GasMarts, Umbilical Cords, and Eco Bridges: Deconstructing Relationships to Understand Complex Systems

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Abstract

Part of the *Cognitive Case Study Series* from Cabrera Research Lab, this case explains how recognizing relationships and identifying their parts—called a Relationship Distinction System (RDS)—can facilitate deeper understanding of phenomena both simple and complex. We also explore the RDS as a tool of business and scientific innovation.

A "cognitive case study"—inspired by the cases used in business and policy schools that involve students in real-world problem solving—is designed to engage students in metacognition (thinking about thinking). Cognitive cases introduce the cognitive patterns underlying our mental models, and then encourage us to explore how our and others' mental models affect our emotions, behavior, action, and even our reality. These cases explore a broad range of topics, from politics to social issues to the physical sciences to everyday phenomena, with the purpose of enabling readers to see the cognitive structures at play across a variety of realms.

> *"Life did not take over the globe by combat, but by networking"*
> –Lynn Margulis & Dorian Sagan (1986) [1]

Introduction

Systems thinking is predicated on the importance of understanding complexity and the critical role of relationships, which are often the invisible parts of a system or network. Even when we acknowledge relationships, we infrequently delve into their complexity. Doing so requires the recognition that relationships can be systems unto themselves.

Relationship is a general term with many synonyms: link, interconnection, interaction, connection, "edges" (in network theory), dynamics (systems of relationships), feedback and causality (specific types of relationships), etc. A relationship can be physical and tangible (such as an Ethernet cord is the relationship between my laptop and the Internet), or physical but somewhat invisible (the relationship between my laptop and the Internet if I have wifi), or conceptual (the relationship between money and influence). Many of the most

Figure 1: The many relationships in this photograph are invisible to the naked eye.

important relationships for us to understand are the ones that are invisible. Because nature often shows us its structure but keeps its dynamic interactions invisible, it is critical to be metacognitive (think about our thinking) when it comes to recognizing, identifying, and systematizing relationships. Nature shows us a family of individuals, but fails to explicate the generational relationships and patterns of interaction. Through the lens of a microscope, we see cellular structures, but rarely see the dynamic chemical interactions. We see a flock of birds in murmuration (what the Royal Society for the Protection of Birds calls "a swooping mass of thousands of birds whirling in the sky"), but we do not see the shifting patterns of interaction between the birds that brings about this emergent murmuration.

In order to fully understand any system, we must understand the relationships between and among its different parts. For example, if we have any hope of grasping family dynamics, we need to understand the history, nature, and strength of the relationships that bind its members. This is all the more true of complex systems. A complex adaptive system (CAS) is one composed of semi-autonomous agents that learn from and adapt to their environment. Ironically, underlying the complex and emergent outcomes of a CAS are simple rules that govern the behavior and relationships of its constituent parts.

Figure 2: The behavior of the flock emerges from the invisible relationships among the birds.

Indeed, the behavior of a flock of starling (or traffic patterns, ants, and many other complex adaptive systems) results from the many thousands of relationships between the individual parts of the system. The bird flock operates in tandem because simple rules govern bird behavior:

- Maintain a constant, specific distance from nearest neighbor
- Adjust direction based on movement of nearest neighbor
- Avoid predators

While these relationships are not visible, they are critical to the system's function (and the flock's survival).

Let's examine a complex system in which many Americans actively participate to see the underlying structure of one of its most important relationships—between coffee farmers/workers and coffee drinkers. According to the National Coffee Association's 2013 survey, 83% of American adults consume coffee, making the United States the world's largest coffee consumer (not, however, per capita). [2] But where does all this coffee come from and how does it get to the consumer?

The Coffee Industry

25 million coffee farmers and workers produce the coffee that fuels 500 million drinkers. [3] The industry is a complex system consisting of farmers and coffee workers, coffee drinkers, coffee roasters, coffee traders, and coffee distributors. Coffee is a $30 billion industry in the United States. [2]

The world's most valuable agricultural commodity, coffee is primarily grown in developing countries and consumed in industrialized nations. [4] A labor-intensive industry, coffee employs 60 million people, or 1% of the world's population. [4] 80% of coffee farmers are smallholders, farming 3 hectares or less. [4]

Coffee is lucrative for some, increasing in price, and the costly specialty market is growing rapidly, yet the working conditions of its producers are

notoriously poor, including the use of child labor, lack of safety standards, lack of contracts and unions and extreme variability in pay, low salaries, poor living conditions, etc.

The coffee industry can be conceived of as a relationship between producers (25 million coffee farmers and workers) and consumers (500 million coffee drinkers). As with all markets, we can identify the relationship between coffee producers and consumer as a supply chain. To better understand this relationship, we must identify the parts of that chain (see figure 3).

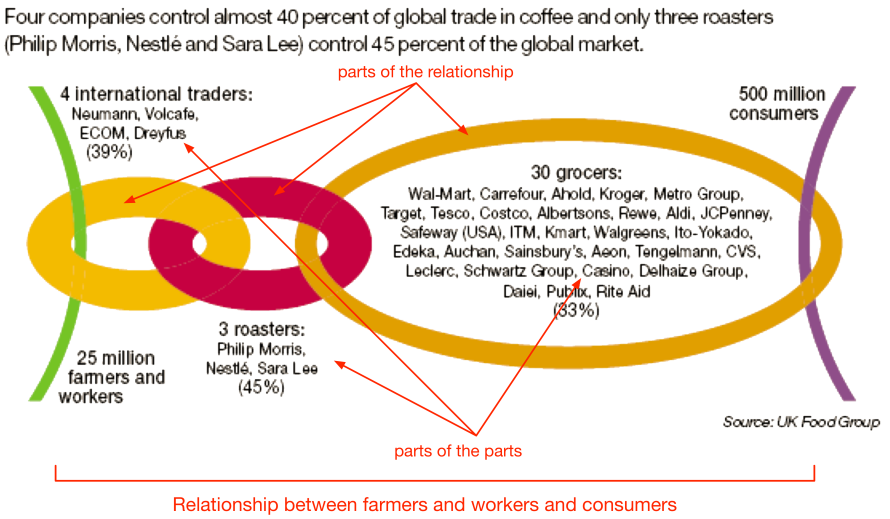

Figure 3. Modified from UK Food/Group diagram showing the Relationship (R) and parts of the System (S) for the Coffee Food Chain.

Applying Cognitive Structures to Understand Complex Relationships

The Cabreras [5] explain that four simple rules (making Distinctions and recognizing Systems, Relationships, and Perspectives or DSRP) are the building blocks of cognition and the underlying rules of the field of systems thinking. The Distinctions Rule states that any thing or idea can be distinguished from the other things or ideas it is with. The Systems Rule states that any idea or thing can be broken into parts or aggregated into a whole. The Relationships Rule of DSRP says that any two or more things can be related. The combination of these rules—a Relationship Distinction System (RDS)—is immensely useful for understanding the workings of complex systems and phenomena.

So, how do we construct a Relationship Distinction System?

Step 1: Make the Relationship

Typically, relationships between and among things are represented by a simple line that denotes Thing 1 and Thing 2 are connected in some fashion. Recognizing that a relation exists between two things is the first step to

understanding systems, and to creating a Relationship Distinction System (RDS). A relationship between two things, using MetaMap, [1] is illustrated in this way:

Figure 4. A relationship (R) in MetaMap—the dot on the line cues the user to distinguish the relationship by double-clicking on it.

Step 2: Identify (Distinguish) the Relationship

The second step is to make the relationship a distinction (identify what the relationship is). Whenever you draw a relational line between one thing and another, be sure to "zoom" into that line and ask yourself, "how would I describe that relationship? (In MetaMap, add a square to the line and label it accordingly.)

A relationship between two things that has been made then distinguished (a Relationship Distinction or RD) is illustrated this way in MetaMap:

Figure 6. An RD in MetaMap

Called the DaVinci of Design, Edward Tufte, in a recent Facebook post (see figure 5), promotes the importance of relationships ("think verbs, interactions"), visualizing relationships ("show verbs, interactions") and to go further in identifying relationships by "annotat[ing] linking lines." [6] Tufte provides an excellent example of this pattern of thinking in Walt Disney's diagram for his new company, where Disney goes beyond merely relating the parts of the diagram by distinguishing each one with a specific label or concept. How much less informative would Disney's map of his company be if upon seeing the relationships, we were left to our own devices to identify what those relationships were?

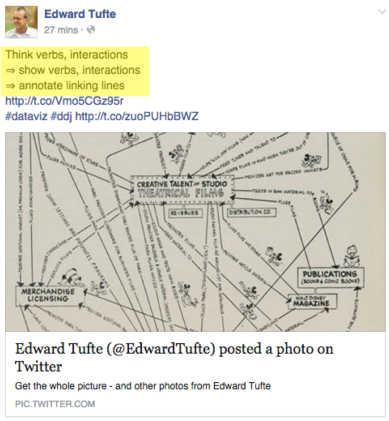

Figure 5: Tufte promotes the importance of RDs when he advises "annotate linking lines." From [6]

[1] MetaMap is a cloud-based software that utilizes DSRP rules to map phenomena of any degree of complexity.

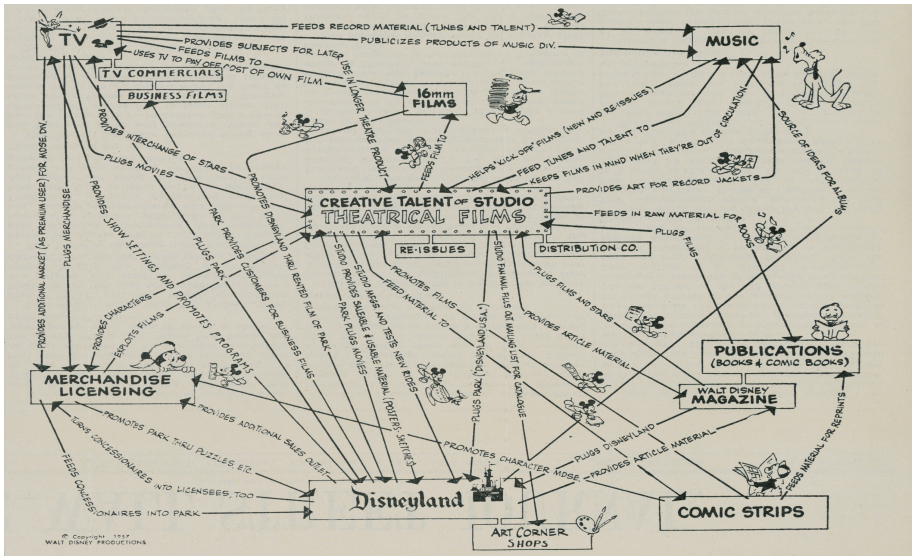

Figure 7. Walt Disney did RDs to form his company

Step 3: Identify the Parts of the Relationship

Once you have related two things and identified the relationship, the final step is to recognize the relationship as a part-whole system. You can see a specific example of this process in figure 3 where the parts of the relationship are broken down into traders, roasters, and grocers, and then further broken down into specific companies. This is what an RDS looks like in MetaMap:

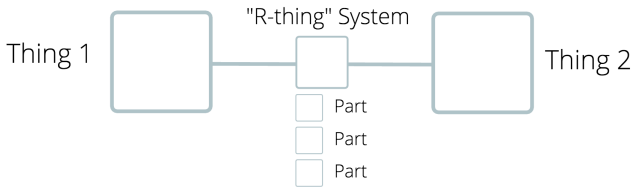

Figure 8. An RDS in MetaMap

We can illustrate the abstract structure of RDS and the steps in creating it with a familiar example:

- Step 1: recognize that a relationship exists between two individuals (R)
- Step 2: identify that relationship as “marriage” (i.e., make a relationship distinction or RD)
- Step 3: recognize that marriage is made up of various parts like love, friendship, finances, progeny, etc. (i.e., make an RDS)

Examples of Relationship Distinction Systems

Below we offer a variety of RDS examples to help illustrate the utility of applying this particular cognitive structure.

Figure 9: An Eco Bridge RDS connecting two ecosystems From [7]

Eco Bridge

An ecological bridge, a type of wildlife crossing, is an example of an RDS (see figure 9). We see first that an ecosystem has been cut into two by a highway and that an Eco Bridge has been built as a relationship between Ecosystem 1 and Ecosystem 2. We identify the relationship between the ecosystems as being constituted by an Eco Bridge (making an RD). The final step is recognizing that the Eco Bridge is made up of a mini-ecosystem (S) of parts such as trees, soil, adequate width, concrete, cameras, etc. (see figure 10).

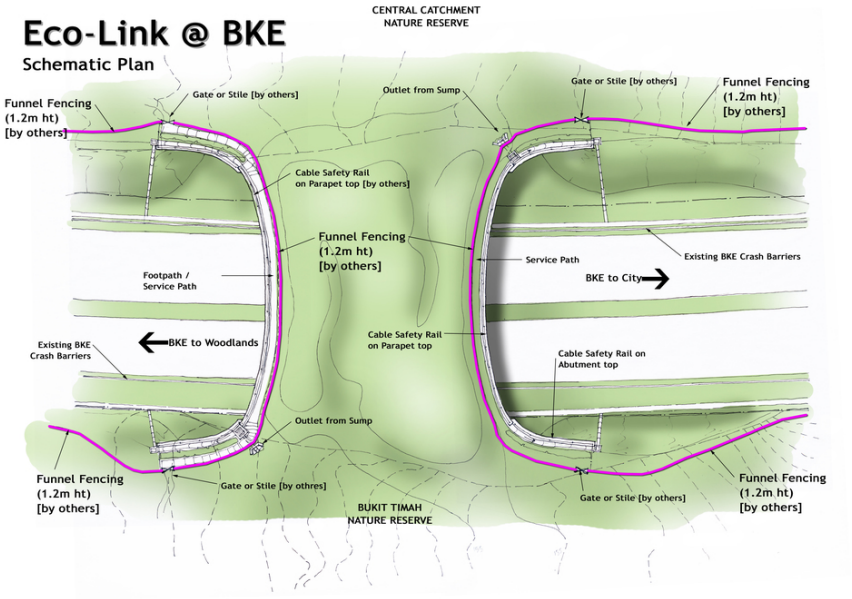

Figure 10. Schematic identifying the parts of an Eco-Bridge system

You might also notice in figure11 that the construction of this system has actually taken into account certain perspectives (the Glossy horseshoe bat, Emerald dove, Sunda Pangolin, the common palm civet, and human visitors to the bridge, etc.). One can imagine that if these perspectives were not taken, a simple concrete bridge may have been built, which would likely inhibit wildlife crossings.

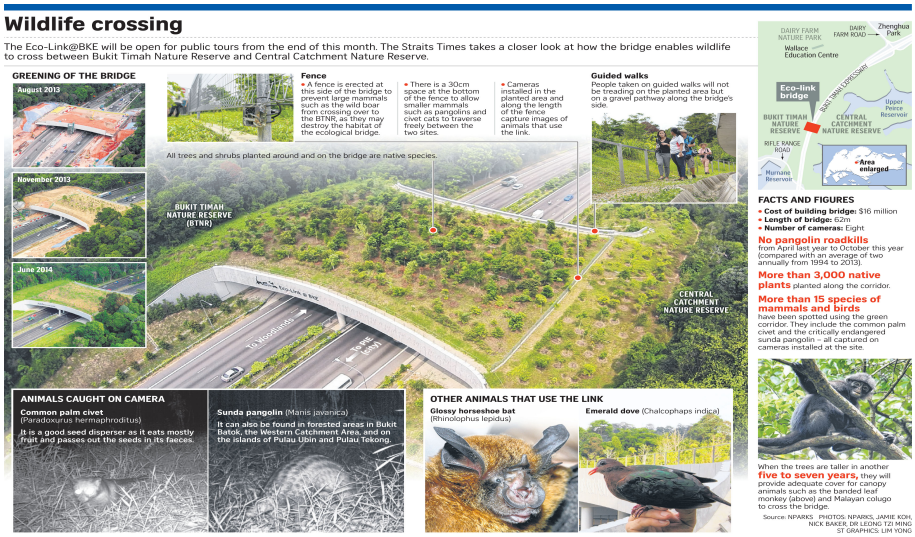

Figure 11. The Eco Bridge is a thoughtfully designed system reflecting multiple perspectives and made up of many carefully planned, interrelated parts.

Branches of Government

Most US middleschoolers understand that our government is made up of three interrelated branches (the Executive, Legislative, and Judiciary). And most can tell you that the basic relationship between them is "checks and balances." But even adult US citizens become increasingly stumped when asked to further distinguish or identify the parts of those all-important relationships between the branches. Few can tell you the specific people, offices, and departments or the regulatory policies and bodies that make up these relationships. Of course, for those inside the bureaucracy, these are important understandings to have and these relationships are made up of people, places, functions, and principles.

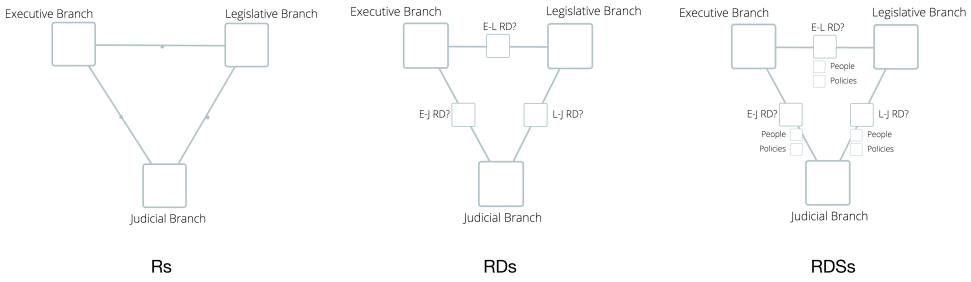

Figure 12. Branches with Rs and RDs and RDSs

For familiarity, we can focus on functions (see table below for an exposition of functions by branch, many of which constitute parts of inter-branch relationships). Zooming into the "check and balance" relationship between the Executive Branch and the Judiciary, we can identify two obvious yet critical parts:

- the US President nominates judges
- The Supreme Court can rule on the constitutionality of Presidential Acts

Legislature (Congress)	Executive (President)	Judicial (Supreme Court)
Passes bills; has broad taxing and spending power; regulates interstate commerce; controls the federal budget; has power to borrow money on the credit of the United States (may be vetoed by President, but vetoes may be overridden with a two-thirds vote of both houses)	Makes appointments to the federal judiciary, federal executive departments, and other posts with the advice and consent of the Senate. Has power to make temporary appointment during the recess of the Senate	Determines which laws Congress intended to apply to any given case
Has sole power to declare war, as well as to raise, support, and regulate the military.	Has the power to grant "reprieves and pardons for offenses against the United States, except in cases of impeachment."	Exercises judicial review, reviewing the constitutionality of laws
Oversees, investigates, and makes the rules for the government and its officers.	May veto bills passed by Congress (but the veto may be overridden by a two-thirds majority of both houses)	Determines how Congress meant the law to apply to disputes
Defines by law the jurisdiction of the federal judiciary in cases not specified by the Constitution	Executes the spending authorized by Congress.	Determines how a law acts to determine the disposition of prisoners
Ratification of treaties signed by the President and gives advice and consent to presidential appointments to the federal judiciary, federal executive departments, and other posts (Senate only)	Declares states of emergency and publishes regulations and executive orders.	Determines how a law acts to compel testimony and the production of evidence
Has sole power of impeachment (House of Representatives) and trial of impeachments (Senate); can remove federal executive and judicial officers from office for high crimes and misdemeanors	Makes executive agreements (does not require ratification) and signs treaties (ratification requiring approval by two-thirds of the Senate)	Determines how laws should be interpreted to assure uniform policies in a top-down fashion via the appeals process, but gives discretion in individual cases to low-level judges. The amount of discretion depends upon the standard of review, determined by the type of case in question.
	Is the commander-in-chief of the armed forces	
	Executes the instructions of Congress.	

Table 1. Duties of three branches of government as per the Constitution of the United States [8]

However, this would be just the beginning of diagramming this RDS. In order to help us identify the parts of the relationships between branches, we would of course have to identify the parts that constitute the Judiciary, and the Legislative, and the Executive. For example, we know the Executive includes the President, Vice President, and Cabinet, which is composed of heads of Departments of State, Defense, Agriculture, etc.

Even for something as simple as the three branches of government, one realizes that distinguishing those three relationships and then zooming in to see the various parts that make up each of those relationships is critically important, but challenging when we consider the complexity of formal and informal institutions, norms, and relationships involved.

It is illustrative to consider the Judicial branch and its relationship with the Executive and Legislative, which is far more complicated than overt functions like appointing and approving judges. As Wheeler and Katzmann explain, both Congress and the President have mechanisms to alter the consequences of court decisions.

> Some of the Constitution's twenty-seven Amendments reversed unpopular Supreme Court decisions. Statutory changes are more common (and easier to enact). When courts say a statute means one thing, legislators who disagree can try to change the statute.

> Scholars estimate that in recent years, Congress has overridden about five percent of the Supreme Court's statutory decisions, and the Court has invited overrides to clarify the law in about eight percent of its cases. [9] [10]

Funding is a complex element of the relationship between branches. The Judiciary, like other branches, relies for funding on annual spending bills, initiated by the President and approved by Congress. There is a statute, however, that specifies that the President is to include the Judicial and Legislative funding requests in the budget unaltered. That statute reflects a constitutional principle governing the interbrach relation. [10] However, as Wheeler and Katzmann [10] note: "The statutory mandate that the executive not meddle in judicial-legislative appropriations relations sometimes gets off track." [10] These legal scholars relay how, in such instances with the Bush and Clinton administration, "The judicial branch used personal contacts with the two Presidents to get the actions rescinded." [11] [10] They expound the importance of informal *associations* in the relationship between Congress and the Judiciary:

> Personal contacts are important in daily judicial-legislative interactions over appropriations. At least since the 1940s, Chief Justices have appointed to the Budget Committee judges with "ability, legislative experience,and congressional associations."60

This is but an example of the complex (often unwritten) system that comprises the relationship between government branches. Developing facility with RDS will go far in increasing understanding of simple or complex systems and facilitate problem solving within them.

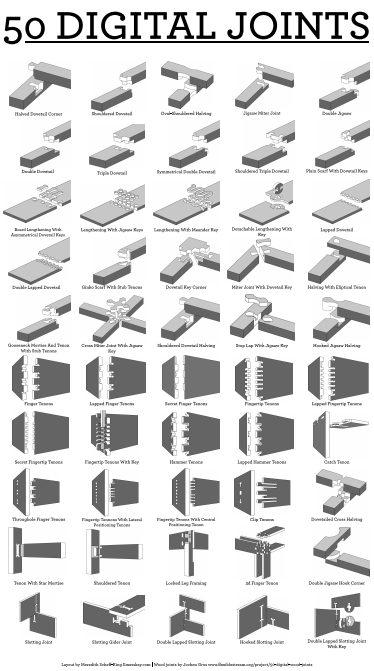

Figure 13: 50 digital joints poster...50 RDSs [12]

The Physicality of Connections: Furniture Joints

It is important to recognize that—as is the case with all DSRP structures—RDSs are not merely conceptual things that occur in the mind but physical things that occur in the real world. In this section we will explore a physical RDS.

For a very tangible example of an RDS, look no further than the furniture in the room you are sitting in.

Take a look at figure 14, which excerpts just one of the joints from the poster in figure 13. We can see that the two boards are related by a type of joint distinguished as a "jigsaw keys joint." We then can see that this joint isn't a single thing but a system made up of multiple parts (i.e., an RDS).

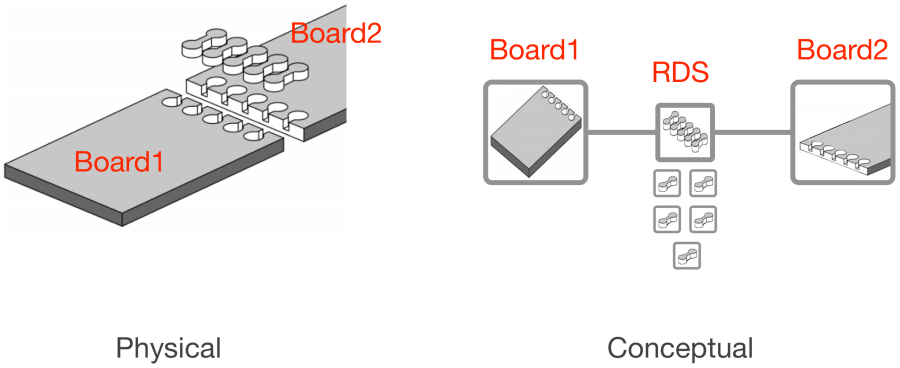

Figure 14. Jigsaw keys joint RDS

Figure 15: The "hooks" of a common burr inspire velcro From [13]

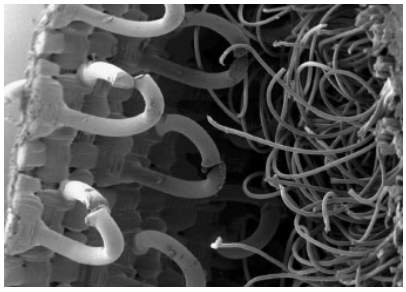

Figure 16: Zooming into the relationship: velcro closeup. From [14]

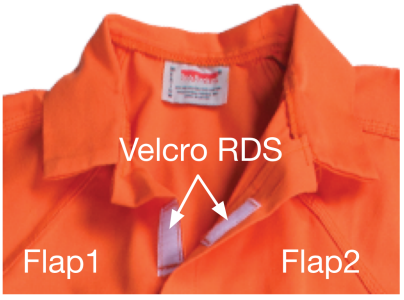

Figure 17: Vecro is an RDS

We could of course break these parts down further and see that they too are made up of parts. The purpose of this case is simply to show how RDS is a common cognitive structure that is very useful for modeling and understanding things both basic and complex.

RDS as a Tool for Exploration, Creativity, and Innovation in Industry and Research Sectors

Industrial/Commercial Innovation and Creativity

Is RDS an algorithm for creativity and innovation in industry? It is often said that innovation occurs in three ways: (1) invent something totally new; (2) make an existing product or service better; or (3) relate two existing products or services in a new way. RDS can play a role in all three ways of innovating.

Velcro Fastenings

Zooming into the parts of a relationship can generate new products. George de Mestral, a Swiss electrical engineer, was inspired by a nuisance (the burrs that clung to his dog and his trousers after a walk) to create the first "touch fasteners."

de Mestral invented velcro—a hook and loop fastener mimicking burrs—consisting of a fabric strip with miniscule hooks that could temporarily attach to another fabric strip with miniscule loops, but could be separated when pulled apart. Examining the relationship between a burr and dog's fur (attachment) led to a practical invention. Velcro is a relationship composed of a system of many tiny hooks and loops made out of nylon and polyester.

Gas up on Fuel and Food

While fuel was first sold by multi-purpose stores, drive-through gasoline stations were soon to follow. These were followed by gas stations that provided mechanical services. Ironically, the next development was a return to a combination of selling fuel and groceries and convenience items to customers. In "The History of Fuels Retailing," the National Association for Convenience and Fuel Retailing explains the 1927 origin of the relationship between grocery stores and gas stations:

> The Southland Ice Company introduces the concept of the convenience store in Dallas, Texas. "Uncle Johnny" Jefferson Green...realized that customers sometimes needed to buy things such as bread, milk and eggs after the local grocery stores were closed. Unlike the local grocery stores, his store was already open 16 hours a day (7:00 am to 11:00 pm), seven days a week, so he decided to stock a few of those staples in addition to items he was already offering. As the company grows, it changes its store name to reflect its operating hours: 7-Eleven. [15]

How is a Gasmart an RDS? Well, it originated as the relationship between a gas station and a convenience store. But today, if you were contemplating starting up a franchise of one of the gasmarts, you would sit squarely in that market. In other words, you wouldn't think in terms of the system of products and services you needed to provide as a gas station (break pads, oil filters, timing belts, oil changes, etc.) or as a convenience store (milk, eggs, toilet paper), but rather wiper fluid, oil, milk, ice, pizza, etc.—that is, the system of products and services that are part of a gasmart system.

Figure 18: RDS: gasmarts

Because we live in a college town, the gasmart near us has a ready supply of ping-pong balls by the register. Not because there's a resurgence of ping-pong enthusiasts among the college-age demographic, but because of the college drinking game—beer-pong. Said a different way, if Fred owns a gas station and Sally owns a gasmart, their business will need to establish a familiarity with a different set of products and services, regulators and distributors, and markets and customers. Sally for example, would likely belong to the the Association for Convenience & Fuel Retailing (NACS) [15] and attend their annual conference. Whereas Fred might belong to the WMDA/CAR Service Station and Automotive Repair Association [16] and attend their annual conference. These are distinguishable whole systems of suppliers and distributors, associations and conferences, products and services, industry data and consumers.

Today, the National Association of Convenience Stores reports "There are 124,374 convenience stores selling fuel in the United States, and these retailers sell an estimated 80% of all the fuel purchased in the country." [17]

Cloud-based Applications

Figure 19: Box and Xactly are RDS

In the same way that RDS-thinking can lead to new products and services, it can spawn new industries and markets in business and technology. Many innovations are simply combinations of things that have yet to be related. Today, much of the Silicon Valley is fueled by taking existing processes (data storage or sales compensation) and making an RDS between these processes and the "cloud"—that is, making them available in cloud-based technology. Some businesses—like Box and Xactly—are entirely based on an RDS that takes an existing function (file storage and variable sales compensation, respectively) and makes it available in the cloud. Prior to Xactly, sales managers and sales people managed their variable compensation packages (commissions) in an Excel spreadsheet usually sitting on the sales manager's desktop. The process was invisible to all but the sales manager. Today, Xactly has moved this process to the cloud, making it possible for sales managers and sales people to "game the sales plan" to optimize the amount of compensation they make. If a sales manager realizes they have too many 2016 blue parkas in stock and wants to unload them, he increases the percentage of commission. Immediately, sales people see they can make more money on their next call selling blue parkas

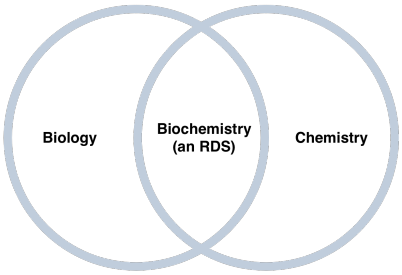

Figure 20: Biochemistry is an RDS

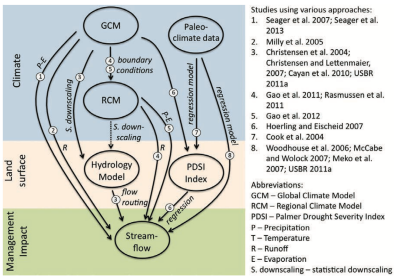

Figure 21: Original Surface Water Research illustrating RDS. From [19]

than red ones. By the end of the week, the blue parka inventory is sold. Xactly, in seeing the relationship between variable compensation management and the cloud, forged an RDS that has changed how the Fortune 500 sells. Xactly made its initial public offering (IPO) in June, 2015, and is today a highly profitable company with over 400 employees. Likewise, Box saw the problems with local file storage and management (losing files, not having access to them, sharing them). Box CEO Aaron Levine (worth over 94 million in 2015) saw the RDS between file storage and management and the cloud. Today Box has over 41 million users and 59,000 businesses—including 59% of the Fortune 500. [18]

What's important to realize is that the folks at Box and Xactly, like the folks who own a GasMart franchise, need to exist in a new world—a new system—where they are simultaneously gaining expertise in the cloud and also in file management or sales compensation industries respectively.

New Fields of Science

The identification and deep exploration of an RDS can facilitate interdisciplinary innovation. There is a reason why *interdisciplinarity* is such a hot topic in education, industry, and with funders: disciplinary boundaries are constricting and crossing them allows for innovation. For example, emerging in the 1800s as a new scientific discipline, the relationship that formed between biology (concerned principally with the study of living organisms) and chemistry (concerned principally with the study of all matter, its composition, how it changes, etc.) is today its own distinct discipline, biochemistry, with its own distinct practitioners (biochemists), departments and degree programs, journals, conferences, and associations (Biochemical Society). The purview of biochemistry (the parts of the relationship between biology and chemistry) is the chemical and physicochemical processes occurring inside living organisms. This includes the study of properties of biomolecules and energy production in cells.

There are over 20,000 disciplines, fields and subfields in science. Like the Biochemistry RDS, any number of those disciplines could be combined to form a new field. In fact, many of the most innovative fields today are being born (bio-physics, econo-metrics, geo-physics, bio-technology, interaction design, etc) as the result of an RDS. The cutting edge of science is often to be found at the boundaries of disciplines, by systematizing the relationship between one field and another.

Managing Interdisciplinary Scientific Research

Imagine you are responsible in some way for an entire field of research. Say for example you are a funding officer for the National Science Foundation responsible for the Requests for Proposals disseminated and awarded in the domain of water research. Or imagine that you are chair of a University department responsible for not only setting the direction of the department, but also for guiding the professional trajectory of new graduate students.

Having a map (see figure 22) of the research area, the relationships between topics, ideas, specific variables, and the validated research (or lack of it) in those areas would be invaluable. Imagine if you could visually indicate relationships that need attention, funding, RFPs, innovation, or graduate student efforts. Using an RDS, you could identify key relationships in the field and explicate them by enumerating their parts.

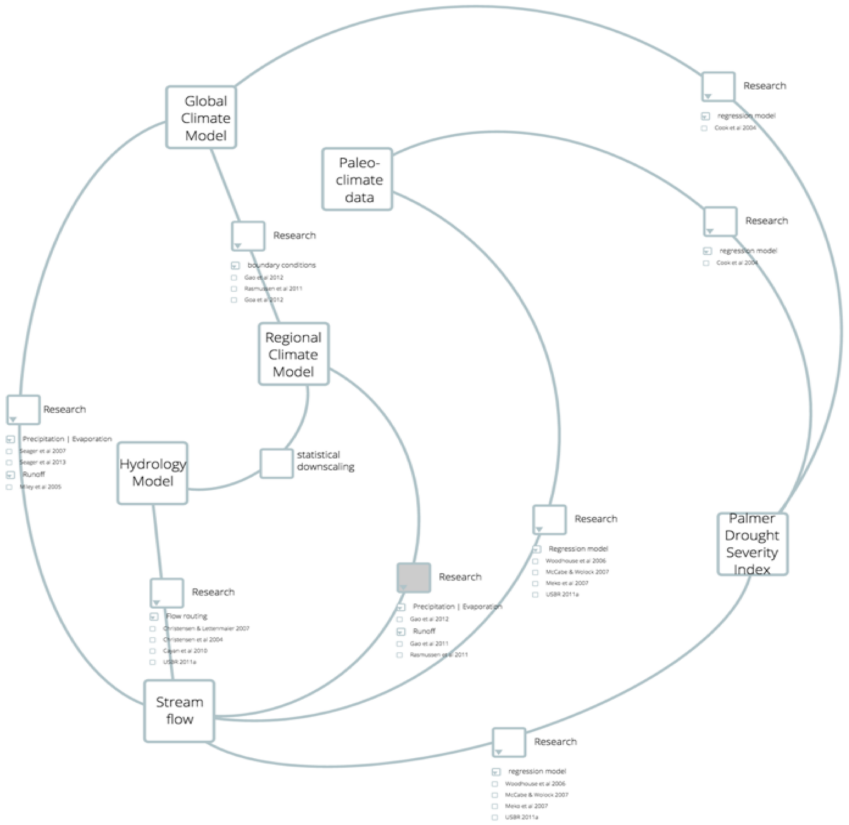

Figure 22. Metamap macro view of Surface Water Research, highlighting RDS to direct and prioritize effort and funding

In figure 23, zooming into the RDSs of the research ecosystem reveals research gaps, such as the RDS labelled "statistical downscaling" between Hydrology Model and Regional Climate Model, where there is no current research as compared to the RDS between Hydrology Model and Stream Flow where four seminal research papers are cited related to flow-routing. Funding administrators and doctoral supervisors could use this map to incentivize research in these gap areas and encourage researchers to break new ground.

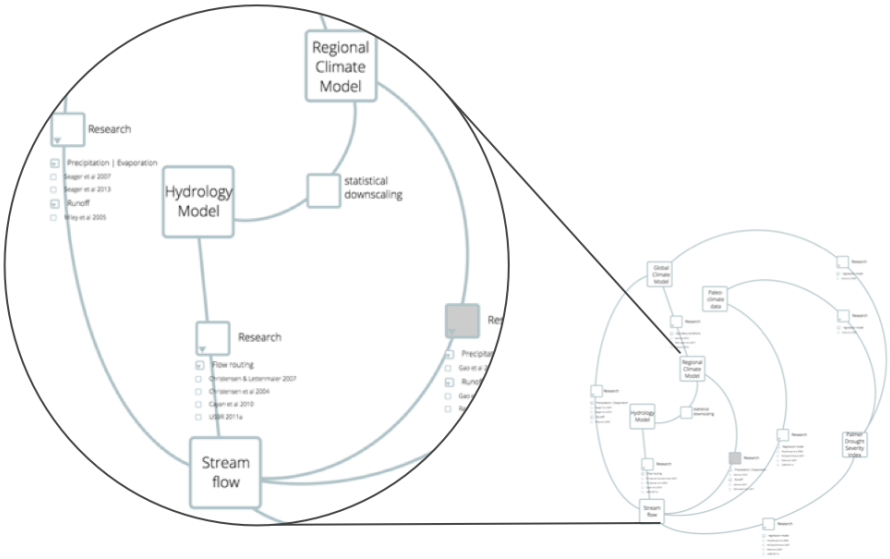

Figure 23. Zooming into RDS to identify research gaps

Relating Systems Thinking to Education, Research, and Outreach on Water Issues

As a nation and a planet, we are all becoming increasingly aware of how vital clean and adequate supplies of water are to the health of humanity and the planet. As we face more and more short- and longer-term crises due to a host of complex factors involving climate, ecology, and human use patterns, there is a need to reconsider our approaches to water-related issues and efforts. This includes several constituencies, notably researchers/scientists, educators at all levels, the extension community, community organizations, and the public.

Systems thinking is an ideal approach for addressing "wicked problems," ones that are complexly layered, have high social, economic, environmental, and/or political stakes, and involve conflicting interests and priorities. Many of our water-related problems today are aptly deemed "wicked" and therefore can seem intractable.

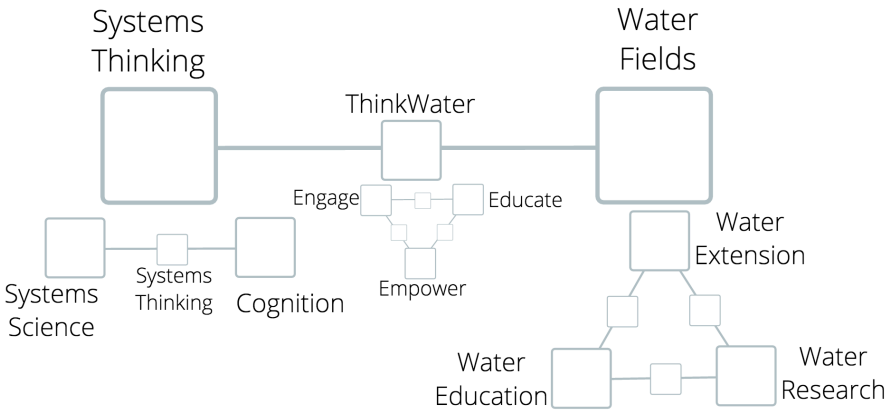

Figure 24. ThinkWater is a set of nested RDSs

[2] Funded by NIFA-USDA Agreement No. 2015-68007-23213

ThinkWater is a national campaign supported by the U.S. Department of Agriculture[2] and led by the University of Wisconsin-Extension and Cabrera Research Lab to help people of all backgrounds and ages think and care deeply about water. It does so by applying systems thinking to existing water education and research efforts and by actively engaging people in a new way around water issues. The ThinkWater Mission-Vision is to Engage, Educate and Empower 7 Billion Systems Thinkers to solve wicked water problems.

ThinkWater is predicated on the critical relationship between systems thinking and water issues, indeed it forms a relationship between the two (see figure 26). That relationship is composed of numerous parts—including public outreach and a media campaign and outcome studies of systems thinking-water initiatives—but also:

- Training water educators to teach systems thinking in order to quickly and efficiently reach the maximum number of people possible. This includes the provision of systems thinking-boosted lesson plans, online training tailored for instructors, new classroom tools and techniques, and a rich repository of resources to help both formal and informal educators engage students in water topics through systems thinking.
- Reaching an increasing number of water researchers, professionals, and education consumers among the public of all ages by offering a high quality and accessible online course in systems thinking, as well as blogs, posters, and infographics.
- Offering systems thinking fellowships to scientists studying water-related topics so they can produce more expansive, interdisciplinary, and comprehensive research that leads to enhanced problem-solving.

To find out more about the RDS that is ThinkWater, visit https://www.thinkwater.us

Discovery of Direct Connection Between Brain and Immune System

In summer 2016, UVA researchers published on a revolutionary new RDS: they discovered that the brain is directly connected to the immune system by a system of vessels previously unknown to exist. [21] The Chair of UVA's Department of Neuroscience reports his initial reaction:

> "They'll have to rewrite the textbooks. There has never been a lymphatic system for the central nervous system ... it will fundamentally change the way people look at the central nervous system's relationship with the immune system." [21] [21] [22]

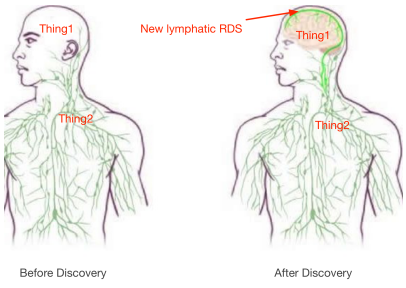

Figure 25: New lymphatic RDS discovered [20]

The discovery of this RDS holds promise for the study and treatment of neurological diseases such as autism, Alzheimers, and multiple sclerosis. As one of the scientists involved in the research explained, "We believe that for every neurological disease that has an immune component to it, these vessels may play a major role." [21]

Improperly folded proteins: Another RDS at the forefront of disease research

In a recent article published in *The Journal of Cell Biology* scientists made an important discovery (shown in figure 26) that is important toward

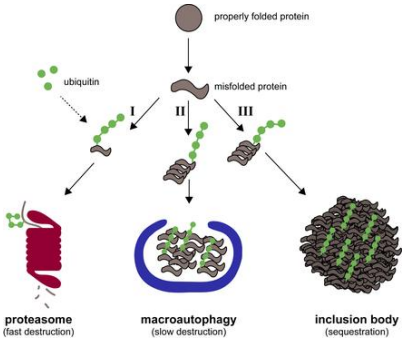

Figure 26: Ubiquitin often present but not necessary to cause "protein misfolding diseases"
[23]

understanding how and why "protein misfolding diseases" occur:

> A large number of sporadic and familial neurodegenerative diseases that differ in their age of onset and manifestation share striking pathological features at the cellular level, suggesting that a common etiology may be responsible for the demise of neurons. Most notable is the aggregation of improperly folded proteins in affected neurons in these so-called protein misfolding diseases that include Alzheimer's, Parkinson's, and Creutzfeldt-Jakob disease, as well as amyotrophic lateral sclerosis and other motor neuron diseases. [23] [24]

What they found has to do with three different RDSs (labelled I, II, and III in figure 26). One of the parts of this RDS system is called *Ubiquitin*. In this study, Bersuker et al. discovered that while "Ubiquitin-containing inclusion bodies are characteristic features of numerous neurodegenerative diseases...whether ubiquitin plays a functional role in the formation of these protein deposits is unclear...[and that]... protein misfolding without ubiquitylation is sufficient for translocation into inclusion bodies." [23]

In other words, in the three different RDSs represented in figure 26, one of the parts of these systems is often present, but not necessary to lead to three misfolding events that are associated with important diseases.

More Science RDSs

Figure 27 from *Nature Reviews Cancer* shows immune evasion mechanisms that limit the therapeutic efficacy of cancer vaccines. The authors discuss how improving vaccine design and using vaccines in combination with other anticancer therapies can boost treatment efficacy in patients with established cancers. Note the four relationships and the complexities that occur within them (shown in corner blue boxes). Those too, are RDSs.

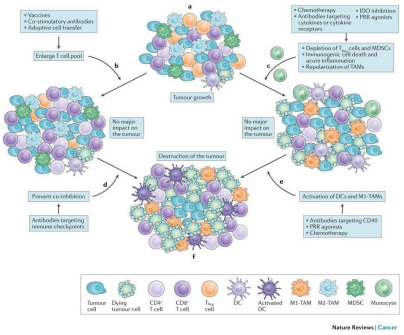

Figure 27: Chemical RDS [25]

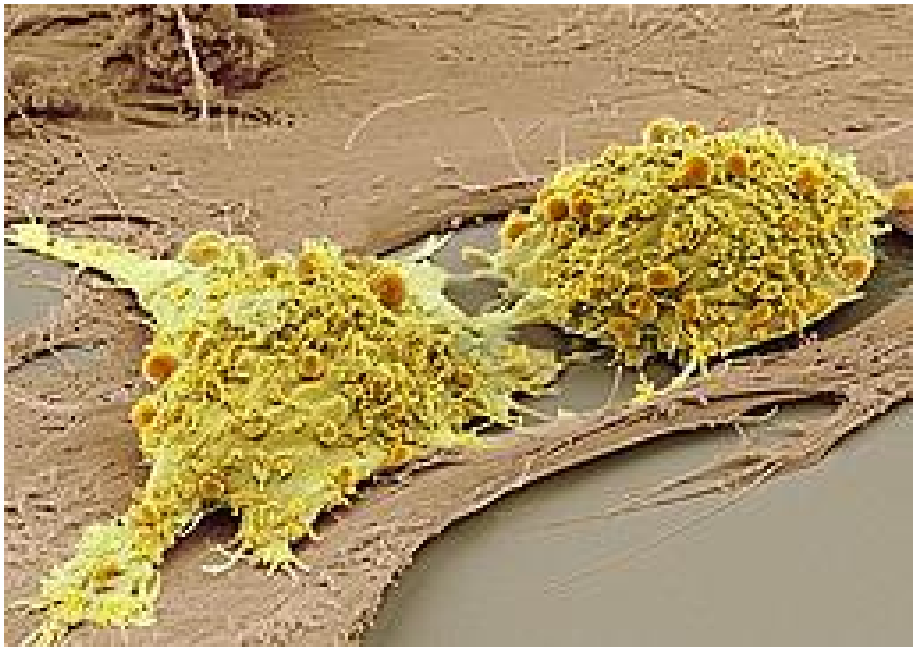

Figure 28. Fractal RDSs [26]

The umbilical chord, an RDS in and of itself, is made up of MSC cells (parts). In figure 28 we see two of those cells and their relationships (also RDSs). The image is:

> Mesenchymal stem cells. Coloured scanning electron micrograph (SEM) of two human mesenchymal stem cells (MSCs). MSCs are multipotent stromal (connective tissue) cells that can differentiate into a variety of cell types, including osteoblasts (bone cells), chondrocytes (cartilage cells), and adipocytes (fat cells). The youngest, most primitive MSCs can be obtained from the umbilical cord tissue. Magnification: x3000 when printed 10 centimetres wide. [26]

The image reminds us of the fractal (i.e., when the same pattern or phenomenon occurs at different levels of scale) structure of both nature and of thought.

Galaxies often exist as parts of larger clusters that contain many galaxies in close proximity. Due to this proximity, galaxies collide not infrequently, as the Milky Way is currently doing with the Sagittarius Dwarf Galaxy. The stars that constitute galaxies, however, are sufficiently spaced out that star collisions are a rarity. Even absent a collision, however, galaxies still exert an effect on each other when they are in close proximity. The gravitation force they exert on each other can cause both galaxies to change shape. Galaxy clashes and near-collisions are known as "interactions," and occur over hundreds of millions of years.

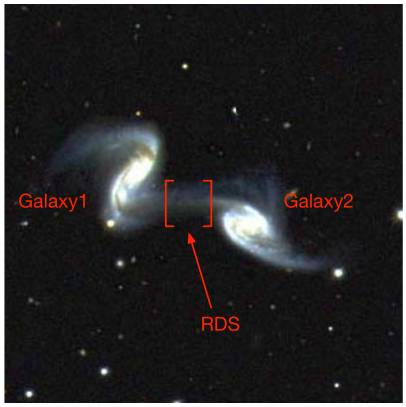

Figure 29: When two galaxies interact, there is a very large system of interactions [27]

Interestingly, these galaxy interactions can be "productive" in that they can yield new stars in galaxies in which star formation had long ceased. This occurs because clouds of gas inside the interacting galaxies can become compressed and collapse under their own gravity, which creates stars.

Poster Summarizing RDS

A poster summarizing a few of the examples from this case is available here.

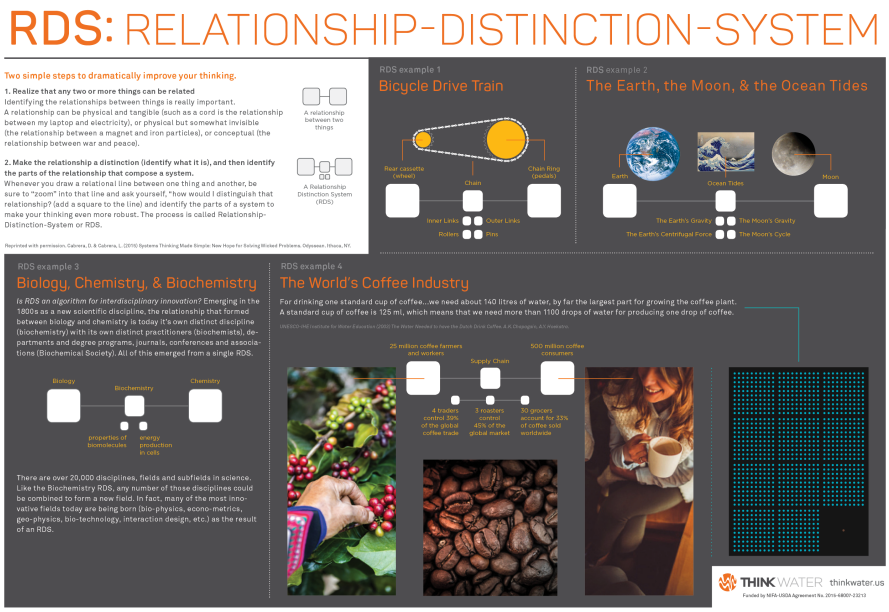

Figure 30. RDS poster. [28]

Questions

- How does understanding that all relationships can be distinguished and systematized change how you approach new knowledge and problem solving?
- Why is it important not only to see *that there are* relationships but also to distinguish and systematize relationships?
- How much would you say your understanding of a system increases with the addition of RDSs (e.g., think in terms of the three branches of government example)?

Task

- Identify a current or historical issue, problem, area of knowledge, or policy for which we could improve our understanding by utilizing the RDS algorithm. Generate a cognitive case or case example describing how RDSs could improve a phenomenon or issue or how RDS is an important part of its success.
- This case has not addressed the Perspectives Rule (Any thing or idea can be the point or view of a perspective) of DSRP. [5] It is of course an important part of metacognition to carefully consider the perspectives involved in all distinctions, systems, and relationships. Consider, examine, and question the perspective from which a particular RDS is constructed.

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