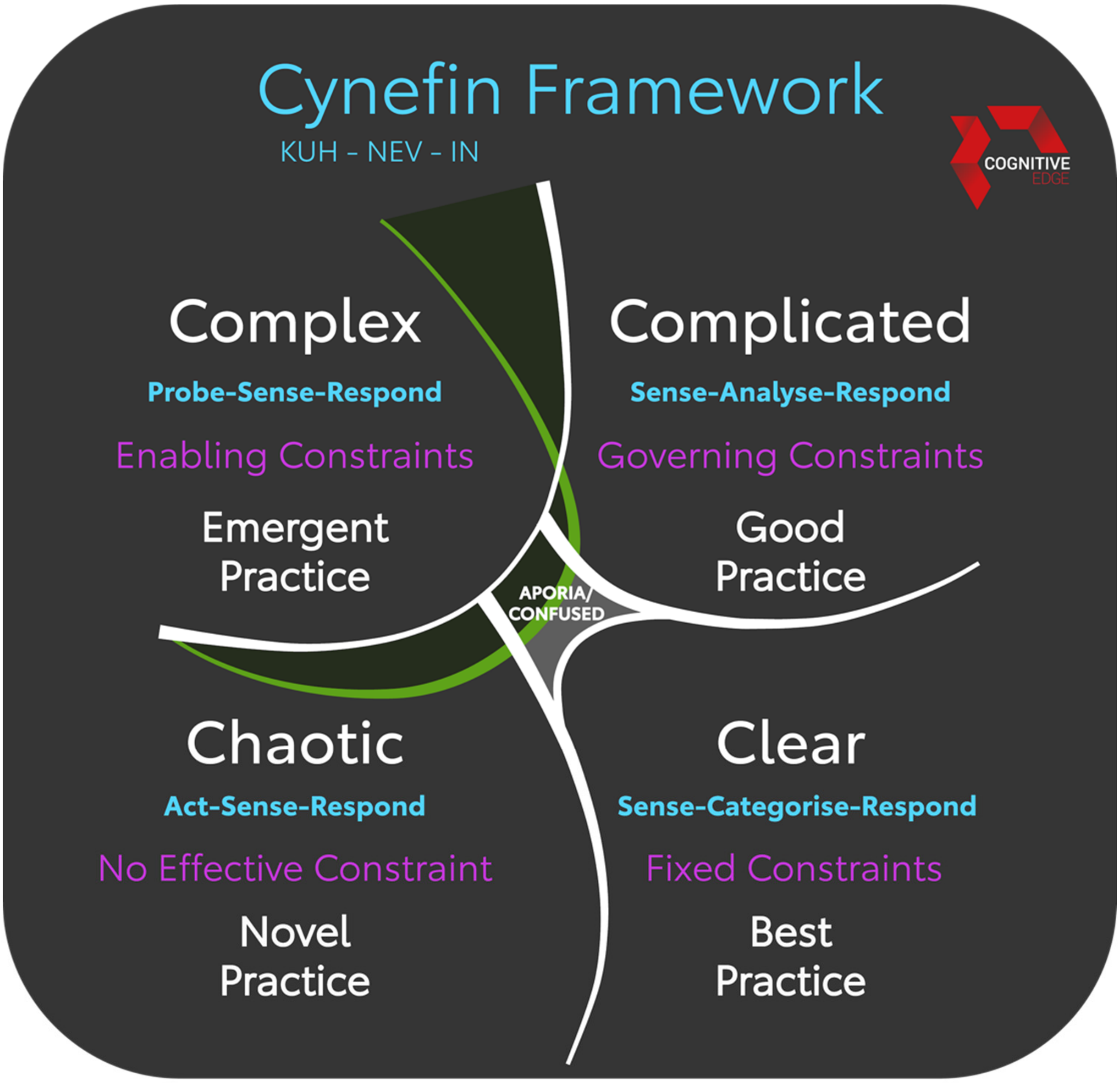

Figure 1. The Cynefin framework. Note: Permission for figure granted by Cognitive Edge.

The Cynefin framework consists of three ontological states, order, complexity, and chaotic [19]. These ontological states can be described by the type of scaffolding imposed in each of the three states. For example, the ordered state involves robust scaffolds that provide specific boundaries for interactions and information. Complexity involves resilient scaffolds to help guide sense-making activities to give some indication of predictability in uncertainty. The chaotic state is devoid of any scaffolding.

The Cynefin framework further separates into five domains (aporetic/confused, clear, complicated, complex, chaotic). At the center is aporetic/confused (A/C), acting as a starting place. Moving outward from A/C you have clear and complicated domains on the right half of the Cynefin Framework representing the ordered ontological states. The ontological states of complexity and chaotic are presented on the left-hand side of the Cynefin Framework. It is common to begin at the A/C domain when first addressing an external threat [19]. Once it can be determined what type of problem or environment one is dealing with, movement to one of the other four domains, or to the liminal areas between states (shown in green a state of suspected transition), is possible.

It is desirable to navigate across the domains in an effort to maximize understanding while minimizing the amount of energy required to process information. The liminal boundaries identify potential paths for these transitions across domains [19]. As one transitions from one domain to the next it is essential to recognize that different methods are used in each domain. As a NSM framework, utilizing the correct methods in each domain results in maximizing the flow of information while reducing the amount of energy required to navigate to a more manageable domain (e.g., complexity to complicated).

The description of the Cynefin framework provided in the current article is the first to depict scaffolding as the defining characteristic between domains. This distinction is necessary to align the Cynefin framework with the substrate-independence theory presented in the current article.

5. Substrate Independence (Information)

Information and time are two elements that remain consistent across domains. They are always present, unaltered, and can be measured in relation to each other. Substrate independence refers to information being the underlying property of the host system. The host system can be the transmitter or receiver of the information as in classical information theory [20], or it can be the agent, organism, or organization that holds the information. Information is independent of the physical medium that transmits, receives, or stores the information, this is the independence part of the substrate-independence theory. Information can be recalled from any part of a system, regardless of the physical properties, meeting the property of interoperability [20]. This point is highlighted in the following from [20]: "The receiver, transmitter and medium are physical systems, but the message is not" (p. 2). The key to the process or organism is information. Emphasized by Wiener, the father of Cybernetics: "It was not some particular physical thing such as energy or length or voltage, but only information (conveyed by any means)" [21] (p. 238). As conceptualized from the Cynefin framework, information is retrieved and transformed into knowledge and knowledge is used to generate more precise information, providing a reciprocal determination, a coadaptation [13], between knowledge and information that varies depending on which domain the information resides.

5.1. Energy Follows Information

Information in a system is tractable because one can identify and manage the flow of information through the system. As more information is needed, more energy is expended. Understanding this allows us to track information based on the amount of energy exerted. Energy can be represented in several different forms. A few examples could be the number of interactions among agents, the number of archetypes created in a given time frame, the usage of internal resources, and the amount of computing power required at any given time.

However, the amount of energy exerted alone is not enough to determine a system's fitness. The flow of energy versus the relevance of the information processed is non-linear, partially due to the concept of mutual information. Mutual information relates to shared information that reduces the amount of energy required from the system because of this mutual or shared information. "Organized objects generally have the property that their parts are correlated: two parts taken together typically require fewer bits to describe than the same two parts taken separately" [22] (p. 364).

Other examples can be found in redundant information systems. Redundancy can be varied, decreased to improve efficiency, or increased to reduce errors [21]. Redundancy is related to the quantity of unnecessary information [23]. Referring to how much information can be removed while maintaining its original meaning, coherence. Redundancy and mutual information highlight a couple of examples showing why interactions (exchanges of relevant information) are a better measure of energy in social systems than measuring 'energy' in computing power and kilowatt usage. It is also necessary to note that in both of these examples, redundancy and mutual information, information that requires the least amount of energy to reproduce or exchange is preferred to alternative means that require more energy (e.g., those without redundancy or mutual information).

The lowest energy gradient is the critical concept to be gained here. The flow of information needs to be achieved using the least amount of energy possible to obtain maximum effectiveness. How this is achieved, through constructors and scaffolds and other techniques (e.g., mutual information, redundancy) will vary from one organization to the other as information is contextual and culturally derived.

5.2. Promoting the Flow of Information

In any system, constructions hold the potential of being either positive or negative. Positive constructions enable the flow of information, while negative constructions delay or block the flow of information. Utilization of relevant information supports adaptation, while non-relevant information, such as information overload, can inhibit adaptation. Constructions should enable the flow of pertinent information to aid any necessary changes required of the system or components.

5.3. Value Is Defined as Providing Actionable Information

Valuable or actionable information must be provided to the end-user or customer. This concept is supported through the concept of logical depth. Logical depth relates to how much value the information provides compared to providing randomly selected information. This value is associated with the amount of time saved by the information provided compared to the time required for the recipient to acquire the information independently. Value relates to "the amount of mathematical or other work plausibly done by its originator, which its receiver is saved from having to repeat" [22] (p. 369).

Long durations of time required to acquire information is referred to as depth. The more time and energy needed to obtain information, the deeper the path to that information. Information depth refers to the path to acquiring relevant information in which there are no shortcuts available [22]. As logical depth increases, the time, money, and computational resources required to access this information independent of the originator increase, making the value of such information more excellent. It is associated with opportunity cost. Is the cost of acquiring information greater than, or less than, the cost of generating it independent of the original source? If the answer is more significant than, having access to the information is deemed more valuable compared to information that is easy to acquire independently. Value is directly related to the information's logical depth.

5.4. Customer Satisfaction and Timely Acquisition of Information

For information to be considered valuable by the customer, or end-user, it must be available when needed. This information must also be relevant and usable given the context. This is what we are calling actionable information. Actionable information is information that would require too much time and resources for the customer to acquire on their own; it has high logical depth. Actionable information is of value because of this logical depth and the fact that the user can apply the information instantly to meet their needs. The quicker the information can be applied, the higher the perception of value that information becomes from the user's perspective.

Value and customer satisfaction are both supported by the interoperability principle of information. Interoperability refers to the possibility of transferring information from one medium to another, across substrates. Interoperability is possible because all information media have in common two counterfactual properties:

1. It can be set to any of at least two states.
2. Each of those states can be copied. [24] (p. 85).

If a system meets these two conditions that are allowed by the laws of physics, removing the composite, what remains is the physical property of information that can be either copied or transformed: "We can abstract away their irrelevant details and simply talk about them as information media, considering their 'information-carrying attributes' only" [24] (p. 87). These information-carrying attributes translate into value, the timely delivery of these information-carrying attributes.

6. Constructor Theory

The distinctions previously identified between informal and formal hierarchies, organisms and mechanisms, constructors and constraints, social and mechanical systems led the authors to constructor theory. We view social systems as complex adaptive systems capable of repurposing their structure to combat external threats by utilizing constructors and substrates. This repurposing involves a variety of methods that can be highly dependent on the context and environment. To identify these different contextual environmental conditions, we utilize the concepts gained from the Cynefin framework [17,25]. We will introduce constructor theory and the components of the theory next.

Constructor theory describes transformations. Transformations can either be possible, those that can be caused, and impossible, those that cannot be caused [9]. Constructor theory is different from traditional physics that makes predictions based on a set of initial conditions. In contrast, constructor theory views the dichotomy between what can be caused and what cannot be caused, along with a description of why for each [20]. Constructor theory is about "what can be done, and what can be made, in physical reality" [26] (p. 7).

The basic principle of constructor theory reflects the following: "All other laws of physics are expressible entirely in terms of statements about which physical transformation are possible and which are impossible, and why" [20] (p. 4). This contrasts with other practices that focus on a set of initial conditions and laws to predict what might happen, to determine the behavior of a system. Constructor theory focuses on the input and output pairings for transformations, rather than deciding if the transformation is or is not possible. Constructor theory describes the world in two different physical systems: constructors and substrates, and the constructor as the change mechanism.

6.1. Constructors, Substrates, and Constructions

As its fundamental element, constructor theory defines a constructor as "anything that can cause transformations in physical systems without undergoing any net change in its ability to do so" [9] (p. 4332). In our theory, however, we expand physical systems to also include cognitive systems. Constructors involve agents transforming a system, temporally, in which the system eventually returns to its original state (see Figure 2). The system transformed is called a substrate. Substrates involve transformations to some physical attributes in which the system is unable to return to its original state [20]. The actual transformation itself is considered construction. Constructors cause substrates to experience construction in which some physical attribute (t_0, Figure 2) changes to an alternative physical/cognitive attribute (t_1, Figure 2). Attributes are identified as any property of the substrate. A formal definition is "any property that the substrate could possibly have" [20] (p. 4).

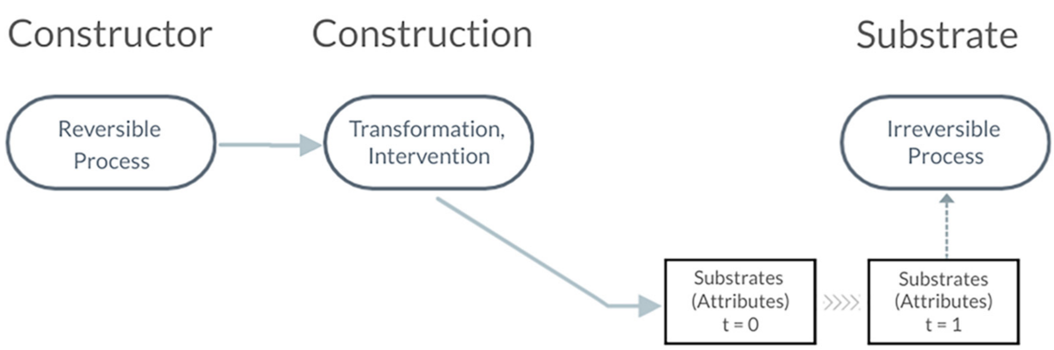

Figure 2. Constructor theory.

6.2. Counterfactuals

Counterfactuals identify what could be or what could be made to happen. This is in contrast to traditional science that only looks at what is [24]. The problem, however, is that science utilizing probabilities to arrive at a state of what is can only be partially accurate, not exact for all situations and conditions. Counterfactuals extend this line of logic to include statements about possible alternatives [27].

Pearl and Mackenzie's [27] ladder of causation highlight three levels of cognitive ability: seeing, doing, imagining. Seeing is associated with our observations and the associations that we make from those observations. Doing relates to interventions, how we observe and attempt to change what is. Imagining relates to counterfactuals that address the questions what if I had done . . . ? And why? [27]. Counterfactuals provide statements of possible alternatives based on our observations and interventions. Identifying these as three rungs to a ladder. Pearl and Mackenzie [27] described the ladder in the following: "While rung one deals with the seen world, and rung two deals with a brave new world that is seeable, rung three deals with a world that cannot be seen (because it contradicts what is seen)" (p. 36).

The scientific method is designed to constantly test existing knowledge and theories as an enduring pursuit toward the truth. To do so, however, we must accept that our theories may not always hold up and, at times, may even be falsified. This can be problematic as human behavior resists change. This has been highlighted by Kuhn [28] in which scientists have been shown to ignore anomalies and do not accept them as counterinstances until threatened by a crisis. This is where Kuhn coined the phrase paradigm shift [28], relating to forced change placed onto scientific disciplines because of their reluctance to shift their worldview or perspective. Kuhn went so far as to state that "there is no such thing as research without counterinstances" [28] (p. 79). Lipton [29] recommended broadening initial conditions to include explanatory consequences. These explanatory consequences help scientists answer the question posed by Lipton [29]: "Do we have any reason to believe that the inferences to the best explanation that scientists make really are truth-topic, that they reliably take scientists towards the truth" (p. 184)? Similarly, Feyerabend [30] advised scientists to proceed counterinductively to produce alternative theories with the understanding that "there is not a single theory that agrees with all the known facts in its domain" (p. 14).

Popper [31] explained this through his concepts of falsifiability, explaining that all theories and their statements must be testable. Producing alternative explanations, or hypothesis, aids in this effort: "The introduction of an auxiliary hypothesis should always be regarded as an attempt to construct a new system; and this new system should then always be judged on the issue of whether it would, if adopted, constitute a real advance in our knowledge of the world" [31] (p. 147).

In relation to constructor theory, counterfactuals provide alternate explanations that provide more accurate explanations compared to those derived based on probabilities alone. Counterfactuals are essential to constructor theory as they provide "explanations about what physical events could or could not be made to happen" [24] (p. ix), similar to the counterinstances, explanatory consequences, counterinductively, and falsifiability approaches prescribed by the philosophy of science field.

6.3. Focal Point

The focal point of constructor theory is the construction (transformation) itself rather than the constructor or substrate. This is an essential concept because it focuses on potential constructions rather than the exact mechanisms that potentially cause transformations. For example, it is desirable for teams to transition into being more effective. While there are a variety of constructors (e.g., teamwork skill training, team coaching, practice) that could result in constructing (transforming) the substrate (team), the number of possible constructors is endless because teams vary in size, type, composition, and context. However, what is necessary is to focus on transforming organizational teams so that they are more effective in their interpersonal processes and taskwork activities. By concentrating on the construction, it is the transformation that becomes essential. How that construction is achieved will vary, but the end goal is the same, to aid teams in becoming more effective. Focusing on the changes or constructions provides a "wider class of explanations" for constructions [9].

Constructor theory is different from other neo-configural perspectives (e.g., qualitative comparative analysis; QCA) that focus on complexity by observing equifinality, conjunctural causation, and causal asymmetry and how these causal attributes contribute to producing an outcome of interest [32]. Constructor theory focuses on the construction rather than the outcome. QCA techniques, for example, concentrate on combinations of attributes that are consistently linked to a specific outcome after meeting the requirements of causal complexity as viewed from equifinality, conjunctural causation, and causal asymmetry [32]. For example, successful organizations (outcome) each have similar attributes. Thus, all organizations that have these attributes will be successful. This distinction becomes more apparent once you are operating in complexity and chaotic environments where causality is unknown. Identifying which constructions result in a desired change can allow one to identify causal mechanisms in a post hoc manner but only after one has moved to a more manageable domain. Causation can be identified after moving to the complicated domain, whereas it is less reliable when attempting to identify causation in complexity because of the constantly changing parameters and variables. This is the advantage that constructor theory provides because it identifies counterfactuals rather than causal mechanisms, and it concentrates on the construction rather than an expected or predetermined outcome.

6.4. Pairings

Constructor theory also considers the constructor (input) and the substrate (output). These are recognized as a pair and termed a construction task, "each designating a legitimate input state for the task and associating that with a legitimate output state for that input" [9] (p. 4333). Therefore, constructors can perform a task if it is a legitimate input state for that task, constructing the substrate into one of the legitimate output states for the same task. The result produces a set of legitimate input states for a set of legitimate output states for a given substrate.

The result will produce a theory of the substrate, specific to the context and situation, similar to grounded theory, where theories are composed in-situ. This is called a constructor-theoretic statement, a statement that only refers to the substrate concerning the tasks placed upon it [20]. Ultimately, this constructor-theoretic statement will identify all possible constructor tasks and their application through a particular construction to achieve the desired attribute changes in the substrate. This produces a theory of the substrate. In the preceding example, the result will create a constructor-theoretic statement for improving team effectiveness given the contextual conditions.

Using the previous example of constructing teams into more effective teams, it is desirable to alter the attributes of the team (teamwork, taskwork, performance, customer satisfaction; [33]) making the team the substrate. The constructor could be approval of funding from management for an intervention to achieve the desired state, improving team effectiveness. Alternate interventions would be considered, such as redesigning the teams (C_1), updating computers and software for the teams (C_2), incentivizing team members (C_3), and training (C_4) designed to improve specific team attributes. These alternative interventions answer the following questions: How might team effectiveness improve? What potential physical transformations are possible? Why? A complete set of legitimate pairings, construction tasks, will be identified for each legitimate construction. In this example, we only looked at a few potential constructions, but many more would be considered in an actual case.

The constructor (funding) will be used for the training (design, delivery, and evaluation) in the preceding example (training was selected over redesigning teams, updating technology, and incentives). After training, or after a predetermined time frame, funding will no longer be available. This is a temporary change, making the approval of training a constructor. Because the training is believed to be the best mechanism for changing the team's attributes (need analysis), this becomes the construction. Funding provides multiple opportunities for training to achieve alternative attributes for the team. At this stage, with the components identified, it is now necessary to identify the legitimate input and output pairings. Face-to-face (C'_{4a}) training (C_4) can be used to alter team member's active listening (S_{4a-1}), cooperation (S_{4a-2}), coordination (S_{4a-3}), and team building skills (S_{4a-4}). Virtual (C'_{4b}) training (C_4) can be implemented to alter team member's concept of a team (S_{4b-1}), virtual communication techniques (S_{4b-2}), project management of task work (S_{4b-3}), and the sharing of information (S_{4b-4}). Coaching (C'_{4c}) as a form of training (C_4) can be utilized to develop further team member's communication practices (S_{4c-1}), conflict management skills (S_{4c-2}), and team member backup behaviors (S_{4c-3}). Table 1 provides the potential pairings for training.

Table 1. Potential pairings for training.

Constructor (C_i)	**Construction (C′)**	**Substrate (S_i)**
Approved Funding	**Transformation**	**Attributes**
Redesign Teams (C_1)	($C'1_a$) ($C'1_b$) (C'_{1c})	(S_{1a-1}, S_{1a-2}, … $S_{1a\text{-}(n-1)}$, $S_{1a\text{-}n}$) (S_{1b-1}, S_{1b-2}, … $S_{1b\text{-}(n-1)}$, $S_{1b\text{-}n}$) (S_{1c-1}, S_{1c-2}, … $S_{1c\text{-}(n-1)}$, $S_{1c\text{-}n}$)
Update Technology (C_2)	(C'_{2a}) ($C'2_b$) (C'_{2c})	(S_{2a-1}, S_{2a-2}, … $S_{2a\text{-}(n-1)}$, $S_{2a\text{-}n}$) (S_{2b-1}, S_{2b-2}, … $S_{2b\text{-}(n-1)}$, $S_{2b\text{-}n}$) (S_{2c-1}, S_{2c-2}, … $S_{2c\text{-}(n-1)}$, $S_{2c\text{-}n}$)
Incentivization Techniques (C_3)	(C'_{3a}) ($C'3\ _b$) (C'_{3c})	(S_{3a-1}, S_{3a-2}, … $S_{3a\text{-}(n-1)}$, $S_{3a\text{-}n}$) (S_{3b-1}, S_{3b-2}, … $S_{3b\text{-}(n-1)}$, $S_{3b\text{-}n}$) (S_{3c-1}, S_{3c-2}, … $S_{3c\text{-}(n-1)}$, $S_{3c\text{-}n}$)
Training (C_4)	Face-to-Face (C'_{4a})	Active Listening (S_{4a-1}) Cooperation (S_{4a-2}) Coordination (S_{4a-3}) Team Building Skills (S_{4a-4})
Training (C_4)	Virtual ($C'4_b$)	Concept of a Team (S_{4b-1}) Virtual Communication Techniques (S_{4b-2}) Project Management of Task Work (S_{4b-3}) Information Sharing (S_{4b-4})
Training (C_4)	Coaching ($C'4_c$)	Team Member Communication Practices (S_{4c-1}) Conflict Management Skills (S_{4c-2}) Team Member Backup Behaviors (S_{4c-3})

6.5. Construction Task Conditions

One condition that needs to be considered is that constructors must be associated with the construction task or pairings, making them contextual. In keeping with the previous example, constructors that result in more effective teams will only work on teams and not so well for groups or individuals. It is also necessary to identify that a construction task only alters the intrinsic attributes, not its extrinsic attributes. The construction is only to modify the internal environment of the substrate and not its external environment. For example, leader development is designed to support an individual in their journey to become a leader. Leader development, however, does not alter the course of an organization. While a leader can make a significant change to an organization, when we talk about leader development, we are talking about educating and training an individual to build their work-place competencies. It is not directly to improve the organization. One final condition is that construction tasks cannot transform one another; only the substrate's attributes are changed. This makes the construction task a non-recursive pairing.

7. Why Constructor Theory?

Why is constructor theory attractive compared to other alternative theories regarding shifting contextual domains (e.g., clear, complicated, complex, chaotic)? When the context shifts, as when the environment changes from a complicated to a complex domain, the construct does not change. Team effectiveness in the complicated domain is still team effectiveness in the complex domain, and the same can be said of leadership in each domain. What have changed, however, are the legitimate input states and the legitimate output states for each. In looking at leadership as an example, the legitimate input states and legitimate output states pairings for leadership in the complicated domain will be different compared to the legitimate input states and legitimate output states pairings for leadership in the complex domain. The construction of the leadership function remains the same, but the pairings of the legitimate input states and legitimate output states have changed for each contextual domain.

Utilizing constructor theory provides us with the opportunity to remain focused on the construction while altering the legitimate input states and legitimate output states pairings to those that are appropriate for the given environmental or contextual setting. This sense-making technique differentiates the use of constructor theory for the substrate-independence theory from its original version. The construction states vary based on the type of environment one is operating in. The attributes that make up the substrate also vary from one domain to the next, requiring differing construction tasks for the same substrate for each domain. This is where constructor theory provides us with a broader class of explanation [9].

8. Scaffolding

Scaffolding is different from a framework in that frameworks provide a structure or form for items to be placed. Frameworks can represent a more permanent form of a scaffold. This highlights the point that varying types of scaffolding are possible and are dependent on the context and purpose (e.g., temporary, permanent, elastic).

As scaffolding supports a planned change or transformation, it supports the construction of the substrate in constructor theory. This is similar to the change triangle presented by Pendleton-Jullian and Brown [1] and Huy and Mintzberg [34]. The change triangle shown in Figure 3 comprises five things: vision of change, metanarrative, micronarratives, mechanisms, and the network of connectivity. Vision is designed to motivate and orient ideas, acting as the overarching idea and intent for the desired change. Metanarrative represents the vision in a granular narrative. This granularity allows the vision to be translated from an abstract idea to a more concrete one and serves as an orientation mechanism. Micronarratives represent the narratives and lived experiences of those closest to the problem (stakeholders). Micronarratives are "personal and unique to every individual" [1] (p. 279). Mechanisms do the work; "they are things that create the means through which an effect is produced, or a purpose is accomplished" [1] (p. 281). The mechanism is associated with constructions in constructor theory. Networks are the channels that distribute the change throughout the system in the change triangle. Putting everything together, the change triangle works in the following manner:

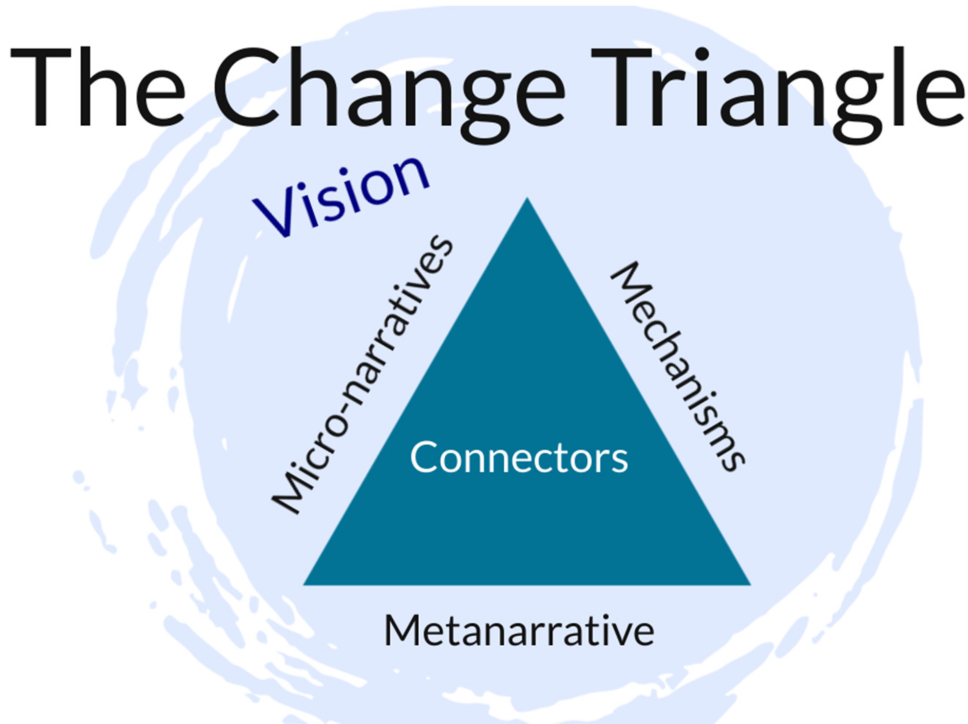

Figure 3. The change triangle. Note: Adapted from "Design Unbound: Designing for Emergence in a White Water World" by A. M. Pendleton-Jullian and J. S. Brown, 2018, The MIT Press, Figure 17.3, p. 277.

"Metanarratives set change in motion by creating a shared story to work toward. Micronarratives contribute to, and draw from, this shared story. And mechanisms do the work required for change. But it is the social networks that distribute these narratives, and spread the work through the system" [1] (p. 283).

Networks are the connectors between the metanarratives, micronarratives, and the work being done by the mechanisms [1]. These connections can be conducted through different connectors, rigid and elastic [1], among others. These connectors are best associated with types of scaffolding. We will utilize various types of scaffolding, such as rigid and elastic from Pendleton-Jullian and Brown's [1] depiction of the change triangle along with other types of scaffolding depicted by Snowden [35,36]. This synthesis provides a description of scaffolding that includes traditional forms of scaffolding and construction tasks (legitimate input and output states) utilized for sense-making to gain some level of control over unknown processes.

It is important to note that we are using construction tasks rather than constraints. First, through constructor theory the focal point is on the construction. The constructor tasks represent the legitimate input and output states (substrate attributes) for a given construction (transformation). Secondly, by focusing on construction tasks the focus is on positive change in the substrate. This is in direct contrast with constraints that can be associated with both positive and negative change. For the substrate-independence theory, we use construction tasks rather than constraints because of this contrasting view and the fact that they are derived through different processes. Construction tasks will be referred to as C-T for the substrate-independence theory and for the remainder of this article.

The C-T that we are referring to are categorized into two classifications, robust and resilient C-T shown in Figure 4. Robust C-T are controlled or facilitated using three types of scaffolding: rigid, elastic, or tethers. Robust C-T are defined as providing "a clear boundary state or type of linkage" [35] (p. 1). The second type, resilient C-T, involve permeable, mutating, or dark scaffolding techniques. Resilient C-T are defined as those that "survive with continuity of identity over time, but it survives by changing and that change may not be explicit or easily understood" [35] (p. 1).

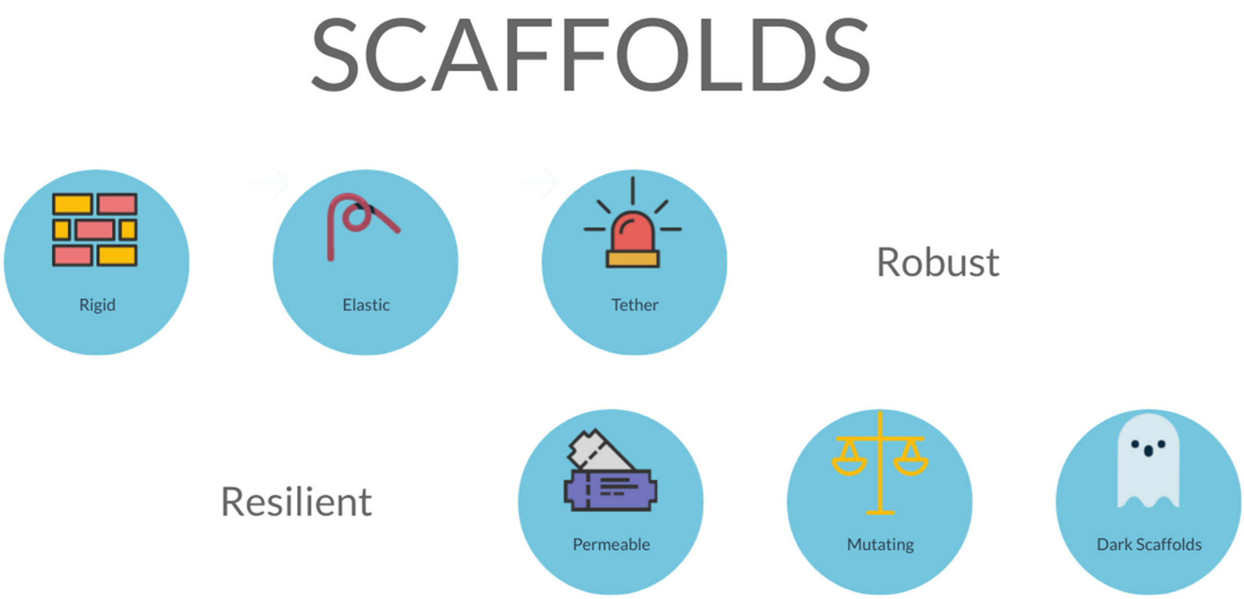

Figure 4. Types of scaffolding to support constructor tasks.

8.1. Robust C-T

Robust C-T examples involve rigid, elastic, and tether scaffolds. Rigid scaffolds are visible with clear boundaries, and they can be described as being fixed or in situ. Some examples of rigid scaffolds include sea walls or dikes. Elastic scaffolds are adaptable as the system changes to a point in which the scaffold can break apart or become destroyed. Examples of elastic scaffolds include an elastic band around a person's wrist as a reminder of which hand is the right hand and which hand is their left hand. If the elastic band were to break, the host could become confused as the elastic band only gave them a false sense of security. Tether scaffolds act as a security line. Examples include a tow rope or a safety line. When required, a tether provides a quick and rigid boundary.

Robust C-T techniques provide clear boundaries for groups of interactions or information. These robust C-T contain interactions and information.

8.2. Resilient C-T

Resilient C-T examples include permeable, mutating, and dark scaffolds. Permeable scaffolds protect by restricting access to unwanted content or materials while also providing access to wanted content and materials. Examples could include a network firewall, protecting against explicit language, or the walls of a cell. Mutating scaffolds are temporary-permanent and slowly change over time. Examples include case-based legal systems or governmental policies. Dark scaffolds are known to be present; they can be seen or experienced, but they are ill-defined or unclear. Dark scaffolds are similar to dark matter or dark energy and can be identical to organizational culture or rituals [36].

Resilient C-T techniques offer "new possibilities for interactions and increasing diversity" [37] (p. 16). These resilient C-T facilitate interactions and the movement of information.

9. The Substrate-Independence Theory

The composite substrate-independence theory is informed by constructor theory, the Cynefin framework, complexity theory, information theory, and the work conducted in the origins of life research effort. The origins of life research present new perspectives on how living systems organize and how information is the essence of life.

9.1. How Living Systems Organize

It is necessary to understand not only how living systems organize at any given level, but also how they organize across levels [38]. For example, biochemical networks exhibit shared structures across all levels of organization [38], so much so that forms at the ecosystem level are similar, but different, from those at lower levels in the ecosystem: "Scaling laws often emerge in systems, where universal mechanisms operate across different scales, yielding the same effective behavior independent of the specific details of the system" [38] (p. 8).

This concept of similar but different across levels can be extended to centralized and decentralized hierarchical structures. Hierarchy "appears as unreciprocated ties directed from each position to the position immediately 'above' it" [39] (p. 5). Hierarchical structures occur when centralized control is desired in which communication channels are directional (e.g., one-way, top-down). Centralization occurs when the incoming and outgoing information is being controlled by a few agents [39]

Decentralized hierarchical structures are associated with two-way communication and reciprocal relationships, allowing agents to communicate freely with little to no control over the communication channels. Because these structures are decentralized, they can freely form networks around repetitive patterns, coordination, and information-sharing behaviors [39]. Decentralized network structures take advantage of the structurational theory of networks: "networks are constituted through a recursive process in which members draw on their knowledge of social structures as they interact" [39] (p. 3).

9.2. Information and Living Systems

"Once life is established, it includes information carriers and executor mechanisms that are selected for increasing, or at least preserving, the likelihood of their own persistence" [40] (p. 68). Life itself is sustained through the transfer of information for storing information to duplicate itself (carriers) or as executors that perform the functions necessary to store information and reproduce organisms. Energy is provided to each of these functions when called upon but at a cost. Due to the conservation of energy law, energy is transferred or transformed from one form of energy to another; "energy available for human utility is not conserved so easily" [41] (p. 85). Energy is transferred or transformed into one type of energy when called upon and is again transferred or transformed to other types of energy when it is no longer needed. The distinguishing factor between living and non-living systems is the ability of living systems to manage and control information [42] that is supported by this energy.

Often suspected as the key factor in the origins of life [43], information has also been identified as being the common origin to life [40]. Other research supports information as the key to life [42], from organisms to social systems to ecosystems. While it is not precisely clear what or how information structures matter, or what information is, it is apparent from the research that information is necessary to structure all living systems [43]. One general agreement is that information is one key aspect of living systems [42].

Part of this structuring of living systems involves developing hierarchical structures. These hierarchical structures allow the flow of information within the system in a top-down and bottom-up manner [40]. This point is highlighted by Walker and Davies [42]: "The manner in which information flows through and between cells and sub-cellular structures is quite unlike anything else observed in nature" (p. 2). This flow of information is responsible for "controlling the properties and behaviour of the system, maintaining its homeostasis, and, ultimately, determining its ability to survive and reproduce under given conditions" [40] (p. 70). Information is contextually based, also known as being causally efficacious in which information determines a system's current state, the dynamics for sustaining life and adapting to potential future states [42].

9.3. Summary

The substrate-independence theory, shown in Figure 5, focuses on the substrate and the scaffolding required to achieve the desired change in the substrate's attributes. The substrate-independence theory requires decentralized hierarchical structures where information flows in a reciprocal manner so that the information is the focus rather than the physical properties carrying, transmitting, or storing the information. Information is expected to flow using the least energy required, providing a quicker conceptualization of the environment when dealing with complexity.

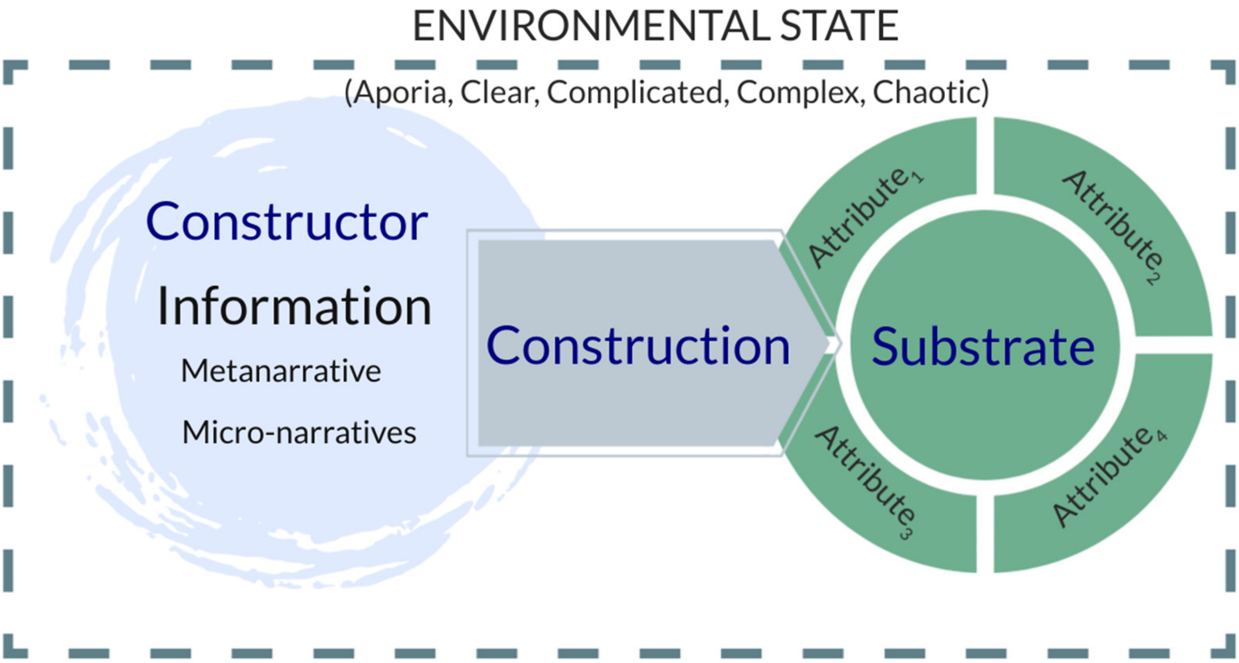

Figure 5. Substrate-independence theory.

This desired state and the scaffolding utilized depend upon the environmental state (aporetic, clear, complicated, complex, chaotic) and the type of construction placed onto the substrate. The constructor is a composite of the metanarratives and micronarratives that identify the need for a new desired state in the substrate. The overarching vision, the same as presented in the change triangle, is implemented in the substrate-independence theory and identifies the information manipulated in the substrate.

The main focus is to identify what is being constructed (construction). In a decentralized organization, information is either stored, transferred, coded, or interpreted to flow to those who need the information to complete their work. This process must be achieved, ideally, by using the lowest amount of energy possible. All constructions are designed to provide the flow of information when necessary and to protect information when critical, using the least amount of energy possible. An example of the former is ensuring that the correct information is obtained by those processing it when the information is being processed, not before and not after. Timely delivery of the right information is what is called for. An example of the latter is when private information needs to be protected. This occurs with federal regulations and compliance issues regarding customer information.

10. Application of Substrate-Independence Theory

The application of the substrate-independence theory will vary depending on the environmental state. This environmental state involves three ontological states discussed previously: ordered, complex, and chaotic. Within these three ontological states we have five decision-making domains provided in the Cynefin framework. These five domains include aporia/confused, clear, complicated, complex, and chaotic. The domains of clear and complicated reside in the ordered state, complex in the complex state, and chaotic in the chaotic state. Aporia is a starting point where agents begin to make sense of their environment when it is determined which domain one is in. Once this is known, the agent can then begin to function within their environment.

10.1. Aporetic Domain

For the aporetic domain, this is the beginning of the substrate-independence theory. By definition, the aporia/confused domain is described as a paradox, "a philosophical puzzle or a seemingly impasse in an inquiry, often arising as a result of equally plausible, yet inconsistent, premises" [25] (p. 26). When in aporia, agents are only trying to understand their environment. As an initial step, agents should begin by asking two primary questions:

1. At what state is the current environment?
2. How much variability is in the current environment? [44]

First, it is essential to identify which domain one is currently operating in (clear, complicated, complex, chaotic). Once this has been determined, it is important to identify the variety and flow of information in the current state. Does the information have a low level of variability, meaning that information is flowing freely and undisturbed? Or does information have a high level of variability, is it restricted from flowing unintentionally? This relates to the concept of interoperability. Is the physical content of information (information media), after removing all other irrelevant details, flowing across substrates freely using as little energy as possible? If not, predictions about the system's tasks need to be assessed through counterfactuals, looking at potential scenarios where the information media is not occluded. This concept of variability in the flow of information begins the process in the substrate-independence theory.

10.2. Ordered Ontological States

The Cynefin framework is a flow concept that places it as a framework when addressing the flow of information within the various environmental states. For the ordered ontological state, the two decision-making domains include the clear and complicated domains. The clear domain has known processes, while the complicated domain involves many unknown processes. The main difference between the two is that, in the clear domain, agents know or have easy access to information for them to complete their tasks (low logical depth). In contrast, in the complicated domain, agents do not always know or have readily access to information (medium levels of logical depth), requiring the exploitation of experts to gain the much-needed information to complete their tasks. When operating in one of the two ordered domains, it is necessary to be aware of the types of scaffolding that can be implemented to guide or facilitate the flow of information.

These two domains primarily utilize robust C-T techniques for scaffolding. Robust C-T are utilized when known processes require specific boundaries for interactions or information. An example of the clear domain would be for data entry. If new information was desired to be captured when taking customer complaints, it would be reasonably easy to add additional fields in the database where the data are coded and stored. Employees would be notified of these new data fields and will be instructed to capture these new data in addition to the previously captured data. The database used to capture customer data act as an elastic scaffold, it can be added to or subtracted from, but the process remains the same. The data fields act as a rigid scaffold in that employees are required to collect data to complete these data fields; it guides employees and directs them to what information is necessary to capture. If a select few employees are not capturing these data fields, a tether scaffold would be put in place, drawing attention to their deficiencies to put corrective actions in place immediately.

An example in the complicated domain could include an organization's safety practices. Safety-I relates to engineering practices, often mandated "by regulatory bodies like the Occupational Safety and Health Administration (OSHA)" [45] (p. 365). These regulations provide a set of good practices for organizations to follow, placing Safety-I in the complicated domain. While not completely known or understood by organizational agents, implementing and evaluating these good practices can be supported through experts who are familiar with current and new policies and practices. Implementing these good practices involves robust C-T that provide rigid scaffolds (safety rules, standard operating procedures) that introduce diversity [45].

For both the clear and complicated domains, C-T can be implemented to determine the best course of action for the desired change. These legitimate input states and legitimate output states can be identified because of the predictability that comes in the ordered domains. Information is readily available in the ordered domains. Information gathered through the metanarrative and micro-narratives define the constructor and substrate, while the construction is dependent upon the type of scaffolding technique required to achieve a permanent change in the selected substrate's attributes. The scaffolding is the construction necessary for each of the selected attributes. The legitimate input states and legitimate output states include the type of scaffolding that will be placed upon each of the substrate's attributes. This identifies legitimate scaffolding states and legitimate attribute outcomes to change the substrate. A new modified version of Table 1 is presented as Table 2 for the ordered domains, supporting the substrate-independence theory.

Table 2. Potential construction tasks for ordered domain.

Constructor (C_i)	**Construction (C')**	**Substrate (S_i)**
Metanarrative	**Scaffolding (S_i)**	**Attributes (A_i)**
Micro-Narratives		
Redesign Teams (C_1)	(S_{1a}) (S_{1b}) (S_{1c})	(A_{1a-1}, A_{1a-2}, … $A_{1a-(n-1)}$, A_{1a-n}) → S_1 (A_{1b-1}, A_{1b-2}, … $A_{1b-(n-1)}$, A_{1b-n}) → S_1 (A_{1c-1}, A_{1c-2}, … $A_{1c-(n-1)}$, A_{1c-n}) → S_1
Update Technology (C_2)	(S_{2a}) (S_{2b}) (S_{2c})	(A_{2a-1}, A_{2a-2}, … $A_{2a-(n-1)}$, A_{2a-n}) → S_2 (A_{2b-1}, A_{2b-2}, … $A_{2b-(n-1)}$, A_{2b-n}) → S_2 (A_{2c-1}, A_{2c-2}, … $A_{2c-(n-1)}$, A_{2c-n}) → S_2
Incentivization Techniques (C_3)	(S_{3a}) (S_{3b}) (S_{3c})	(A_{3a-1}, A_{3a-2}, … $A_{3a-(n-1)}$, A_{3a-n}) → S_3 (A_{3b-1}, A_{3b-2}, … $A_{3b-(n-1)}$, A_{3b-n}) → S_3 (A_{3c-1}, A_{3c-2}, … $A_{3c-(n-1)}$, A_{3c-n}) → S_3

10.3. Complex Ontological States

Safety in the complex domain is viewed as being nonlinear rather than linear. Safety-II views safety as an emergent outcome of a complex adaptive system. Safety-II addresses uncertainty in safety, where work is accomplished safely by agents continuously monitoring and making necessary adjustments under both expected (Safety-I) and unexpected (Safety-II) conditions [45]. This comes from the realization that not every potentially dangerous situation can be planned for in advance. It becomes necessary to provide agents with tools to navigate situations safely instead of using a set of good practices for every occasion. Safety-II in the complex domain involves trial-and-error experimentations when experiencing an unknown situation. Resilient C-T are called for to help guide agents when facing unsafe conditions and to identify better what scaffolding techniques were missing when failures do occur (chaotic domain). Safety in organizations is a "messy, constantly changing entanglement of human factors interrelated with organizational systems, processes, and structures" [45].

Unlike the ordered state, the complex state cannot be easily mapped as done in the example shown in Table 2. There are too many unknowns and missing information to develop a detailed plan. However, what is called for in the complex domain is to rely more heavily on the metanarrative and micro-narratives as a sense-making technique to understand the environment better. Random experiments will also be required to collect information about the environment and its conditions. These experiments will begin to shed light on which type of scaffolds will be helpful. The second column in Table 2 would identify different scaffolding techniques as part of an experiment to determine which scaffolding technique(s) helped in the sense-making endeavor. Once legitimate scaffolding techniques have been determined through these experiments, they can be mapped with different attributes until the desired change in the substrate is achieved.

This process is an intentional process rather than a prescriptive process. The intent is to understand the environment and change various attributes within the environment so that movement to a more manageable domain, typically the complicated domain, can be achieved. This process can be mapped, as shown in Table 2, but only retrospectively (after-the-fact). Mapping will help visualize what has been done and will show changes in the environment due to the experiments. This aids agents in their sense-making process, providing them with information based on their experiments. The environment will change as these experiments alter the conditions within the environment, providing a visualization of these dynamic changes essential. Scaffolding during these experiments will begin to show patterns, further showing the contribution of the scaffolding techniques and the attributes manipulated. Once patterns start to emerge, construction states can be identified and utilized as a means of moving toward the liminal area or complicated domain. The substrate-independence theory and techniques aid agents in identifying proper scaffolding techniques for specific attributes that can result in noticeable changes in a substrate. Once a substrate can be altered, it can be moved into the complicated domain to be further modified to achieve the desired outcome.

10.4. Chaotic Ontological State

Entering into the chaotic ontological state often occurs accidentally or randomly. In chaotic systems, small changes to the initial conditions result in "avalanches of changes" [46] (p. 174). Because of these avalanches, there are no constraints or scaffolding present in the chaotic state. The complex state functions as a transition between order and chaos [46]. Therefore, movement out of the chaotic state can only be toward the complex state or the aporetic domain. These are the only two options for any practitioner or leader aside from the option of self-destruction that is to be avoided.

Movement is dependent upon the initial conditions and the fitness of the system or organization. Knowing that the initial conditions can organically result in an avalanche of change, it becomes essential to identify counterfactuals because of the numerous potential outcomes that could occur that cannot be predicted or planned for in advance. Counterfactuals provide the only means of identifying potential outcomes that would not have been predicted using traditional methods.

Movement is also dependent upon the system's fitness. As the fitness of a system or organization becomes more structurally sound, the potential avalanches that could occur are minimized. Having a sound fitness provides a structure with both formal and informal networks working freely and interdependently to reduce the effects of these avalanches: "Such systems adapt on relatively smooth fitness landscapes" [46] (p. 226). These formal and informal networks within a system provide the system with the resilience and adaptive capabilities to counter these avalanches. The more rigid a system is, the less adaptive it becomes. With little or no informal structures in rigid systems, once the formal structure is disrupted the system has no defense against the avalanche of change. In contrast, for systems that have both a formal and informal structure, the lines of defense against these avalanches increase, providing the system with the resilient forces to combat the change, thus preventing the system from being destroyed.

For systems that are structurally fit, with smooth fitness landscapes, the formal and informal landscapes produce real-time landscapes as agents begin to understand their environment. This occurs through rapid experimentation using multiple disciplines while distributing decision-making capabilities. As more knowledge is gained more information can be distributed to further develop the landscape to reflect real-time information, resulting in movement toward the complex state. Once more information becomes distributed, scaffolding can then be included to make the appropriate changes to the requisite substrates and their attributes. Once this has been achieved, the agents are in the complex state.

11. Discussion

Through constructor theory, we know that constructors influence change in specific attributes of a substrate through a construction or transformation. Rather than taking a reductionistic perspective or a deterministic worldview, we look at many possible input and output states as potential causes to the desired change in the substrate's attributes. Figure 6 provides a complete overview of the substrate-independence theory presented in the current article.

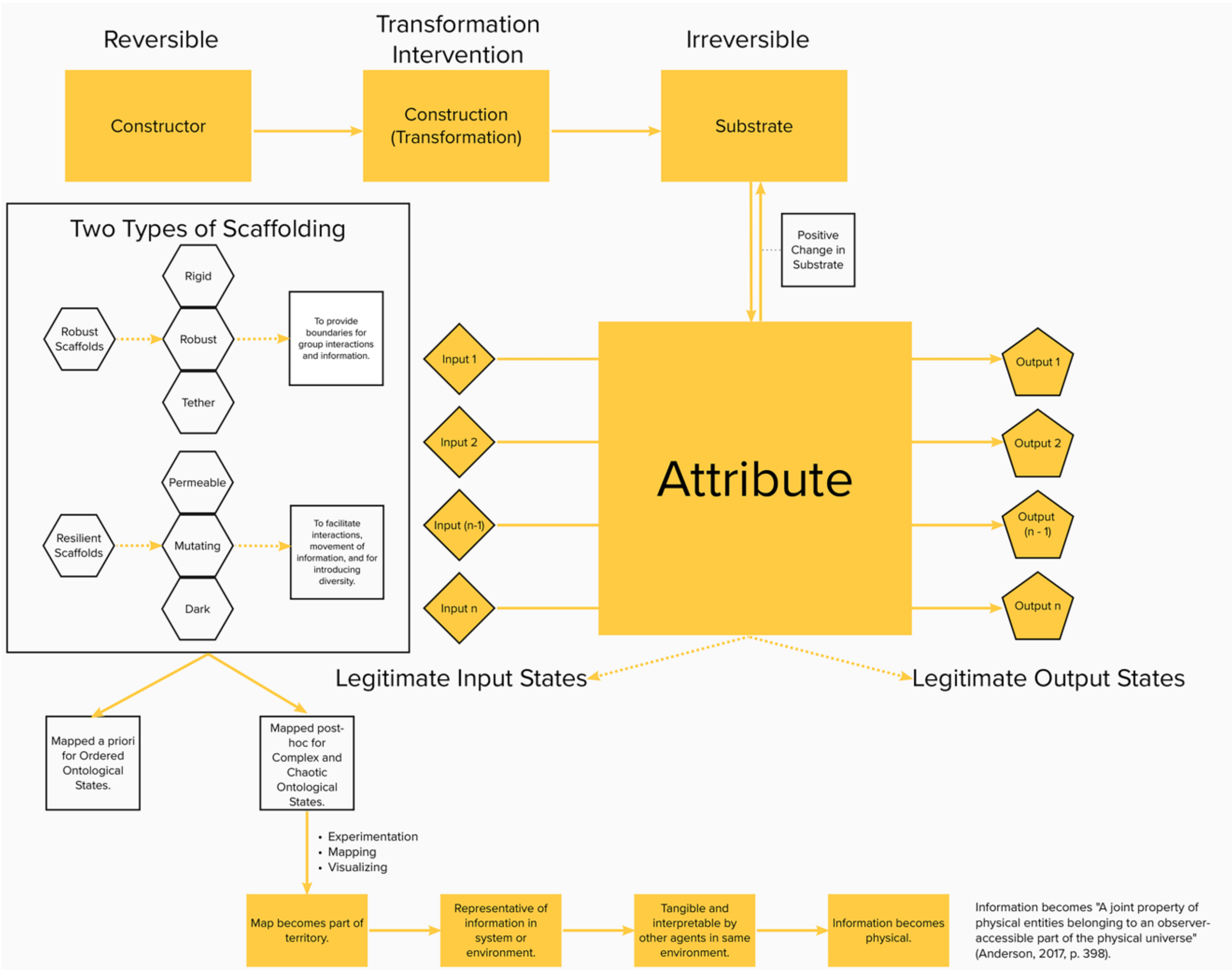

Figure 6. The substrate-independence theory.

The input and output states are called construction tasks (C-T) and are accomplished using two primary types of scaffolds, robust and resilient. Robust C-T include rigid, elastic, and tether scaffold and are primarily used to provide boundaries for group interactions and information. Resilient C-T include permeable, mutating, and dark scaffolds and are primarily used for facilitating interactions, movement of information, and for introducing diversity. These C-T can be mapped a priori in the ordered domains (clear, complicated) and can also be mapped post hoc or in real-time in the unordered domains (complex, chaotic).

When working in the complex domain, the act of experimenting and mapping or visualizing C-T and scaffolding practices places the map as being representative of the information within the system. It is tangible and can be interpreted by other agents in the same environment. The map becomes part of the territory. In this sense, information is physical (the map) and can be defined as "a joint property of physical entities belonging to an observer-accessible part of the physical universe" [47] (p. 398). This mapping in real-time in unordered domains becomes a type of scaffolding with its own C-T.

This concept hints at two additional possibilities when viewing the substrate-independence theory. First, there are other potential scaffolds that could be presented to aid the C-T and the overall transformation of the substrate. The scaffold of developing a map in real-time would be conceptualized as being both a robust and resilient C-T, one that survives over time with minor modifications while also providing continuity of identity. This scaffold would be an applied scaffold, one that agents utilize as part of the information transfer process to support learning.

The applied scaffold within the substrate-independence theory would provide opportunities for agents to capture cues, gestures, and objects from their environment to support framing and understanding. Cornelissen, et al. [48] viewed how agents constructed cognitive frames to successfully coordinate activities during action. Their research found that cues, gestures, and objects acted as mediators to sense-making that became part of the activity of constructing meaning in real-time [48]. Others have studied how sense-making is enhanced through the use of cues [48], as a holistic model that extends the mind to body experience [49], and through physical artifacts [4]. Maitlis and Christianson [5] highlighted the following four features of sense-making from the literature:

1. Sensemaking is dynamic process that unfolds over time.
2. Cues play a central role in sensemaking.
3. Sensemaking is a social process.
4. Sensemaking concerns action that people take to make sense of a situation (pp. 66–67); see also [49].

The substrate-independence theory captures each of these four features when applied to sense-making activities in real-time. The sense-making and scaffolding tasks are co-created by agents present in the environment that transition between sense-making and sense-giving activities among agents that promote action toward change.

Second, this example introduces a multilevel process to scaffolding, where scaffolding techniques are used within other scaffolding techniques to achieve the desired change in the substrate attributes. Single scaffolds may not be adequate, and, sometimes, especially in the unordered domain, it may be necessary to design scaffolds within scaffolds to achieve a desired outcome. This places scaffolding, within the frame of the substrate-independence theory, as being multidimensional and multilevel as depicted in Figure 7. An illustration of this could be the example previously discussed relating to improving a team's effectiveness. Different scaffolding techniques used at the individual level of analysis could be utilized to change individual team member's attributes (team members affect, behavior, cognition, tasks). At the same time, other scaffolding techniques could be applied at the team level of analysis to change the team's attributes (team reflexivity, shared cognition, interdependent taskwork). Combined, these scaffolding techniques along with the C-T for each would constitute a multidimensional and multilevel approach to altering the attributes in the targeted substrate. For this example, the substrate is the team, and the attributes are identified at the individual and team levels of analysis.

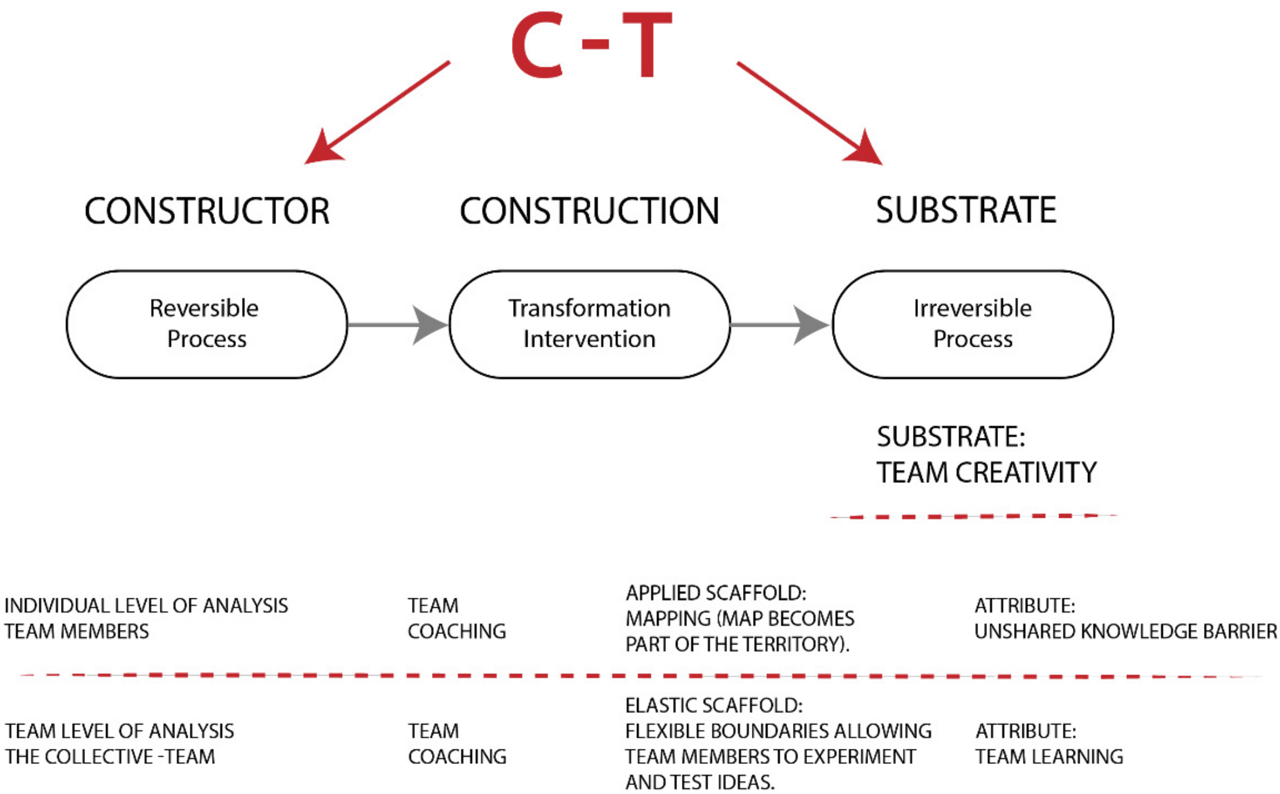

Figure 7. Multilevel model.

Alternate multilevel scaffolds are possible within the C-T perspective. Future research and discovery are needed to identify potential multilevel scaffolds that can be included in the substrate-independence theory. Additionally, there may be some scaffolding pairings that can be shown to be more effective in a multilevel capacity compared to their effectiveness independently. One example of this could be where individual team members use an applied scaffold, such as when a map becomes part of their landscape, supported by an elastic scaffold at the team level that allows the collective to experiment and test ideas to develop novel and creative ideas or products. Future research efforts will be needed to identify which scaffolding pairs across levels are most effective. This would aid in providing the best solutions by using the least amount of energy possible.

12. Conclusions

The substrate-independence theory advances the current literature on sensemaking because it extends current sense-making techniques from being viewed primarily as a cognitive or discursive process [4] to one that is inherent within any organizational change process. Scholars have called for techniques to help advance sense-making research in the areas of strategic change, as this is one area that has been underdeveloped [4]. The substrate-independence theory provides substantive methods that leaders and practitioners can easily implement to begin any strategic change intervention. More importantly, the advancement of the substrate-independence theory that includes multidimensional and multilevel scaffolding techniques expands the literature and answers additional calls from researchers who are asking for tools for leaders so that they are better able to influence their employees' sense-making capabilities during change implementation [4]. This line of research is necessary for practice because it deepens employees "understanding of sense-making during strategic change not just as an intellectual but as a multimodal process" [4] (p. 816).

Theory

In considering what constitutes a theoretical contribution, Corley and Gioia [50] contrasted theory based on two dimensions, originality and utility. Originality referred to the theory's contribution, novelty, value-added insights, and new knowledge. The originality matrix can be categorized as being revelatory or incremental. Given the newness of the constructor theory to the field of physics alone, not to mention to the broader disciplines outside of physics, the substrate-independence theory would classify as being more revelatory than incremental. In addition, the contribution to the discipline of multilevel scaffolds and real-time mapping to drive change in complex environments is new and would be considered a revelatory rather than an incremental contribution. On the other dimension, utility was described in which a theory provides new insights or perspectives to the larger discipline. One criteria provided by Corley and Gioia [50] is that the theory is able to improve research and practice. Utility is categorized as being either practical or scientific to represent both sides of the theory-to-practice divide. The substrate-independence theory provides potential advances for both practice and research and would be evaluated high in the utility matrix. This measure of utility, one that includes both practice and research, supports previous calls for theories to cross the divide between sense making and sense giving, cognition and action [51]. The substrate-independence theory provides one theory that is high in originality while providing utility across both domains of research and practice.

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